Manfred Rätzmann
Clinton De Young

Galileo Computing

Software Testing and Internationalization

- In real-world implementations
- For agile, risk-driven testing
- Internationalization of software applications
- Localization testing

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Manfred Rätzmann
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Chapters 1 to 5 written by Manfred Rätzmann
Chapter 6 written by Clinton De Young

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An Extremely Subjective Foreword

by Manfred Rätzmann

When I began to take a more intense interest in software testing a number of years ago, the first thing I felt was a great deal of uncertainty. On the one hand, I had always tested my own programs carefully or done "test drives" and had never been faced with a quality disaster. I had to admit that there were always a few bugs after completion ... Sure, a whole string of unique situations hadn't really been covered ... But by and large the software programs worked pretty well. On the other hand, fairly soon I had this creepy feeling that the approach I was taking when testing software did not have all that much in common with what was described or expected of testers in books published on the subject. I partly attributed that to the difference in scope of the projects described in the books or to the academic background of the authors, but my journeyman effort wasn't insignificant at the time either – around 20 programmers had worked on developing the software. I went through three phases. First I would say to myself "*I've got to radically change how I'm doing things.*" Then, "*Now I see how it works, but I won't do it myself yet.*" Until finally, I was saying "*That's out of the questions – that won't ever work*!" My daily grind had a hold of me again.

What I've learned in the meantime is to trust my experience and judgment. What you do and don't do in software development, what priorities you set and what order you do things in – all these things emerge based on experience gathered in projects over time; your own ideas and those of others, discussions, reading material, trying and failing – in short, by constantly dealing with the issue. This almost inevitably leads to the emergence of certain preferences. I have a lot more fun finding out what causes a software bug than I do retesting functions after each change in code. That's why I immediately try to automate tasks like that. After all, I'm a software developer, and software developers always want to automate anything which is a pain!

I think software testers and developers are becoming more and more similar – developers test and testers develop. The idea that testing automation is the same as software development (a highly fascinating concept), will be making the rounds in the years to come. Quality assurance will become more tightly integrated within the software development process, causing testers and developers to draw even closer together. The qualification required for both specialists is the same; their points of view, however, are different. That is where I'll go out on a limb, we'll get to that a little later on.

I wrote this book by myself, but I'm not the only one living on this planet. There are always people on the sidelines who are also affected when one takes on a project of this type. I would like to express my thanks to these people for the support and tolerance they have shown over the past six months. Thank you, Moni, for making it possible for me to drop out of sight. Thanks, Wolfgang, for carrying on a dialogue with me over the years on software development (and reining me back in at times). Thanks, Jan, for your unstinting proofing and many helpful comments. Thanks, Alf, for providing the impetus which led to writing this book. Thank you, Judith, for the trust your have placed in me and your commitment to this book. I want to express my gratitude to all the people who have helped me. Thanks for being there!

A Global Foreword

by Clinton De Young

In the early 90's, during a trip to Japan, I received my first non-English versions of DOS, Windows, and a handful of software titles. I was excited to have Japanese versions of these programs until I installed them and was met with missing features, poor translations, and an underwhelming level of quality. Soon after this disappointing experience, I began working with contacts in Japan and the US in an effort to improve the quality of Japanese translations in software and documentation.

After working on several translations I still wasn't satisfied with the functionality of the software I was translating. Too often features were left out of the Japanese versions of software, and the quality was somewhat diminished. My interests evolved from translations to internationalization and localization testing, and then finally into internationalization engineering.

During the years, I have worked on many projects and seen many successes, and even a few failures. My desire in this book is to share some of my experiences and to discuss aspects of testing global software that will help you successfully ship quality products to all of your international customers.

The tools available to developers for creating international products have improved, as has the overall quality of localized software during the last 10 years; however, there are still areas that need work. Hopefully, once you have completed this book, you will be able to improve the quality of the software you work on, and help others do the same.

I have enjoyed the internationalization and localization aspects of development and testing over the years. It has provided me with a unique opportunity to get to know people from all over the world, and make friends I never would have otherwise. I have been able to travel to many countries and experience many different cultures. It is a path in my life that I am very glad I traveled. I hope you have an equally enjoyable experience as you work with global software.

There have been many who have helped make my experiences in international software good ones, and people who have taught me along the way. To show my gratitude, I would like to acknowledge their contributions here. I would like to thank my wife Hiromi and my children for their support in all I do. I would like to thank my friend David Stones for taking a chance on me when I lacked experience so many years ago. Thanks to Guenter and Teri at Lemoine International for making my contributions to this book possible. I also offer my thanks to my dear departed friend Craig Adams (to whom I still owe a lunch) for his mentoring and unparalleled friendship. Finally, I would like to thank my parents for the life I have to live.

1 Rapid Application Testing

"There is something fishy about this!" shouted the hare: "Let's do it again—turn around and go back!" And he rushed off like the wind, his ears flying behind his head. As he approached the top of the field again, the hedgehog called over to him: "Beat ya!"
(Adapted from [Schröder1840], "The Hare and the Hedgehog")

1.1 Everything Is in Flux

Times change. Particularly in the software development world, everything is always changing. Not only are customer requirements undergoing constant transformation, but so are the limits of technology, software user interfaces, and the ways humans and computers interact. This has an effect on how software is built. Since the environment is constantly changing, software that constitutes an obstacle to change should not be built. In the age of the Internet, every type of bureaucratic overhead related to software development is being questioned.

Testing on internet time

Software testing is not immune to all these changes. For a long time, the basis for generating test plans and metrics was coverage of functional properties and coverage of specifications (see the section "Test Coverage" on page 130.) After it was realized that not everything can be tested, methods were developed to uncover redundancies within test cases and test data. In addition, methods were also developed for evaluating the risks of testing certain parts of the software less intensively than others. However, because all this still did not keep pace with the increasing speed of software development, people began to question more and more the aspects of their own methodology.

1.1.1 Software Development as a Game

Ever since the overwhelming victory of the object-oriented paradigm in software development, few other issues have excited more controversy than changes in software development methodology.

Ten years ago, the prevalent view was that Computer Aided Software Engineering, or CASE, was the answer to every problem (perhaps primarily because of the expensive tools involved). People like Alistair Cockburn [Cockburn, 2002] now describe software development as a cooperative game, bounded by its specific content, which moves toward a specific endpoint over a given period of time. The cooperative group is made up of project sponsors, managers, specialists, technicians, designers, programmers, testers, and in short, everyone who has an interest in the success of the project. In most cases, the endpoint of the game is to deliver the required system as quickly as possible. Sometimes the focus is placed on other software endpoints: easy to use, bug-free, or safe from possible third-party liability claims.

Agile processes

This view of the activities involved in the software development process, as elaborated and justified by Cockburn, dovetails perfectly with the current debate on software development methodologies. Agile processes are in demand: processes which can adapt quickly to changes and rely more on communication, self-organization and the delivery of real-world software than on the planning, monitoring and documentation of the development process [Fowler and Highsmith, 2001].

1.1.2 The Art of Getting a Program to Crash

The game between the software tester and software developer is reminiscent of the race between the tortoise and the hare.

The games testers play

The rules of the game are simple: The testers try to find the most important errors as quickly as possible. In other words, they try to prove that the program will fail under certain conditions. The most obvious indication of failure is the common crash: a general protection fault or the program freezing ("Nothing is happening"). In this sense, rapid application testing can certainly be described as the art of getting a program to crash.

The games programmers play

Programmers do everything they can to deny the testers the thrill of victory. The developers win if they can say, every time the testers run into a critical performance issue with a program, "Beat ya!" —like the tortoise. This does not mean that a program must perform faultlessly in every imaginable situation. However, the program must respond in a predictable and stable manner—for example by generating an error message and instructions for how to resolve the error—no matter what nasty tricks the tester employs.

1.1.3 Error Weighting

Program failures do not always reveal themselves as blatantly as with a crash. More subtle failures range from processing or output errors to computing errors and usability flaws, all the way to inadequate care in the treatment of confidential data. Because not all errors are equally important, a rank order for error weighting should be set up based on the agreed-upon rules of the game. The following is a proposed four-level scale for generic error weighting developed with software end users in mind. Using this scale, errors are ranked by their importance within four groups:

1. Errors that render the program inoperable
2. Errors that make it impossible to use the program as planned unless workarounds are used
3. Errors that cause annoying and unnecessary effort while using the program
4. Errors adversely affecting the software's user interface.

In this context, use refers to the user's entire experience with the program, and therefore also includes installation and administration.

The most serious errors on this scale are those which prevent users and administrators of the program from working and cannot be worked around. Anything that forces the user or administrator to resort to a workaround to accomplish a given task is ranked second. The next level down is anything which is annoying and inconvenient. Inconsistencies in the look and feel of the software are placed in the final category.

The scale assumes that the prescribed use of the program has been defined somewhere, for example in use cases, functionality specifications or in menu item descriptions. The mere desire for a particular use ("I should also be able to do this...") is not sufficient grounds for reporting an error.

Adhering to project goals

In the end, rules for ranking errors by importance will be determined by the project goals and the project stakeholders. For example, market competition may make a software product's graphical user interface vitally important. In this case, factors such as whether the product appeals to younger or older users, whether it is "hip" or corporate, or whether it comes across as conversational or professional make inconsistencies in the GUI more important than missing functionality.

1.2 The Rapid in Rapid Application Testing

The objective of Rapid Application Testing is to find the most serious defects in a software product as quickly as possible. That is why the approach is called Rapid Application Testing rather than Total Application Testing. Finding all the errors can also be an intriguing game—but the question almost always arises of who will pay for it.

On the Web site of his software testing company Satisfice [Satisfice], James Bach, author of several books on software testing, distinguishes between his approach, which he calls "rapid testing," and standard testing methodologies. He lists the following ways in which Rapid Testing differs from the formal testing methods traditionally used:

- Mission
  Rapid testing does not begin with a task like "create test cases." Instead, it begins with a mission such as: "Find the most important errors—fast." Which tasks are necessary to complete the mission successfully? That depends on the nature of the mission. No activity considered necessary under the formal testing approach is indispensable; all activities must prove their utility in relation to the mission.
- Capabilities
  The conventional testing approach underestimates the significance of the tester's ability, knowledge and skills. Rapid Testing requires knowledge of the application being tested and the potential problems which may arise during deployment, as well as the ability to draw logical conclusions and devise tests that produce meaningful results.
- Risk
  The traditional testing approach attempts to cover as many functional properties and structural components as possible. Rapid Testing

focuses on the most important problems first. To do this, testers develop an understanding of what can happen and what results when it does happen. Afterwards, potential problem areas are explored in order of their importance.

▶ **Experience**
In order to avoid descending into "analysis paralysis," Rapid Testing recommends that testers rely on past experience. In conventional, formal testing methods, tester experience usually enters into the work unconsciously and is therefore unexamined. Testers using Rapid Testing, however, should collect and record their experiences and validate them through systematic application.

▶ **Research**
"Rapid Testing is also rapid learning," says James Bach [Bach, 2001]. The application under test (AUT) is investigated and defined during testing. The next test always derives from the results of the preceding tests. Exploratory testing goes straight to the core problems of the software more quickly than scripted testing.

▶ **Collaboration**
Testing can often become a lonely undertaking if you follow conventional methods. One important technique used in Rapid Testing is *pair testing*—i.e. two testers on one computer. This technique was adopted from eXtreme Programming and, according to James Bach, also works very well in Rapid Testing.

Above all, Rapid Testing is exploratory testing (see the section "Testing Strategies" on page 38). For professional testers who must test programs "cold," exploratory testing is often the only way to get control of a demanding work project. The general procedures for testing functionality and stability that back up the "Certified for Microsoft Windows" logo were developed by Bach based on the exploratory testing approach [Microsoft, 1999].

1.2.1 Integrated Testing

James Bach describes Rapid Testing from the viewpoint of a professional tester. I have inserted the word "application" and produced the term Rapid Application Testing (RAT) in order to emphasize its similarity to

Rapid Application Development (RAD). Both are concerned with the entire development process—RAT does not exclusively focus on testing, and RAD does not exclusively focus on the user interface, as some descriptions imply. Both efforts have the same goal—not to waste time.

Rapid Application Testing is integrated testing. In other words, it is integral to the software development process and not a secondary, ancillary software validation process. Just as tasting is an integral part of cooking, testing is always part and parcel of the software development process that leads to a product or an intermediate engineering product.

Rapid Application Testing provides various strategies and techniques for doing this. Important strategies include "testing by using" and embedded testing. For more information on this area, see Chapter 2, "Testing: An Overview," and its section on testing strategies. All strategies and techniques have one thing in common: they focus on the risk that each (intermediate) product may pose to the success of the entire software development process.

1.2.2 All Good Things Take Time

Did Rapid Application Testing get its name because software errors and behaviors that are only annoying, superfluous or unpleasant are not found and corrected? Or because bugs will remain inside programs forever merely because some are not that critical? Or because nobody is willing to deal with spelling errors in screen forms?

This is not what the term means. Rapid Application Testing simply indicates what testers should pay attention to first. It does not imply that the effort to enhance quality should fall by the wayside after testers have found all the bugs in the "Crash" and "Workaround Required" categories. The most important principles of Rapid Application Testing, such as goal orientation and trust in the creativity, ability and experience of those involved—rather than rigid reliance on formal procedures—are fully applicable to tracking down bugs that are only a nuisance. It is precisely this type of interference with workflow, caused by inconsistencies in the program's look and feel, user interface design flaws, or poorly designed input dialogs, that will almost never be found using prescribed test cases.

One should not of course be overly optimistic and assume that such goals can be achieved as rapidly as the most serious software errors are discovered. Some things take time. That includes, among other things, allowing software to become "fat" and "sleek" in development.

Rapid Application Testing must mean getting the software ready for market. That not all software introduced to the market is "robust" or "sleek" or even "mature"—and that it neither can nor must be—is something I probably do not need to tell you.

1.3 Testers and Developers

1.3.1 The Way Things Stand

Why is knowledge of testing strategies, techniques and basics so important for developers, software architects, analysts and designers, i.e. for everyone involved in the software development process? Isn't it enough if the testers know their way around testing? The answer is as simple as it is compelling: Because many projects do not include a tester. If those involved in a project still want to deliver high-quality software, then they will have to test it themselves.

Everyone tests

Currently, "tester" is predominantly viewed as a role that anyone can fill when called upon to do so. After completion of development tasks or at convenient points in a project, a software developer may slip into the role of tester and give the application a "once over." In most projects someone has designed the software and makes the final decision on changes and extensions. This someone typically watches with eagle eyes to make sure that the original design is preserved and that "his" or "her" program does what he or she intended it to do. Sometimes the project manager does not want to put his or her name on the line for the next release version without testing the program first. All of these persons had better get a grasp of the topic quickly. Formal specifications of test activities, which are reasonable enough for well-funded projects with relaxed schedules, are more of a hindrance under these circumstances.

Rapid does not mean ad hoc

The gap between formal requirements and real world practice (but not only in testing) has been around for a long time, probably since software has been around and since people recognized the need for testing.

"Ad hoc" testing is standard practice on underfunded projects where the focus is necessarily on the most important features due to budget or time constraints. This type of improvised testing often makes everyone on the project queasy. So much hasn't been tested—but really—shouldn't everything be tested?! This uncertainty arises when people do not realize that they are participating in a "software development" game—a.k.a. a mission—and thus do not understand the object of that game. Their own role in the game and the duties attached to that role also remain unclear.

Testing is not viewed as a means of minimizing risk; instead it is seen as an imposition. The rationale for and scope of testing remain vague. One has a vague sense that expectations will never be met. This produces uncertainty about what should be tested first. Those involved try to master their insecurity by going back to the book—taking formal methods straight out of textbooks. However, there is not even enough time to properly develop the documents specified by the "IEEE Standard for Software Test Documentation" [IEEE829]: *test plan*, *test design*, *test case specification*, *test procedures*, *test item transmittal report*, *test log*, *test incident report and test summary report*. The testers (if there is a budget for them at all) test "something, anything." The developers get annoyed because the testers report more or less marginal problems ("I'm glad the test is working and then he starts bugging me with stuff like that!"). In the end, the team trusts in the Almighty and delivers the application.

1.3.2 Theory and Practice

In their standard work *Testing Computer Software* [Kaner, 1999], Cem Kaner et al. compare software testing with the experimental testing of scientific theories. On development teams, testers are the practitioners. They set up test procedures with which to confirm their paradigm of the program. Or they intend to prove that the program fails under certain conditions. Testers are skeptics. They see the program from a user perspective and ferret out the practical uses of the programmers' theories.

In this analogy, the developers are the theorists. They conceptualize and envision only with great difficulty where their ideal world might clash with harsh reality. Developers like to believe that the whole world works the way they imagine it working. They view programs—and software bugs—as interesting assignments and intriguing challenges. Usability is less important to them unless they have to use their application themselves.[1]

This characterization may seem a little extreme, but it gets to the heart of the issue. Anyone who has done both jobs—developing software and testing unknown software—knows that as a tester or developer, you can easily get to feeling what Kaner describes.

If one sticks to the principle that software developers and testers must be different people, this will usually not help much with real-world software development projects. In many projects, the developers are the only ones who try out the program before it is released. This can hardly be called testing; it would be more accurate to describe it as confirming the validity of their theories (see above).

To ignore this situation and the factors behind it, and to insist on a formal division between testing and development, is no solution. For many projects which privilege direct contact with the customer and flexible response to customer change requests and bug reports, a formalistic approach of this kind would be fatal. It is better to accept the situation as it is and provide project members with the techniques and tools they need: not only take control of the situation, but also to extend their competitive advantage by producing high quality products.

1.3.3 Self-Awareness

How do you feel?

How do people feel when somebody finds an error in their program? Especially if the program is your own work or built by your team—and the release date is bearing down on you? There are many different reactions to this kind of pressure. Some people knew all along (they say) that the developers for this particular module couldn't cut it—they didn't even think to check such an obvious feature ("This would never happen to me, because ..."). Others would rather look the other way because they know that the error—there for all to see in its gory detail—will only lead to another project delay ("We're behind schedule already as it is!").

1 If a developer creates programs for his or her own use, then ease-of-use is usually their weak point.

Yet another group will simply think it is a pain to consider a minor issue like that an error, because they know that they will have to test the revised code after the bug has been fixed.

Mission possible

Sure—you can't help having these feelings. Maybe such feelings should not be stated so clearly to avoid demoralizing others in the group. But a tester of a product or program component could also clarify for himself or herself, in one or two sentences, his or her own role, the object of the game, and the mission. It is worth a try.

Certain tests are designed to find errors. Other tests are intended to show that certain requirements have been met by the program. The following applies in both cases: the sooner the better. The sooner an error is found, the sooner it can be eliminated. The sooner you discover something is missing, the sooner you can add what is needed. Ignoring the issue or procrastinating does not help in either case.

When I discover an error, I have done a good deed for the project. If the error is grievous, I have really done well. I say this because a project will stand or fall based on early detection of show stoppers.

Two pairs of eyes are better than one

A developer who tests his or her own program is in a certain way handicapped. Subconscious fears may keep the developer from carefully checking certain parts of the program. Some burned-out programmers will stare at their own source code for several minutes without seeing the error that is hidden there. More often than not, unexamined convictions will also blind a programmer to possible sources of errors.

Things look different if software developers review their colleagues' programs, for example during pair programming, or serve as an auditor during peer or group reviews, or take on the role of the end user. If asked to use an unknown module, even normal developers will respond with the "let's just have a look" reflex. The module's GUI is experienced as what it is: an interface. The developer will distrust it instinctively, check the claims made in the interface description (if it exists) for accuracy, and so on.

1.3.4 And the Winner Is ...

Testers and developers must realize that they both have a role in a game. Many feel very uncomfortable taking on the apparently aggressive or destructive role of the tester, especially if the roles of developer and tester are combined in one person or group.

However, one can make a virtue of this necessity if both roles in the game are seriously acted out, if the objective of the game is known, and if the rules of the game are followed. The testers know their mission and plunge into their work without reservations, even if they were still developers only moments before. The developers know what testing means and take appropriate proactive steps. Later, they utilize their experience when acting as testers on more demanding tests. Everyone knows that the only good error is a known error and nobody gets bent out of shape. If feelings do get hurt, it helps to exchange roles from time to time and have candid team discussions. If the developer says this to the tester: "Hey, thanks for your error report. I would never have thought of that!" then both of them are on the right track.

The winner of the game is always the program being tested. The other winner is the team of people that creates this program; they get a bigger part in the larger game played within the company or on the market. In his excellent article, Alistair Cockburn says: *"The project has two goals: to deliver the software and to create an advantageous position for the next game. If the primary goal isn't met, the next game may be canceled."* [Cockburn, 2002]

1.4 Ideas, Techniques and Tools

This book is intended to introduce ideas, techniques and tools which can be used for Rapid Application Testing: ideas for determining the right questions to ask; techniques for devising a testing cycle that can answer them; and tools for recording, interpreting and managing the test results. The most important link in this chain is the first one: asking the right questions. If your testing criteria are the wrong ones, even the most ingenious testing cycle and the most sensitive measuring tools will not help you a bit.

Ideas, techniques and tools are needed to:

- Detect errors
- Find the source of the error(s)
- Manage the testing process

Not all of these ideas will be applied to the same extent by both testers and developers. In order to detect errors, testers require tools and techniques to monitor programs and compare execution results; developers on the other hand need tools and techniques for analyzing how the program behaves. Both the tester and developer need to get an idea of what could go wrong with the program.

Project managers and people with responsibility on the project need techniques for assessing risk and tracking the current status of the project, as well as numbers to use for decision-making and comparison with reference data from other projects.

Two-fold benefit

Many of the ideas proposed here can be beneficial in two ways. To get a two-fold benefit means to carry out an activity which delivers a primary and a secondary benefit. In our case, the secondary benefit is ongoing quality assurance and control.

Because the line between developers and testers is becoming more and more blurred in the real world, this book is not written for testers only. Nor is it a manual on debugging for developers. Whenever it makes sense, both perspectives should be addressed and various approaches should be presented together.

In general, this book is not aimed at specialists buried in a particular field, but rather professionals who can look outside their discipline regardless of how specialized they are. Rapid Application Testing has a lot to do with the fact that team members must play disparate roles in nearly every small or medium-sized project. Large-scale projects definitely follow their own rules—which have more to do with politics than with getting results.

Rapid Application Testers know their role in the game, understand their significance to the project, and have recourse to every useful tool available to plan, execute and analyze their test activities.

2 Testing: an Overview

Quality means that the customer keeps coming back, not the product.
(Herrmann Titz, founder of the Hertie department stores)

This book presents various techniques for testing software, evaluating prototypes during software development, retesting functionality after software has been modified or enhanced, and so on. These techniques were developed for various purposes, but in pursuit of one goal: to maximize the quality of the software product.

2.1 What is Software Quality?

Quality assurance is generally broken down into productive and analytical quality assurance. Productive quality assurance includes all activities that improve the product, while analytical quality assurance comprises activities which ascertain its level of quality.

Within this schema, software testing belongs to analytical quality assurance and falls within the subcategory called dynamic testing. The most important statistical tests within analytical quality assurance are reviews, code analysis and model validation. Tests alone do not improve the quality of software. That would be like losing weight simply by standing on the bathroom scale once a day. Tests and other analyses can only reveal where there is a problem. Quality has not been assured until the reported problems have also been eliminated.

2.1.1 Possible Definitions

There have been many attempts to interpret or define the term quality, for example the definition given in the German industry standard DIN 55350:

"Quality is the aggregate of all characteristics and properties of a product or activity that relate to its suitability for meeting specified requirements."

As obscure as this definition may appear at first glance, it provides some important pointers for answering the question: What is software?

"Quality is the aggregate ..."

means that all characteristics and properties of the software are included in the term quality, not merely requirements specified somewhere in writing. Software can therefore meet all written requirements and still be of low quality. The desired "look and feel" of a program or a consistent user interface across all its modules is often left out of system or business requirements. However, the quality of the software would be significantly lowered if the design kept changing completely from screen form to screen form, or if the meaning of function and shortcut keys kept changing, and so on. A large number of informal quality characteristics always accompany the formal ones.

"... that relate to its suitability for meeting specified requirements."

Here is where the requirements for the program come into play. In this context, "requirements" comprises more than the explicit requirements included in a written specification. Equally important are the implicit requirements generated by the product environment and the end user. Kaner et al. list possible sources of such implicit requirements [Kaner et. al., 2002]:

- Competing products
- Products from the same series
- Older versions of the product
- Internal project discussions
- Customer feedback
- Articles and books in specialized or technical fields
- Internal and general style guides for the user interface
- Compatibility with the operating system or IT environment
- Personal experience

Applications are not tested (or evaluated) against implicit requirements most of the time. Nevertheless, implicit requirements should not be neglected. When implicit requirements are not met, software quality will suffer—just as it will when explicit requirements are disregarded. In some cases—especially when the user is directly affected—legal action may even be taken to ensure fulfillment of implicit requirements.

What is missing from the DIN 55350 definition of quality is any reference to the user. Features which "meet specified requirements" for an experienced user may be useless to an inexperienced one—because they are beyond him.

The IEEE standard on software quality (ANSI/IEEE Standard 729-1983) includes a section on user requirements. According to the IEEE Computer Society glossary [IEEE Glossary], software quality is:

1. *The totality of features and characteristics of a software product that bear on its ability to satisfy given needs; for example, conform to specifications.*
2. *The degree to which software possesses a desired combination of attributes.*
3. *The degree to which a customer or a user perceives that software meets his or her composite expectations.*
4. *The composite characteristics of software that determine the degree to which the software in use will meet the expectations of the customer.*
5. *Attributes of software that affect its perceived value, for example, correctness, reliability, maintainability, and portability.*
6. *Software quality includes fitness for purpose, reasonable cost, reliability, ease of use in relation to those who use it, design of maintenance and upgrade characteristics, and compares well against reliable products.*

It is noteworthy that the IEEE Computer Society includes reasonable cost among the quality characteristics of software. In a testing context, this means that testing cannot go on forever—no more no less. At some point (and that means pretty quickly), excessive testing will no longer enhance the quality of the software, but rather diminish it—because it runs up costs without achieving any corresponding improvement in quality.

2.1.2 New Approaches to Quality

In his book Process and Product Orientation in Software Development and their Effect on Software Quality Management, W. Mellis presents two different notions of quality derived from different software development models [Wiecz and Meyerh, 2001]. These contrasting concepts imply very different testing strategies and methods.

Transformative software development

Transformative software development migrates a well-defined, clearly understood and relatively stable process to an automated environment. The process to be automated can also be precisely analyzed and modeled. Requirements defined through analysis form the basis of software development. The resulting software is high quality when it behaves correctly and meets all requirements, and when its intended users can use it without experiencing major problems. These days, transformative development projects are very often in-house projects carried out by large corporations to develop custom solutions. Customized software can be built around a particular process with no ifs, ands or buts. Flexibility is priority two, almost always substantially reducing the complexity of the software. In this kind of project, tests based on system requirements and system design can be planned well in advance. Chaos usually creeps into this type of project only when a lot of users come forward with special wish lists. This chaos can be contained if a formal requirements and change management system is in place.

Adaptive software development

In contrast to transformative software development, there is no clear-cut, easily automated process of adaptive software development. This can be due to several factors: The software is so innovative that potential system requirements and user issues have yet to be researched. The software's area of application—its domain—is so chaotic that a process suitable for automation cannot be identified. There are many processes which conform to each other on a high level but vary in detail and must be harmonized. This last is probably the most common reason. This usually happens when off-the-shelf software is developed to please many diverse customers and be compatible with their workflows.

Adaptive software development often starts with a vision. At the conceptual stage, everything still fits together because "it just does." Then the detail work begins. Developing a vision requires abstract thinking and creativity. The software kernel, which represents the least common denominator of the process being modeled, must be made flexible enough to allow the finished program to be adapted as closely as possible to still unknown environmental conditions.

Here quality has little to do with correct behavior (nobody knows what "correct behavior" would be in this case). Fulfillment of requirements also drops out as a quality characteristic because the key characteristics have not yet been formulated in a detailed functional specification (or because the next customer has already specified different requirements).

Underlying concepts

Naturally, underlying concepts behind quality, such as accuracy, robustness, speed and fulfillment of the implicit requirements of the application area also apply. The term quality has much more to do with content in an adaptive software development process than it does in a transformative one. Here high quality means that the software is generally useful (or is fun to use or "cool"); that the abstract model works; that the software is flexible and can be adapted to the unknown requirements of the customer; that it supports rather than obstructs workflow; and that it hits the bulls-eye and is a hit with users. These are all things which become apparent only after the software has been released. Tests with these criteria can hardly be planned ahead of time because adaptive software development remains essentially an R&D project long after the program has been rolled out.

2.2 The Overall Course of a Test

Before we jump into testing practices, I would like to present a brief overview of what actually constitutes a test, of current general test procedures and current types of testing, of how test phases are broken down within a project, and of how and when other quality assurance methods can be used.

A single test normally includes three steps.

- Planning
- Execution
- Evaluation

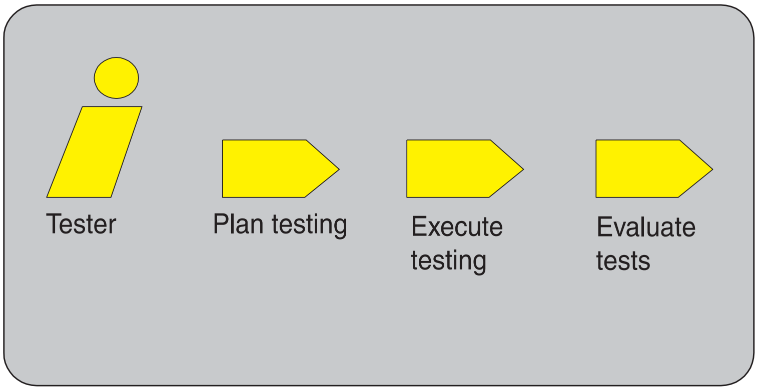

Figure 2.1 General test procedure

Even if the person carrying out the test is not aware of these three steps, they are still there—or conversely, if one of the three steps is missing, then the process can hardly be called a test.

The test situation

If someone sits down at a computer, starts a program and tries out a few features, they are still not testing the program. But as soon as they are perplexed by something specific in the program, and try to trace the source of what they suspect is a problem, this becomes a testing situation. It then includes the steps described above: Planning ("If I exit this text input field empty and still click OK, the program will probably crash ..."), Execution ("Let's see if it does ...") and Evaluation ("It sure did!").

2.2.1 Planning

During the first step you determine what should be tested. This planning step should not be confused with overall test planning which is carried out as part of project planning. Detailed planning—also referred to as test design in the literature—first identifies the test case, then specifies the test activities, and finally indicates how test results should be defined. This sounds very elaborate, but really in its essentials is simply an idea of what has to be tested ("The programmer definitely didn't think of this!"), of how to proceed ("If I exit this text entry field empty and click OK anyway ...") and of what will be tested and when ("... the program will probably crash"). One must also have an idea of the correct outcome ("The program should be able to handle that"). Testing makes no sense without a conception of the desired outcome. What use are test results if you haven't got any idea if they are right or wrong?

Risk-based testing

Rapid Application Testing is risk-based testing. In Chapter 3, "Testing in the Real World," I have provided a description of risk assessment methods that will help you determine your testing priorities based on acceptance risks and technical risks. However, reliance on intuition as well as method is an important part of testing practice. The ability of an experienced tester to divine a program's weak points is called "error guessing."

Always try to plan your tests so that they cover the widest area of risk possible. At the same time, stay focussed on the single most important risk: that the program will not work at all. You should always start with the assumption that the program will be used in an optimal operational environment—the so-called best case. Only after you have checked this off your list can you begin to consider alternative scenarios.

Key features

Organize your test planning around the program features. Break the features down into key features and supporting features. An example of a key feature is that the user can save his or her work as a file to the hard disk at a certain point in the program. A related supporting feature would enable the user to select the directory path for saving work via a Browse or Search button. Focus first on the key features. A key feature which is buggy or does not work will be unacceptable to most users. The user can usually find a work-around for errors in the supporting features.

Error frequency

Tests can only prove that errors exist, not that a program is free of errors. Just because 100 errors have already been found, that doesn't mean that 1,000 more errors aren't waiting to be discovered. If you can't find any more errors, this could mean that the program is free of errors (this is rarely the case). It could also just as easily mean that your test procedures and cases are not up to finding the errors that are still there.

As a rule of thumb: Where there is one error, there are more. This is why the results of previous tests should be taken into consideration during test planning. This rule may apply to a module which has proven to be particularly buggy, or to insufficiently secure access to resources such as files, printers or modems. Or it may apply to specific workflows which are inadequately or improperly supported by the program.

Test planning Test planning for Rapid Application Testing does not mean planning and formulating every single test case in advance. This method is not particularly effective in most cases because it shifts you from risk-based testing to a formal approach. It is more important that the overall testing plan concentrate on key risk areas and provide possible testing strategies. Detailed planning should remain flexible and take previous test outcomes into consideration.

In addition, planning all test cases in advance is not an option when you are getting to know the program to be tested through the testing itself. During exploratory testing (see below), additions to the test plan are always made based on the results of previous tests.

Your test plan will look very different depending on whether you know the application under test from the inside out, or if you are only familiar with its GUI. Hence the difference between White Box and Black Box testing. Neither technique is better or worse than the other. Not only do their requirements differ, but also their objectives. For a detailed discussion of this issue, see "Testing Methods" on page 49.

2.2.2 Execution

The execution of a test is also a three-step process:

1. Preparing the testing environment
2. Completing the test
3. Determining test results

Special test data types may form a part of the testing environment as well as metadata used to control the software being tested. In subsequent test phases, the complete hardware environment may also be included.

The testing environment is a important factor for whether or not a test can be reproduced. If a test must be repeated frequently, for example in order to check performance improvements after program tuning, it makes a lot of sense to automate preparation of the required testing environment. Not only does this save time, it ensures that you won't forget anything important.

Test interface

How a test is executed very much depends on whether a test interface is available for the program or component under testing. If this is the case, the test interface can either be used to conduct the test interactively, or, if the test is to be automated, to write a program which executes the test. Test frameworks are available for this purpose for almost every programming language. For more information on test frameworks and how to use them, see Chapter 4, "Methodologies and Tools." For more discussion of test interfaces, see the section "Test-driven Application Development" on page 191.

If no test interface is available, you have no other option than to test the program or program unit using the end-user interface. Interactive testing is only possible via the GUI in many cases, but this can be a real problem in automated testing. For that you need a support tool that will record and play back end-user inputs and mouse actions. See the section "Automating Testing Procedures" on page 158 for an exhaustive discussion of potential areas for automation.

Tool support

Often, one is also dependent on a support tool when determining test results. For programs which work in conjunction with a database, for example, the database must be accessible without having to use the program. Systems with a distributed architecture may require tools that can log and graphically display network traffic. Performance tests may call for tools that can record the program's response time.

Simple tests are normally all that is needed to reach a quick verdict on a program's reliability and robustness. Bear in mind that a test is designed to reveal problem areas. It is not the tester's job to track down the source of the problem—that is the task of the developer.

2.2.3 Evaluation

To evaluate a test session means to compare the actual test outcome with what the correct outcome should have been. The expected (correct) outcome should be easy to record for this purpose. You cannot test whether a program output is correct or not if you have no idea what a correct result looks like.

If documentation exists, this is naturally the first place to go for information on correct program behavior. Documented specifications include development task descriptions and business models, application flowcharts and text-based descriptions of application scenarios, GUI design specifications, printouts of sample reports, Online Help, user manuals, installation manuals and other related material. Whatever behavior is documented there can be tested directly.

Considerations for specialized software

If accuracy in the context of a specialized field requires checking, then the requisite knowledge must be made available for this purpose. Specialized aspects may be mentioned in task descriptions, Online Help or user manuals, but are rarely discussed in detail. The user manual for a financial accounting software product is not designed to teach the user financial accounting, but rather the use of this special application. As a tester, you must usually rely on an expert in a case like this.

Validation program

You may be fortunate enough to have another program available to validate results produced by the program being tested. This is always the case when the application under test outputs data which is required for subsequent processing (or used by another program). If the program under test creates an XML file, you won't necessarily have to eyeball the file for correct content and format. The XML document can also be opened in a program able to output XML files in order to verify that it is well-formed (at the very least). Bear in mind, however, that the validation program must not be too tolerant. If an error in the document being tested is tolerated or overlooked, this will cloud the evaluation of your testing results.

Verification test

You should generally be skeptical if the evaluation of the test session only includes outputs from the program being tested. You will frequently find that faulty program behavior is hidden behind another set of errors which behave similarly. For example, bad database field updates may be overlooked if the developer simultaneously forgets to export the new field to a linked report. Therefore, always try to validate results by using a different tool. To verify the real result generated by a program which writes data to a database, access that database directly with another tool.

2.3 What is to be done with the test results?

The test result should be recorded in a "suitable form." Easy to say, but wait a minute: Which forms are suitable and which are not? This depends on what you want to do with the test documentation. If the test runs smoothly and no new errors are discovered, in most cases it is enough just to record what was tested and when. Perhaps the program version should also be stated.

If an error is discovered and included in a program modification (testing and tuning), a short note is sufficient—in other cases, the result should be recorded more formally, e.g. in a database of completed tests and outcomes. You will find one suggestion for how to organize such a database in the section "Quality Control" on page 231.

Error report

In addition to general information (name of the tester[s], date of the test, program tested, program version), the test document—the error report—should document the three stages of the test, i.e. planning (what is actually being tested), execution (how it was tested) and assessment (what should have been the correct result, what was the actual result). This entails as pragmatic an approach as possible. The following sample report contains all three points in abridged form. *"When the pickup table is empty, a message box appears briefly when the program is started with the missing text '[ERR] PickupTableEmpty'. When this happens, a default sentence should be entered."*

The environmental conditions under which the test was performed also belong in the test documentation if they are relevant to the test result. They are of particular interest if the error cannot be tracked down in the development environment. In this case, changes in the application's behavior under various operational conditions often provide the information essential for localizing the error.

It is also important that when a test is repeated after the error has been corrected, the original conditions can be reproduced. For this reason, the tester must have the detailed specifications he needs to reproduce the test environment.

2.3.1 Checking

The outcome of a test normally leads to modification of the application and error correction. After this is done, the same test should be carried out again to make sure that: 1. The error was corrected in the right way; and 2. The right error was corrected. Since checking error correction is very time-consuming and provides no new information, the tester often prefers to leave out this compulsory check.

Don't turn a blind eye

When testing, you often find errors you were not looking for. In other words, even if the testing is risk-based, it can produce test outcomes related to less risky program behaviors. These outcomes are simply the many small errors that an attentive tester notices in passing. These errors should not be ignored—but rather reported. However, these less important test results need not be checked. Checking should also be geared toward the level of risk associated with a given program behavior. As a tester, you should not waste time correcting incidental errors.

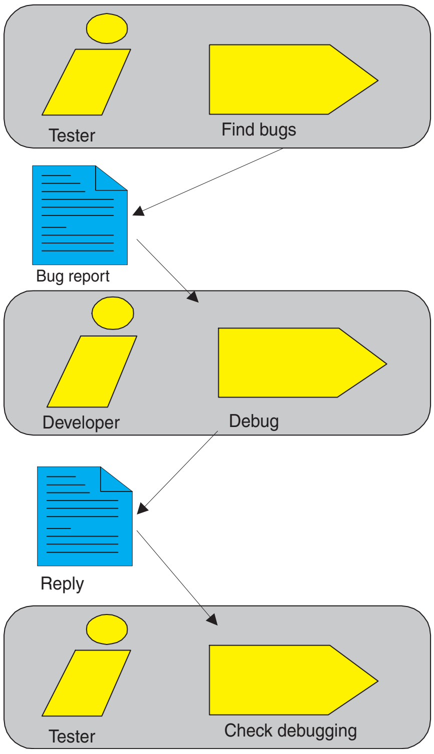

Figure 2.2 Testing, debugging and checking

Accordingly, the procedure shown in Figure 2.2 should only be followed when error reports and corrections are sufficiently important. The direct path shown is only recommended if the number of error reports is low—for instance in the final phase of a software product's life cycle. In all other cases, error reports are first collected. When the next program version is released, the issues that have been dealt with are reported back in one block. A central database is normally used for this. If the testers are not members of the development team, someone on the team should be given the job of screening and prioritizing the incoming error reports and checking the outgoing replies.

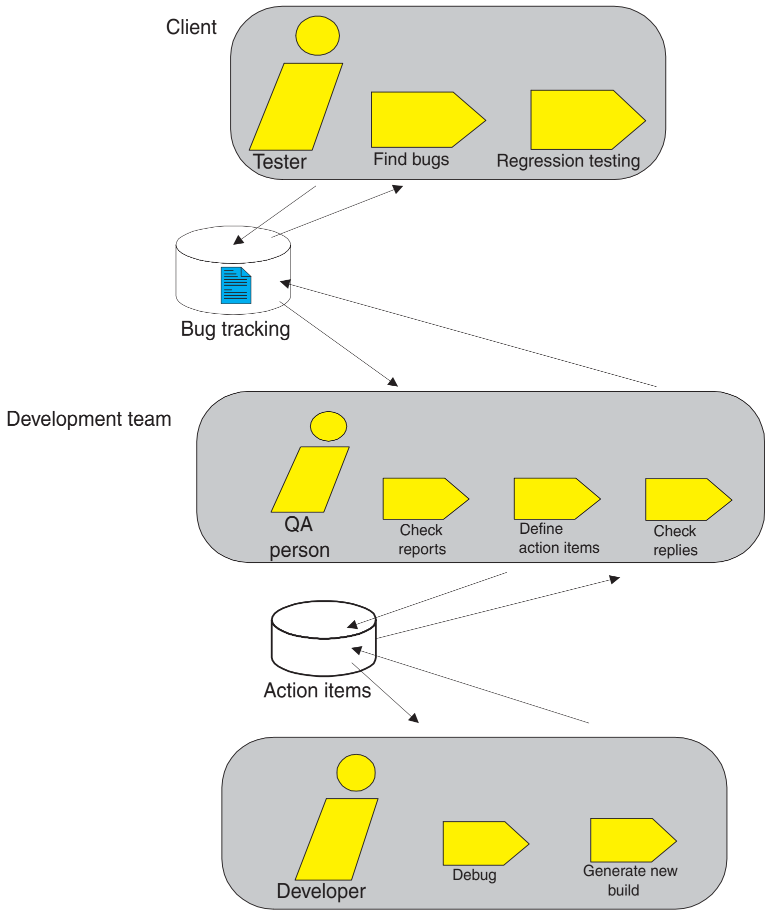

Figure 2.3 Checking error reports and developer feedback

It also makes sense to add change management to the responsibilities of the QA officer described in Figure 2.3 (see "Test Case Tracking" on page 233). But make sure that there are sufficient resources available for this role to avoid creating a new bottleneck at this position. During hectic periods, a QA officer is working flat out—pulling along two to three testers on his left and three to four busy developers on his right.

2.3.2 List of known errors

If for any reason it is impossible to correct an error, the test results still generate a list that tells you how reliably the software works in certain situations. Such a list can, for example, be included in the manual under the heading "known errors." Moreover, it is always worth taking the trouble to find out which mistakes were made most frequently during the development. This kind of information will help you decide what continuing education and advanced training your people need. Or it will help you decide whether to change your software development process, use different tools etc.

2.4 Testing Strategies

The strategy you should adopt for testing basically depends on whether you are a program developer or an external program tester. In other words, it depends on whether testing is integrated into the development process or conducted independently. In addition, the level of resources allocated to testing is obviously a crucial factor.

2.4.1 Exploratory Testing

If you aren't familiar with the program to be tested, then you may want to opt for a method called "exploratory testing." When exploratory testing is performed, the test cases are developed during testing, not before. The results obtained from the first test cases help define subsequent test cases.

The objective of this method is to reach the critical failure points in the software as quickly as possible. It would be extremely time-consuming, and above all a waste of time, if your first step was to get to know the program, your second step was to plan your test cases, and your final step was to execute each test case one after the other. By the time you had become expert enough to find and write down all the necessary test cases, the next version of the program would already be out and the software provider would have hired another tester.

Ideal testing situations

If you do not know the program you have to test, then you are in an ideal testing situation. In this situation, the program makes the same impression on you as it will later on the user who opens the program for the first time. Everything that you do not understand intuitively, or at least after a reasonable amount of effort, points to a possible defect in the user interface. Data processing problems and "roadblocks" in program flow are most apparent when you are first getting to know the program. Later, this awareness will be "dulled" as you get used to the program's "quirks" and learn to avoid them.

A subset of exploratory testing is so-called guerilla testing. This involves short but intensive testing of a limited section of a program by an experienced tester. The objective is to ascertain the degree of risk posed by this program unit. Using the most extreme means available, the tester attempts to make the program fail in this area or crash. If the program weathers the attack reasonably well, the unit "attacked" can be put on the back burner for further testing or completely dropped from the test plan.

You will find helpful links on the topic of "exploratory testing" in [Kaner] and [Satisfice].

2.4.2 Testing and Improving (Testing and Tuning)

The most widely used strategy for testing within the development process is probably simultaneous software testing and improvement. Testing and error correction are not separated in this strategy. Testing is primarily seen as "ground work": a necessary step toward fixing parts of the program that don't yet work very well. Testing and tuning of this type is a classic developer strategy. Before a program module is released, the developer tests whether everything is running smoothly and immediately corrects any errors she finds. In this phase, the developer is also more concerned with catching potential problem situations not dealt with during development than with completing deliverables on schedule.

The Test Maturity Model (TMM) developed by the Illinois Institute of Technology [IIT] unfairly labels this strategy as TMM Level 1: a default testing approach to be "surmounted." Nobody should still expect developers to refrain from testing their modules before they are released. Especially when you reflect that approximately ¾ of all code exists to react to exceptions and errors, leaving only a quarter for the actual processing instructions (many estimates even give a figure of only 10 % for processing code). It is precisely this strategy of trial and error, correction and repetition that works best for dealing with exceptions and errors.

Testing and improving

Therefore, testing and improving is in reality an important phase of software development and the Test Maturity Model can be used to build on this basic strategy. The first three stages in particular indicate how to proceed. With level 1 as the point of departure (the testing process is either completely undefined, or badly and chaotically structured and overlaps with debugging), level 2 testing may be understood as a separate phase in the development process which is typically carried out after coding. Level 3 testing is then implemented as an independent activity in the overall development process. In level 3, testing is now no longer a phase after coding, but an integral part of analyzing, designing, coding, integrating and distributing software.

Once testing is integrated into the development process, testers also become members of the development team. In many projects, it is standard practice for testers and developers to switch places. You test my module and I'll test yours.

2.4.3 Automated Testing

The importance of testing and automating tools has increased tremendously as applications and system environments have grown more complex. In most cases, currently available tools have their own programming language for creating test scripts. The latest trend is toward employing widely used script languages which can also be used for software development itself, such as Perl or TCL, JavaScript, Visual Basic, or similar languages. The job of creating automated tests is frequently given to a programmer.

The tools used in testing usually do more than find errors. The same tools are also used to trace the source of the errors. There is no clear-cut difference between testing and analyzing functions either.

Low cost automation

In principle though, test automation does not require the deployment of expensive tools. A great deal can be checked automatically using tests embedded in the source code (see below). Test frameworks for programming and managing unit tests can be downloaded from the Internet [xProgramming]. Scripts can also be created using tools and script languages which are either provided with the operating system or available as freeware on the Internet.

Please note!

Despite everything that automated tests can do to make your life easier, you must not lose sight of a few realities:

1. **Test automation has to be learned**
   Creating automated tests is initially very time-consuming. The demanding learning curve must not be underestimated. If you only have a little time for testing, it is not a good idea to count on test automation. It is better to take your first tentative steps toward automation in early project phases or during projects without time pressure (if there is such a thing) and commit to slow, steady improvement in your automation concept. Begin by automating only simple (but important) tests. Alternatively, automate only portions of the test procedure such as the preparation of the necessary test environment. Over time, as you become more experienced, you will also be able to automate more complex test scenarios.
2. **Testing tools are no replacement for testing staff**
   Testing tools are only effective in the hands of a trained tester. These tools are not machines—you cannot feed them the program and expect them to spit out a tested program complete with a test summary report. Risk assessment and test planning, preparation and testing of scripts that specify how the test will be conducted, and interpretation of the recorded results are all activities that no tool can do for you.
3. **Not everything can be tested, even with automation**
   As a tester or testing manager, you will have to accept the fact that not everything can be tested. Implementing tools that automate testing

won't make any difference here. When planning an automated test, focus on the risks associated with the program module to be tested, just as you would for a manual test. Concentrate on technical risks and place less emphasis on acceptance risks (for more information, see the section "Risk assessment" on page 84). Technical risks associated with the system environment provide the most fertile ground for automated testing. If you have to test your software and all subsequent modifications across several platforms, well-planned test automation can save you a lot of work. By contrast, automated tests which repeatedly check the same program feature in the same environment will rarely turn up new errors. As a general rule, tests which are designed to prove that a program works—referred to as positive tests—lend themselves more readily to automation than tests intended to find previously unreported errors (see the section "Smoke Tests" on page 46).

4. **Automated tests must be continuously updated**

   The process of creating an automated test often uncovers more errors than the finished automated test script finds later.[1] And just because the scripts are finished does not mean that the work of testing is over. If an automated test fails, the causes must be investigated. In many cases, the test script no longer matches the software after modifications or enhancements have been made. An automated test does not distinguish between a program enhancement and an error. As far as the test is concerned, anything which is different from last time is going to be wrong. If the change is indeed not an error, then the script must be modified accordingly. New scripts may eventually be needed to test possible new scenarios generated by program enhancements. Some routine automated tests may also persist long after changes to system requirements have made them irrelevant. Whatever the case may be, proceed on the assumption that automated tests will have to be continuously developed and updated along with the software. Increased focus on testing and continuous refinements to test activities make for better quality software, but naturally at a cost.

1 Unfortunately, most of the errors that interfere with automated tests have no effect on normal program use.

5. **Automating tests costs time and money**

   Kaner et al. [Kaner et. al., 2002] estimate the cost of creating an automated test at ten times the cost of equivalent manual testing. My own experience confirms this assessment. It takes approximately half a day to automate a test procedure that can be done manually in 15 to 20 minutes. One tester will barely be able to automate more than two such test cases a day. If you have identified several dozen (or even a hundred) important test cases, you can easily calculate how long it will take to automate all of them. The first scripts will probably be obsolete by the time the last scripts have been created.

   To expenses related to the creation and maintenance of scripts must be added the price of testing tools. These vary from a few thousand dollars for GUI testing tools to many tens of thousands of dollars for stress testing and performance testing tools.

2.4.4 Testing by Using

One of the most fruitful testing strategies is called testing by using. This strategy is especially well suited for testing quality characteristics within an adaptive software development process (see the above section "What is Software Quality?" on page 25).

Testing content aspects

As explained above, the quality characteristics of an adaptive development process are largely determined by content aspects. The strategies used to test content aspects of the software differ from those used to test formal aspects. Once the software has been pronounced relatively robust and error-free, it must be used. Only through usage can crucial questions raised during an adaptive process be answered:

- Is the software really useful? How could usability be improved? What features are missing that would make the software really rock?
- Does the software support all (or at least the most important) user workflows? Does the program enhance or impede workflow?
- Do the users see themselves and their domain of work reflected in the software? Are the specialized terms correct, are the abstractions logical?

- Is it fun to work with the software, or is it tiresome and annoying? Do users feel overwhelmed or are they bored?

Testing by using must take place in a normal operational environment, not in a usability lab. On large-scale or high-risk projects, a live testing or beta testing phase is normally planned prior to product launch. On more modest projects, but still risky ones for the developers, the software has been known to remain perpetually in beta testing. You can use the "testing by using" approach during your project at the module or component level as well.

Modularizing

Modularizing the program, i.e. breaking the required programming work down into different levels (layers) or working with a modular component architecture, is almost always a good idea these days. It is almost the only way to cope with the complexity of modern software.

If your project has no formal budget for testing, or if nobody can be spared from development to concentrate completely on testing, following this approach will help you secure or improve the quality of your software. Through modularization, layering or component architecture, "real-world use" conditions are built into the development process right from the start. They do not appear at the end after development is over. Developers should be able to use each other's modules, components, classes and features—preferably without looking at the source code.

On some projects, all the developers are expected to own the source code, meaning that they should all know their way around the source code equally well. When following the testing by using approach, however, it is better if the tester's familiarity with the program is restricted to the GUI, the problem description, and a general statement of the software solution.

A fresh point of view is important!

The tester should not be too familiar with how the software under test has been developed. To evaluate an idea, one needs a perspective different from the one present at its creation. That's why it is simply better—safer and more effective—to have people on the project focussed primarily on testing. This does not mean that testers cannot have other roles on the project. Analysis and customer relations are responsibilities which overlap nicely with the duties of a tester. On the other hand, they should distance themselves as much as possible from the design and coding of the product. If you want to be a tester who programs, specialize in the development of test scripts.

2.4.5 Testing by Documenting

Writing user documentation provides another opportunity to apply testing by using. User documentation should not be handed over to a developer—or at least not to someone involved in the development of the program module in question—but rather to someone who has actually experienced the program like a user. Doing this increases the chances that the user documentation will answer questions that actually interest users. On the internal side, whoever writes the documentation must get to know the program before writing the user manual—and get help from the developers as needed. This process closely resembles exploratory testing, assuming that the documentation is not based merely on task descriptions or other analysis documents. Instead, the writer of the documentation should ask the same question every time he or she writes a sentence: "Does it really work the way I say it does?" The writer must also be able to execute a complete series of commands. This boils down to making a working version of the software available to documentation specialists rather than making them work with screenshots. They need to be able to recognize problems and be allowed to investigate them. In addition to having direct access to developers, they should also have a say whenever the program they have documented is being assessed. In other words, they must be the kind of people who can tell developers: "Hey! Why didn't you make CTRL+C the shortcut key for copying text?"

2.4.6 Regression Testing

When the behavior of a program changes for the worse after a modification or addition, this is called regression. The goal of regression testing is to bring a change for the worse to light. Regression testing's primary objective is to ensure that all bugfree features stay that way (also see the next section on smoke tests). In addition, bugs which have been fixed once should not turn up again in subsequent program versions.

Because regression testing should be repeated after every software modification, or at the latest before the next product release, the desire to automate these tests is particularly strong. Cem Kaner and others point out, in Lessons Learned in Software Testing [Kaner et. al., 2002], that automated regression tests quickly become obsolete (Lesson 117: Automated regression tests die).

Because of the considerable expense, it is not a good idea to promote all tests which have ever uncovered an error to the level of a regression test. An easier and better way to reduce the risk of an error recurring in a later version is to use Source Code Control Systems (SCCS).

Broad coverage testing

Good regression tests include a lot. In other words, they cover a large number of internal and external program features. Spot check tests (see below) work well as regression tests when they cover a wide range of validated input data. If data types processed without difficulty by earlier program versions are now causing problems, this behavior provides valuable clues for finding potential program errors.

Performance tests also lend themselves well to regression testing. If the execution time of a transaction on the same computer significantly deviates (by a factor of two or three) upward or downward in the new program version, i.e. when the software has become dramatically faster or slower in performing a particular step, then this behavior should be looked into and the cause investigated.

2.4.7 Smoke Tests

Smoke tests are a battery of tests which check basic program functionality. Smoke tests got their name from the smoke that rises (metaphorically) from the computer when the software fails one of these tests. We are thus concerned with a limited set of regression tests which zero in on basic functional properties. If the software build fails smoke tests, it is not acceptable and is not released for any further testing.

Smoke tests are frequently automated. They belong in the category of positive tests—they aim to prove that a specific functional property exists and that no errors crop up.

One approach which is becoming more popular is the "nightly" build. Every day, all the source code released by developers is combined into one build and subjected to an automated smoke test.

Another variant is to give the developers smoke tests and make them use them before releasing code to each other. This approach is always attractive when the development team is dispersed across several locations.

2.4.8 Embedded Testing

Smoke tests—or more generally regression tests—can be directly embedded in the source code. In many programming languages, ASSERT statements (or similar ones) are available for testing the preconditions of a routine or a class method. This concept is known as “Design by Contract" in the Eiffel language. In this case, the tests are directly integrated into the language. When the keyword “require" appears at the beginning of a method, a list of assertions is given that introduces the preconditions. After an “ensure" keyword at the end of a method, there follows a list of assertions introducing postconditions. After the keyword “invariant," additional conditions can be specified that are always true for all objects of a class (invariants). The Eiffel compiler makes sure that all of the assertions are executed, or none of them, or only the preconditions, or the pre- and postconditions. A discussion of the “Design by Contract" concept can be found under [ISEDbC]. Attempts to duplicate this concept in C++ and Java are discussed in [Maley and Spence, 2001] and in [Völter, 2001]. Java Version 1.4 and higher includes an assertion facility. The documentation for Java 1.4 also provides some instructions and tips for reproducing Design by Contract through assertions [JavaSun].

Permanent regression test

In most programming languages, preconditions can be evaluated without too much difficulty before a method executes. ASSERT statements or simple IF statements at the beginning of a method ensure that all assumptions for the start of a method are available. Checking preconditions (Eiffel compiler's default setting) is sufficient for our testing purposes. When the postconditions of a method or the invariants of a class do not hold, this becomes apparent at the latest when they are evaluated as preconditions for the next method. If certain postconditions or invariants are not used anywhere as preconditions, they probably are not all that important.

Carefully testing the preconditions of all routines or methods is equivalent to conducting a permanent regression. Test drivers are used to make sure that all the functions under test have been invoked. The test drivers record the return values or catch exceptions. In an object-oriented programming language, test drivers can be stored as test code methods in an abstract class. The advantage of this is that you save effort by managing the code under test and the corresponding test driver together. They are kept in the same physical location (most often in a source code file). This "one source" principal has proven value in documentation and also makes sense when working with code and test drivers, at least at the unit testing level.

Speaking of documentation: Testing preconditions at the beginning of a function has the pleasant side effect that the function's preconditions are correctly documented. Text descriptions of preconditions in function headers or as constraints in a class model have an unpleasant habit of becoming unreliable over time. When the preconditions for ASSERT or IF statements at the beginning of a function are tested, the results are more than comments. They describe real program behavior. Moreover, they are actually readable, at least for software developers.

2.4.9 Live Testing

Live testing of a system is conducted by prospective users, initial users, experts, fellow developers interested in the software, and so on. The most well-known form of live testing is the beta-testing done prior to a product's official release. Given the ways products are released these days, however, it is fair to include the first official versions in the live testing phase.

As described in the "Testing by Using" section above, lives tests measure software quality differently from formal tests. In addition, live testing "thrives" on variety—variety in the ways the product is used, in the ambient conditions, and in the potential operating failures that users can contrive. This level of variety can hardly be achieved in testing labs.

Results from live testing are often very vague. You might even receive some pointless bug reports. However, live testing often yields surprising and important information, for example that the program is being used in ways not planned by the developers. One of the most important results of live testing is the reconciliation of actual use with the expected user priorities defined during risk assessment (see Chapter 3). In order to get a picture of the software that is as valid as possible, it is important to recruit users for live testing who resemble future customers as closely as possible.

2.5 Testing Methods

Test procedures often differ greatly between functional and structural tests. Traditionally, functional tests have been termed Black Box tests, and structural tests White Box tests. Between the two, one finds a large group of tests which do not fit into either category. These tests employ both functional and structural approaches as needed for test case selection and for developing test procedures. These increasingly important methods are called Gray Box tests.

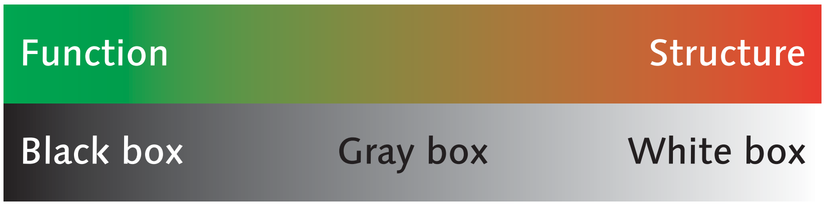

Figure 2.4 An overview of testing methods

2.5.1 Black Box Testing

With the Black Box method, the outside world comes into contact with the test item—a program or program unit—only through a specified interface. This interface can be the application interface, an internal module interface, or the INPUT/OUTPUT description of a batch process. Black Box tests check whether interface definitions are adhered to in all situations. Product acceptance tests completed by the customer are also Black Box tests. They test whether the product conforms to all fixed requirements. Test cases are created based on the task descriptions.

Naturally, it behooves the developer to conduct these tests prior to the product's release. That way she has a chance to find mistakes before the customer does.

2.5.2 White Box Testing

In the case of the White Box method, the inner workings of the test item are known. The test cases are created based on this knowledge. White Box tests are thus developer tests. They ensure that each implemented function is executed at least once and checked for correct behavior. Examination of White Box testing results can be done with the system specifications in mind. For example, the success of a transaction need not be verified by checking a printout or an account balance displayed in the program interface, but instead can be directly verified by reviewing the resulting data since the data structure of the account is known. The accuracy of the journal entry and the displayed account balance must still be checked of course. White Box tests, therefore, do not replace Black Box tests—they only ruin the suspense.

2.5.3 Gray Box tests

Hung Q. Nguyen [Nguyen, 2001] defines Gray Box testing as follows:

> *"Gray-Box-Testing consists of methods and tools derived from the knowledge of the applications internals [sic] and the environment with whitch [sic] it interacts, that can be applied in Black-Box-Testing to enhance productivity, bug finding, and bug analyzing efficiency."*

Gray Box testing, like Black Box testing, is concerned with the accuracy and dependability of the input and output of the program or module. However, the test cases, risk assessments, and test methods involved in Gray Box testing are developed based on knowledge of internal data flows and structures. Gray Box tests often use the same tools to find errors that software developers use to uncover the causes of errors, i.e., tools that let you directly observe the software's internal operations.

Component-based IT structure

Gray Box testing rapidly acquires importance in a component-based IT structure. This occurs because the notion of a component does not quite fit either the Black Box or the White Box testing paradigm. The efficiency of a test depends on our mental model of the application under test. If we think of a piece of software as a monolithic block, we will use the Black Box testing method. If we are familiar with a program at the source code level, and our mental model is composed of statements to be processed, branches, nested elements, loops, and so on, then we will lean toward White Box testing. However, if we view software as the interplay of many components, we will develop test cases for risky components and leave out components that are less fault-prone. We will have a sense of how the components communicate and exchange information, and use it to come up with ideas for tests.

Background knowledge

Imagine that you were supposed to test a Web application and you were completely ignorant of browsers, clients, and servers, as well as of the necessity of connecting them. You would have viewed the Web application like a desktop application. The test cases you would have derived from this mental model would certainly have been different had you been able to incorporate background knowledge of Web applications into your model. You would probably have found errors for which the browser vendor or Internet service provider was responsible. The awareness of the distances involved in Internet communication is enough to make us tolerate response times that we would never accept from a desktop application.

Gray Box testing is also the method of choice for Rapid Application Testing. Due to time constraints, we will limit ourselves here to functional tests, where availability, reliability, performance, and robustness are seen as software functions. However, we will get ideas for effective test cases wherever we can find them—mostly from our knowledge of internal structures and their inherent risks.

2.6 Types of Functional and Structural Tests

2.6.1 Requirements-Based Testing

As the name suggests, requirements-based tests are tests created using functional specifications. These tests check whether the program is doing what it is supposed to do. Requirements-based tests are often acceptance tests. Acceptance tests differ from other types of tests in that they do not try to find errors. Instead they aim to prove that all requirements have been met. This makes them positive tests. Test cases for acceptance tests are most often structured in such a way that they cover the fulfillment of a single acceptance criterion.

Sometimes, this is easier said than done. If an acceptance criterion states that a search for a customer in a database of customers should last no longer than five seconds, irrespective of the search criteria, should the corresponding acceptance test actually build queries to the customer database covering all combinations of all search criteria and test the duration of each query? A set of 10 search criteria would already generate 1023 combinations. This procedure is so time-consuming that only a program can do it. Therefore, acceptance tests with criteria like these are sometimes executed in spot check testing. Alternatively, an extended testing period is arranged to get people using the program earlier. The hope is that any critical requirements gone astray will be found in this phase.

Implicit requirements

As outlined above in the section "What is Software Quality," there are not only explicitly formulated and documented requirements, but also de facto requirements derived from the software type and software environment. These implicit requirements are not dealt with in acceptance tests, but they can provide important test cases, especially for evaluating the design of the user interface.

Whatever is not explicitly stated in the functional specifications is also not a contractual acceptance test item. If the functional specifications indicate that a data entry field should accept date values equal to or greater than the current date, and if nothing is specified for date values in the past, then the current date and a later date **can** be entered in an approval test, but **never** an earlier date. However, if you want to deliver high-quality software, you won't be able to stop yourself from entering a date value less than the current date just to see what happens. Not only that, the integrated quality assurance process should have uncovered this flaw in the requirements specification well before acceptance testing (see the section "Integration of Phases in Rapid Application Testing" on page 64, and Chapter 5, "Agile Quality Management").

2.6.2 Design-Based Testing

These tests check adherence to design specifications. The most obvious example are GUI specifications. Using this method, one can check compliance with layout specifications. This will ensure that the entire program has a consistent look and feel. Possible test fields include font size and type, button size, label location and so forth. Many of these items can be checked with automated tests. In most cases, however, you will have to write a program to test adherence to your design specifications.

Other design specifications may also affect workflow. For example, if users are required to confirm all their deletions, this is definitely a design feature that should be tested. This is also true for design specifications that affect implementation, such as coding guidelines, naming conventions and database design requirements. Requirements like these are usually reviewed rather than tested.

2.6.3 Code-Based Testing

Code-based tests deal directly with the source code. This is always White Box testing. For one thing, code-based tests should check whether program code is generating run-time errors. Code-based tests are also used to assess the efficiency of algorithms.

Code-based testing is more important (and resource-intensive) when interpreter programming languages are involved. Unlike compiler languages, these are not highly-typed. If highly-typed language is not used, then a compiler will not be able to catch assignment errors because most value types are only implemented at runtime. This flaw can be spotted with code-based testing. Other sources of run-time errors, which also apply to compiler languages, include accessing database fields based on field name, accessing dynamic memory, pointer calculations etc. These are all things whose results only become known at runtime.

Runtime errors

In order to minimize runtime errors, code-based testing activities attempt to cover as much of the program as possible. Each line of source code should be gone over at least once. Along with this statement coverage, there are other degrees of coverage which we will discuss in more detail later on.

Code-based tests are normally run by the developers themselves. Their most important tool is a state-of-the-art source code debugger. It is a good (and profitable) habit to begin your examination of a new program function by completing a walkthrough using a debugger. Many special situations, oversights, or things which developers like to skip over during coding will often strike you immediately.

2.6.4 Performance Testing

Performance testing is designed to measure how quickly the program completes a given task. The primary objective is to determine whether the processing speed is acceptable in all parts of the program. If explicit requirements specify program performance, then performance tests are often performed as acceptance tests.

Performance tests are also suitable for regression testing (see "Testing Strategies" on page 38).

As a rule, performance tests are easy to automate. This makes sense above all when you want to make a performance comparison of different system conditions while using the user interface. The capture and automatic replay of user actions during testing eliminates variations in response times.

2.6.5 Stress Testing

Stress testing is a form of performance testing which measures program processing speed as system load is increased. System load typically means the number of concurrent program users (clients). It may also refer to the volume of data to be processed, the number of data records in a database, the frequency of incoming messages or similar factors.

2.6.6 Robustness Testing

Robustness or stress testing determines the conditions under which the program will fail. To do this, system load is increased (see "Stress Testing") in order to determine the point at which the load can no longer be processed. The program's behavior in this situation is observed.

Alternatively, resources are successively removed from the program in order to reach the minimum resource requirement level and to determine how the software behaves after resources fall below this point.

2.6.7 Long-term Testing

The objective of long-term testing is to determine that software does not become faulty after prolonged use, i.e., that it does not eat memory, significantly alter its processing speed, or flood disk space with temporary files, or that internal stacks do not overflow or other similar problems occur. Long-term testing may take hours, days or even weeks.

2.6.8 Installation Testing

Installation testing establishes that a program can be installed and uninstalled on the various target platforms that it was designed to support. This includes testing of both clean installs and updates of currently installed software.

If necessary, older program versions that are still in use are installed. These are then updated to the most recent version. The expectation is that data created by the older version will be correctly updated and that the software is still problem-free when fired up immediately after the update.

An additional topic related to installation testing is user permission. What rights does a user need to install the program? If administrator rights are required for installation, for example, a check is made of what happens when a user without administrator rights tries to install the program.

2.6.9 Security Testing

Security testing determines whether the program and its data are protected from hostile access. A distinction is made between external attacks, via the file system for example, and internal attacks, in which users attempt to access information without proper authorization.

2.7 Testing Types with Various Input Data

An entirely different way of distinguishing among testing types is to look at the range of possible input data.

2.7.1 Random Data Testing

Random data tests confront the application under test with input data generated at random. Typically, testers pay no attention to expected data types. They feed a random sequence of numbers, letters and characters into numeric data fields.

Documenting test activities and recording results can be a problem with this type of test. Little is gained by simply starting the test and noticing after a while that the program has crashed. The sequence of characters fed to the program must be recorded in order to determine which sequence of input data caused the program to misbehave.

Area of testing

Furthermore, it is usually not possible to thoroughly check the state of the program after each random operation. So you have to concentrate on one area of testing. Candidates are: robustness (the program should not crash), data integrity (the database should remain consistent), as well as operational integrity (the program should always be in a controlled state and not run into deadlock situations etc.).

Random workflow testing is a subset of random data testing. In this type of testing, input data is limited to control commands and mouse clicks. Every button you can get to is clicked, menu items are selected, windows are closed and so on. The same rule about recording results applies here: Record the random sequence of mouse clicks or control commands to be able to reproduce the test procedure later.

The point of doing random testing—or live testing—is to generate variety which cannot be achieved using a deliberate, planned approach. This is how a bug was found in VI, for example, even after the Unix editor was considered a classic, completely bug-free program for years.

2.7.2 Spot Check Testing

Spot check testing resembles random data testing—they both have a random component. But in this approach, input data is selected from a mass of real data that the software will encounter in its future area of use. To make this approach work, you need the largest quantity of "real world" data possible. Ask one of your customers (or better still, several) to provide you with real-world data. The more data you have and the more heterogeneous it is the better. Using a random algorithm, select a manageable subset from this pool of data. Then feed the data to the system.

Again, the problem here is to define the expected outcome. If the number of spot checks is small, you could come up with probable results for each individual test. This becomes difficult when the number of spot checks is great. If you want to make a preliminary determination of the expected outcome of thousands of data inputs, your budget will disappear fast. What does one do in this case? First, set a legitimate global objective. If you have a posting program that you want to test with a large quantity of real batch records, the first test goal should be smooth processing of all correct records. If the posting program rejects particular records, investigate these processing problems more closely.

Reference data

If the set of test data corresponds to an exact time period, reference data may also be available with final values or results for that period. In our posting program example, a completed posting period would constitute such a timeframe—perhaps a month. In a basic scenario, you would enter the opening balances at the beginning of the month, feed the entire month of posting records into the program, and compare the closing balances with the known values held in the reference program.

One goal of spot-check testing, as well as of random data testing, is to verify the integrity of the data after processing.

On database development projects, it is always advisable to deploy a program for checking database integrity as soon as possible.

2.7.3 Boundary Value Testing

Boundary value tests are specific tests which check the most extreme values of input data. A boundary value test checks how the program reacts to entries in a two-digit whole number field between 0 (zero) and 99, as well as to entries outside this range—e.g. from -1 to 100. Text fields are filled in completely, left empty, or overfilled by entering an extra character.

Boundary value tests are always individual tests with expected outcomes that can be precisely specified and checked.

For applications which write data to a database, it is a good policy to run a boundary value test on the application interface. This way you can ensure that data entry field lengths in the user interface correspond to field length limits in the database. A common mistake is to change the size of data fields during development and then forget to modify data entry fields in the interface. However, this kind of test takes a lot of time and effort. Assess the risk you are taking if the user enters an incorrect maximum value into a specific data field in the database. Boundary value testing should be automated for high-risk entry fields. Your best option is to employ a program which identifies the entry fields in screen forms and fills them with valid maximum values. Finally, directly access the database to determine whether all completed fields actually contain the maximum values.

When conducting a boundary value test of the application interface (going in the other direction), directly access the database to fill the entry fields in the GUI with maximum values. The interface is subsequently checked to determine if all maximum values have been correctly displayed.

2.8 Phases of Testing

Now that we have taken a close look at testing per se, and contrasted different testing strategies, methodologies, test case types and input data, the last question is when a given test should be carried out in the development process. In the following section, we will turn our attention to the timing and sequence of various phases of testing. Here we must make a distinction between conventional test planning models and production-oriented approaches within Rapid Application Testing. The way in which testing activities are distributed within the development process is often precisely what distinguishes Rapid Application Testing from conventional approaches.

2.8.1 The Classic Test Planning Model

The classic test planning model breaks the testing process down into three phases:

1. Unit, module and component testing
2. Integration testing
3. System testing
4. Acceptance testing

Regression testing is special because it is not a testing phase, but rather an ongoing activity in phases 1 through 3.

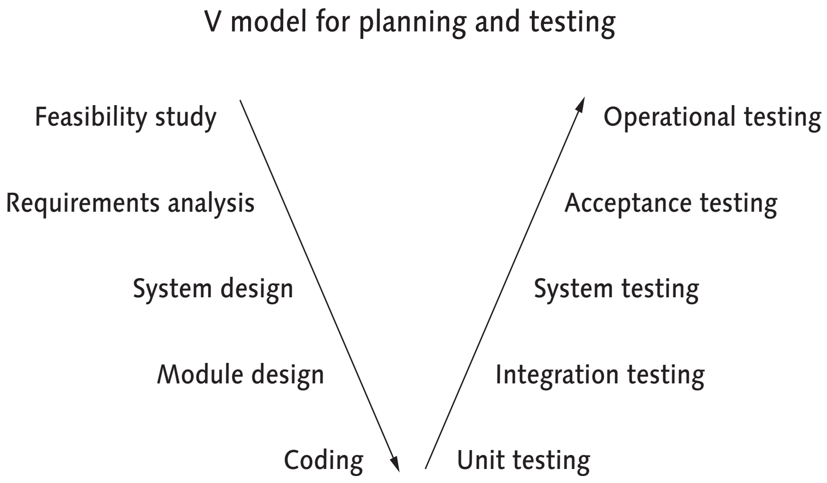

Figure 2.5 Classic test planning model

The classic test planning model is often depicted as a V to more clearly illustrate the relationship between development and testing. According to this model, the test cases executed during the testing phases on the right are planned during the development phases on the left. The feasibility study furnishes test cases for operational testing, the requirements analysis provides test cases for acceptance testing, and system testing takes its cue from the system design. The module design specifies the interfaces to be included in integration testing. After coding is underway, test cases can be prioritized for unit testing based on the feature set and the structure of particular units (classes, methods, functions, etc.). This diagram is not meant to imply a "Big Bang" development project. Given current development practices, the development and testing phases shown here more likely represent the flow of a single iteration.

Incremental? Iterative? Evolutionary?

If you are not familiar with the term iterative software development, see below for a brief explanation of this approach. For an in-depth treatment of incremental and iterative processes, you can consult the work of Beck [Beck, 1999], Kruchten [Kruchten, 1999], Dröschel [VMOD, 1997] and many other writers.

The incremental approach involves step-by-step development of a complete system. The complete system is designed as a whole and then built in steps. Each iteration adds more functional properties to the system, but in a purely incremental approach the overall objective of the system is clear from the start.

An iterative procedure entails breaking down the entire development process into a series of like steps. Each iteration or step involves the same set of activities: analysis of requirements, system design, construction and testing. Before development begins, core requirements (only) are specified and project parameters are defined.

The standard approach to software development nowadays is incremental. In the case of object-oriented system development, projects are frequently iterative as well.

In addition, there is the evolutionary approach. Here developers have the opportunity to modify core requirements and product limitations every time they start on a new product version. As a result of this, the new version might not simply extend the previous one, but completely replace it.

Unit, Module or Component Testing

This category comprises all tests carried out at the program unit level. A program unit may be an individual function or class method, or an entire module or class in objected-oriented programming. In the following section, we will use the commonly accepted term "unit testing."

Unit tests are carried out by the developer of the given program unit. Errors found in these tests are rooted out as quickly as possible. The test which revealed the bug is repeated after the bug fix.

Unit testing is concerned with three questions:

- Have all the requirements for the program unit been correctly implemented? The functionality specifications serve as the basis for these tests. Hopefully, they clearly identify every individual requirement. In the classic testing approach, the developer does not have to worry about whether the specification itself is correct. The developer is only responsible for its correct implementation. However, this way of thinking does not belong in the integrated approach of Rapid Application Testing! The developer who implements the requirements is now the user specified in the specifications. As such, he or she is entitled and even expected to view the specifications critically.
- Have all design decisions been correctly implemented? Correct implementation of the system design in a program unit is typically checked during system reviews. Design decisions appropriate for testing may include layout specifications for the application interface, for example.
- Do all internal functions work flawlessly? These are the basic tests. Internal functions, calculations, etc, are checked to establish whether they return correct results. Important tests in this area confirm that functions check parameters passed to them, handle boundary values successfully, and so on. In these basic tests, each line of source code must be executed at least once, but this is not so easy to achieve with 100% statement coverage. Later we will consider degrees of coverage in situations like this where 100 % is sometimes inconceivable even with all the good will in the world.

Checklists for unit testing typically include questions about:

- Functional correctness and completeness
- Error handling

- Checking input values (parameters)
- Correctness of output data (return values)
- Optimizing algorithms, performance

Integration Testing

Integration testing checks whether program components interact correctly. Program units previously tested at the unit level are assembled into larger components. When testing involves multiple functions in a single module, or integrated methods in a single class, this is still considered part of unit testing. The interaction of modules with other modules is the domain of integration testing.

Integration testing is thus not concerned with the implementation details of individual units, but rather with the requirements and design decisions that apply to their interaction. These might be requirements related to response times, for example, or to workflow between individual modules, access protection during multiple user operation, or individual access rights, etc.

Depending on the size of the organization and the resources available, integration testing is performed either by the responsible developer (or development team), or by a separate testing group.

Checklists for integration testing include these items:

- Functional correctness of transactions across several modules
- Interaction of menus, toolbars, function keys and called program units
- Interaction of processing and interface modules
- Response of program components to system events

System Testing

When complete systems or add-on modules are deployed, system testing is performed. System testing deals with questions like completeness, performance under heavy system load, security, integration in the system environment and so on.

When system tests are performed, they are often assigned to a separate testing group.

System testing checklists include questions about:

- Functional completeness of the system or the add-on module
- Runtime behavior on various operating systems or different hardware configurations.
- Installability and configurability on various systems
- Capacity limitations (maximum file size, number of records, maximum number of concurrent users, etc.)
- Behavior in response to problems in the programming environment (system crash, unavailable network, full hard-disk, printer not ready)
- Protection against unauthorized access to data and programs

Regression Testing

Regression testing does not constitute a single testing phase. Instead, it involves repeating tests from the first three phases to test specific features or subfeatures.

If any part of the program is modified or enhanced, it should be subjected to a new unit test by the developer. It is not sufficient to limit the testing to new functionality. The developer should also ensure that the modification does not interfere with existing functionality. This can best be achieved through the use of embedded tests (see "Testing Strategies" on page 38) in combination with test frameworks.

Every part of the program which is supposed to work with the modified or enhanced unit should be subjected to integration testing. System testing should also be repeated prior to release of new software versions.

Because of their high cost, basic integration and system regression tests are done as automated smoke tests (see "Testing Strategies" on page 38). Extensive regression testing is only carried out in preparation for a new release.

Acceptance Testing

Acceptance testing takes place after the development team has released the program. These tests are performed by the customer (or representative of the customer). The operational conditions are defined as the normal installation conditions.

If a formal acceptance test is part of the contract, you as the software vendor should develop the test cases yourself whenever possible. Base them on the requirements specification and guidance from the customer. This way you prevent a contractual acceptance test from becoming an acid test of the software's usability.

In the context of agile project management and integrated quality management, acceptance testing is synonymous with collaboration between the customer and the development team. Even at this late stage, there is a real possibility that hidden bugs may crop up when using the application under real-world conditions. Change requests should always be welcomed by an agile project team after all, there is no way to avoid them.

For more information on agile quality management, see Chapter 5.

2.8.2 Integration of Phases in Rapid Application Testing

The classic test planning model is based on the software production process.

If you flatten the V from Figure 2.5, you get a timeline of production and testing phases. The sequence of phases is reminiscent of the waterfall model. Advocates of structured processes argue that the waterfall model can still work for single, manageable iterations.

Problems with the process-oriented approach

The problems of a process-oriented approach to testing are made abundantly clear in Figure 2.6. Errors originating in any production phase may surface in any testing phase. If test cases are developed in the analysis phase or at the latest in the design phase as specified in the V model they will probably find bugs generated during analysis and design. As a result, the potentially most serious bugs will be discovered during the last phase of testing before delivery. Whoopee!

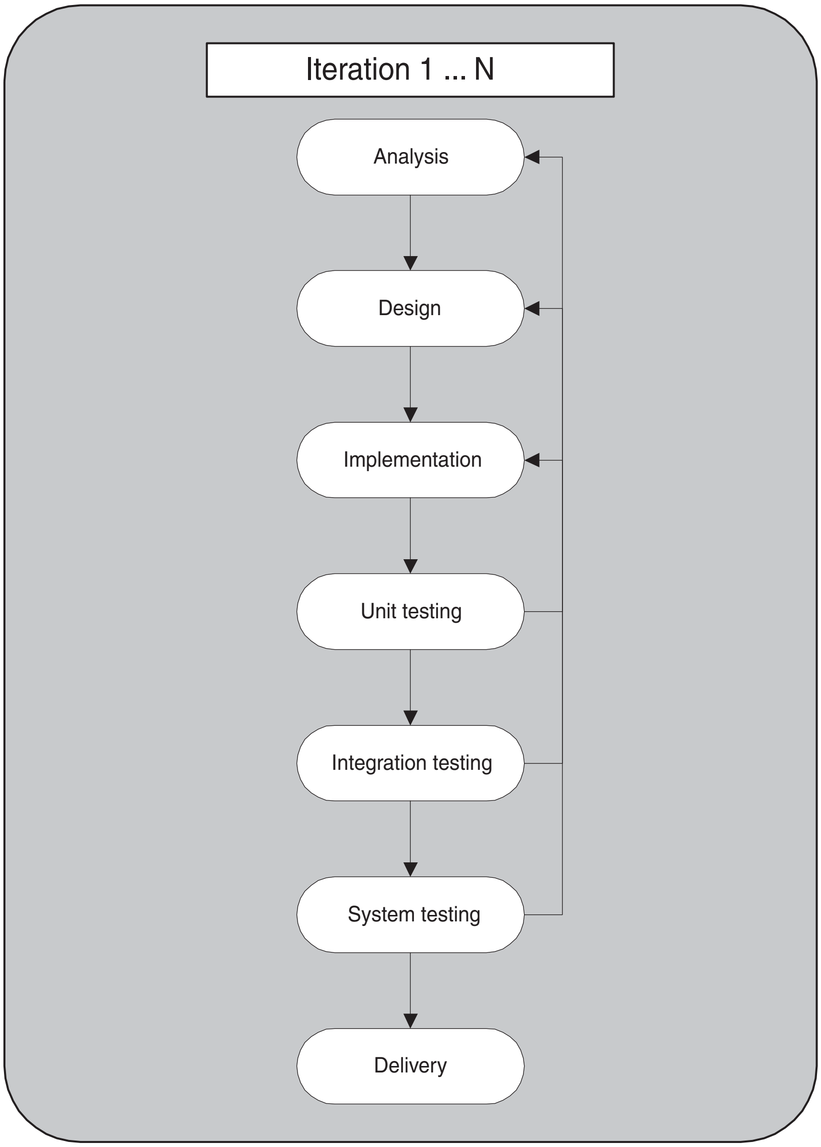

Figure 2.6 Classic production and testing phases

Rapid Application Testing is Integrated Testing. It is not organized around production phases, but rather around software products (or intermediate engineering products).

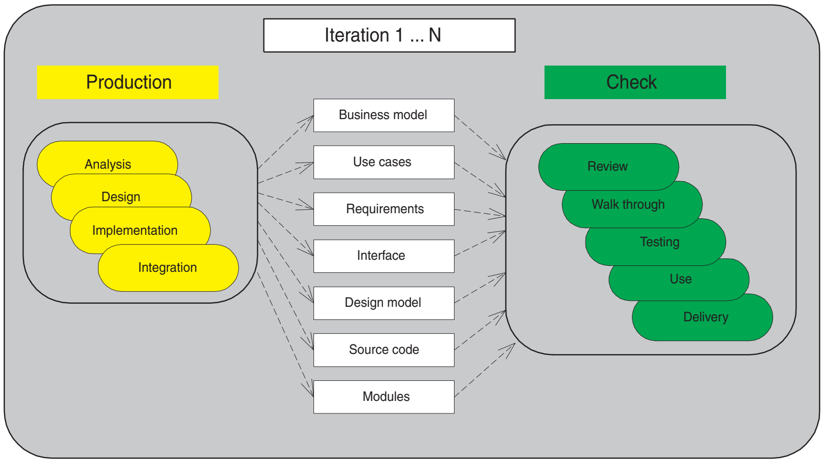

Figure 2.7 Building and Testing Products

Products of software development exist as soon as someone uses them. Once products exist, they should be tested ASAP. It doesn't really matter which product was built in which phase. What is important is which testing method suits which product. The question of whether a user interface prototype will be available during analysis or design, or later during clarification of implementation details, is secondary. It is more important that developers, designers and system architects have the right idea at the right time: "Product XYZ (a model, prototype, use case, source code, . . .) would help us here, and I or somebody else could check it with method ABC (review, walk-through, test, using the app, . . .)."

"Impromptu" testing

Rapid Application Testing is essentially "impromptu" testing. Production and testing phases alternate as products or intermediate products become available during development. Once a software analysis document has been created, it is reviewed. Design decisions are checked as soon as possible against a model. As soon as a class is fully programmed, it is tested and then used. When the team follows a strategy of "early integration," integration tests are also performed on an improvised schedule. In extreme cases, a general build is created several times a day and automatically run through the most important integration tests.

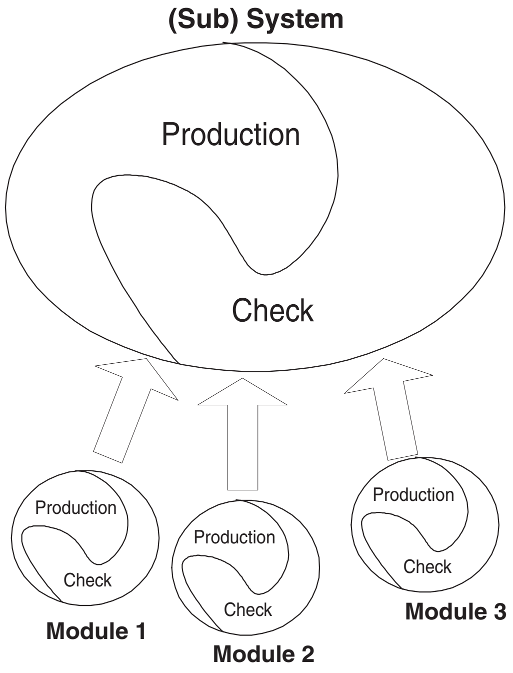

Figure 2.8 Yin and Yang in Software Development

Although Rapid Application Testing neither requires nor implements a progression of testing phases for software development, we can still use the phase of testing concept and the well-established terms "unit testing", "integration testing", "systems testing" and "acceptance testing." From a product-oriented perspective, these phases are tied to a product's (or intermediary product's) journey through the development process. The modules and subsystems indicated in Figure 2.8 are only examples. In the development of products of any magnitude, there is an inseparable link between building and testing.

Production and continual testing of software products form an integral part of any development process. Ideally, each activity checks the quality of its own input variables. This requires critical thinking and good communication from everyone involved on the project. Specialists give seminars to share their knowledge, architectures are discussed and compared, design decisions take software testability into account, programmers know how to test, and testers concentrate on system-dependent weak points.

2.9 Other Quality Assurance Methods

For a long time, testing was the most commonly employed method to assure software quality. In some cases it was the only method. This was unfortunate. Timely reviews during product development, for example, could have found many more bugs and different ones than testing alone. Reviews are usually cheaper than tests, and reviews of existing programs and projects are an excellent way to learn from past mistakes. The results of a review can find their way into the next project's analysis and design templates, coding guidelines and process improvements.

Of course, no one can afford to dispense with testing simply because regular reviews have taken place. The number of retests conducted after bug-fixes can be reduced dramatically, however, if there are fewer bugs to fix. Static code analysis and model validation methods also provide a similar benefit (see below).

2.9.1 Design and Code Reviews

There are two types of reviews: peer reviews and group reviews.

Peer reviews

Peer review means that one developer takes a good look at another developer's code. The reviewer should have at least the same level of expertise as the reviewee. Naturally, the process works better if the reviewer has more experience and better qualifications. Peer review can happen informally at any time. Or it can become de rigueur prior to first releases and the integration of new modules. Peer reviews are the most frequent type of review in Rapid Application Testing.

Group reviews

The second type of review is a group review. In this case a developer presents his module to the group and the group asks questions (“*“Why do you use PRIVATE here instead of PROTECTED?”*”), makes suggestions for improvement (“*This loop could be optimized by doing this ...*”) or turns up weak spots (“*That won’t work there because...*”). This type of review is something like an oral defense in graduate school. Group reviews are important at very critical stages in development and as post mortems after iterations.

Combining the two

The two types of review can also be combined. In this case, each member of the group takes a section of code or a specific feature, method or submodule and examines it alone. The results are summarized as bullet points and then discussed within the group. This combination approach makes it possible to review larger program components than is possible with pure group review a big advantage. At the same time, each participating developer gets an opportunity to learn something from the discussion and to share his opinion on a section of code.

For document reviews the procedure is the same. However, different questions are raised here. For example, when reviewing a requirements specification, team members might focus on whether each requirement has a testable acceptance criterion, or whether specifications are technically feasible at all, or whether they are unambiguously worded, or whether two specifications contradict each other.

When reviewing a class model, attention should be given to whether class assignments are correctly distributed, whether the visibility of class attributes is specified correctly, whether the class methods and attributes have been uniquely named in each case, etc.

For group reviews that take place frequently, it is advisable to compile checklists. These are first distributed to reviewers along with the object under review. Next, the reviewers go down their lists. Finally, each reviewer presents his points in the group session.

2.9.2 Static Code Analysis

Static code analysis does not observe software during runtime (as testing methods do), but instead analyzes source code directly. Through analysis structural errors are hunted and caught. These may include:

- Unused variables
- Unreachable code
- Missing return values
- Language dependent errors such as
  - Invalid nesting
  - Invalid allocations of values
  - Calling non-existent procedures

This type of statistical code analysis is built into most modern compilers and produces error messages and warnings.

More extensive code analyses check for adherence to coding rules. In general, this requires an add-in tool for each programming language. Most analysis tools on the market also allow you to specify your own coding rules and even have them checked as well.

2.9.3 Model Validation

Modern modeling tools designed for database modeling, or for creating class and object models for applications, also use validation methods. For example, database models created with state-of-the-art modeling tools can be automatically analyzed for redundant or missing indices, consistency of external and primary keys, tables without fields, etc. In addition, it is possible to make a reconciliation between the model and the database.

Model validation can only be used if the model is exact and sufficiently detailed. This is frequently the case when modeling databases, however, because complete databases can now be created directly from models without any further operations. In principle, this is also possible for modeling classes and objects, but this approach is very seldom taken. Class and object models are usually only sketches which facilitate an exchange of ideas. Whether formally correct class and object models will one day replace programming in high-level languages, or whether programs will one day be generated using only models, remain hotly debated issues.

3 Testing in the Real World

Each day is 24 hours in length, but the width varies.
(Wolfgang Neuss, cabaret artist and philosopher)

3.1 Developing and Testing

Rapid Application Testing focuses less on the phases of software development and more on the products or intermediate products of each phase. Products and intermediate products of development are also referred to as "artifacts" in the Unified Process Model [UPM]. In Rapid Application Testing, each artifact is tested explicitly or implicitly: explicitly when implementing test procedures tailored to the special product type, and implicitly when using artifacts critically in the continuing development process.

Manufacturing quality

Testing procedures can only determine product quality or the lack thereof. They cannot manufacture quality. Therefore, product development approaches and testing procedures must be complementary. Ideally, development will be strengthened by parallel quality testing of all preliminary products that flow into the final product. This sounds harder than it is. What you need are committed and interested team members; a project environment conducive to the exchange of ideas; and a simple process that avoids unnecessary formalism and permits substantive changes at any time.

3.1.1 A case study

The following case study presents some possible testing procedures for typical products and intermediate products of software development.

Not just testing

It is not limited to testing in the classical sense, but also includes different types of testing such as document reviews, walkthroughs, prototyping and model validation. Concrete examples from actual practice better reveal how all these procedures can be combined into one approach that, in addition to rapid application development, also achieves permanent quality control and expeditious discovery of the most important errors, a kind of Rapid Application Testing. Kent Beck writes in the conclusion of eXtreme Programming explained [Beck, 1999]: *"I am afraid of doing work that doesn't matter."* Anyone who has tried to deliver a product he can stand behind with a typically inadequate budget for software development can relate to this.

The example considered here is a software module used for licensing a data analysis program and monitoring compliance with the contractual terms of the license. The documents provided are based on original project documents. The development process essentially unfolded as presented here. The licensing module has been in use since the end of 1999. No modifications or corrections have been required since the release of the first version.

In cases where a procedure did not produce any meaningful documents, I have brought in samples from other projects.

Task description, software development task description

Usually, the first document created when developing new software is some kind of a task description. In this case, the license module was defined as a subtask in the course of preparing the overall project task description. From the very beginning, the licensing process was designated as a "module" without specifying any particular program structure to make it work.

Task Description for the Licensing Module

The licensing module should ensure that the XYZ system can only be used on workstations stipulated by the terms of the license. Licenses were issued:

- For each workstation
- With and without expiration date
- For each database to be analyzed
- For a set number of analyses per analysis type

Compliance with these licensing terms must be monitored by the licensing module.

…

Specifying tasks in writing

The task description was approved and endorsed by the customer.

The following items are relevant to QA:

- The tasks to be performed by the program are specified in writing.
  If a written analysis is required, one is forced to think more deeply about a topic. In addition, a document is created that can be checked and which serves as an aid to memory later on.
- The task description will be subject to a review which involves the customer.
  Even if you have received only one call from the customer requesting a special program feature, you should document that telephone conversation and submit a summary to your customer.
- The task description is signed off by the customer.
  This can be done formally (with a signed contract) or verbally. If the customer does not explicitly request any changes to the last telephone conversation report, you can usually assume that you have correctly understood and described the task. Work can proceed on this basis.

Developing a concept

Working closely with the customer

Initial conceptual work on the system design included an analysis of the situations the program had to guard against. For example, the user of the analysis program might try to hack his way around the licensing system and the program had to be able to react effectively. The project team prepared a document laying out various security solutions and associated (developmental and administrative) costs and went over it with the customer.

With the aid of these written system design proposals, the customer was able to decide what level of protection he wanted against software pirates and fraudulent users.

...

If the passwords are permanently stored within the program itself (such as the xyz password), a hacker who is able to crack the ... algorithm and successfully decompile the program will have gained access to the passwords. Furthermore, the passwords could only then be modified by the developer. This is why we are proposing adoption of the ... solution.

Implementation and administration expenses:

1. The least expensive implementation can be achieved by adopting the software design approach using xxx because the in-house activation of workstations and external program licensing follow the same procedure. Only the contents of the license file vary. The license file and the INI file can be created and maintained using the administration program for the program licenses. No dongle administration is required.
2. Compared to Solution 1, dongle-based activation requires slightly more implementation effort because the license file must be used in conjunction with the dongle. Additionally, a procedure for deactivation must also be provided for in the program.

...

Figure 3.1 Excerpt from the system design proposal

Assigning resources based on risk

System design was identified as a high-risk step, because the development team would not have time to learn important lessons from the module's initial use. If at all possible, the licensing system was supposed to meet the customer's security requirements right off the bat. It was unlikely that bug reports would come in from hackers who cracked the licensing system.

That's why extra effort went into quality assurance during drafting of system design recommendations:

- Brainstorming and review
  Several developers met and came up with attack scenarios and possible safeguards, which they discussed in depth. The developer in charge of the licensing module summarized the discussion points into a recommendation which he circulated within the team for review.
- Feasibility testing
  In order to be able to make an informed estimate of pending development costs and subsequent administrative costs related to

deployment of the licensing system, the build and maintenance of licensing files and dongle programming and other options were tested in advance.

- The system's limitations were clearly stated
  The system design recommendation also covered scenarios which had not been safeguarded against. It described in detail a scenario which could only be prevented using an external system that compared system date and time. This gave the customer the possibility of choosing whether to guard against this potential scenario.
- Involving the customer
  The system design recommendations were fully discussed with the customer. Examples of potential risks were used to illustrate the pros and cons of each security procedure. The development team's recommendation reflected the known requirements of the customer up to that point and was accepted by him.

Use case analysis

Use cases are requirements

Using the approved system design, a brief use case analysis was performed in order to determine where in the complete program the user would come into contact with the licensing system.

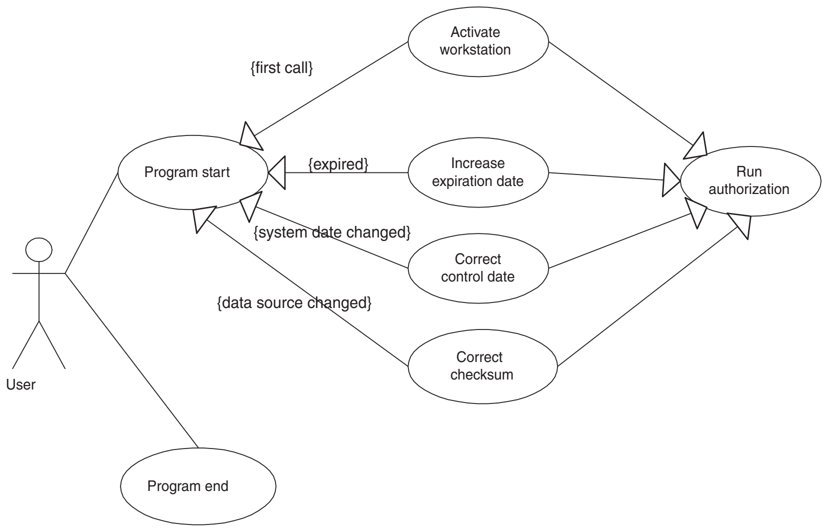

Figure 3.2 Use cases of the licensing module

Each use case in Figure 3.2 was discussed in an accompanying text file.

Test Cases for Later System Testing

Later on in the project, a table of individual requirements and corresponding test cases was prepared based on the text descriptions of the use cases.

No.	Requirement	Test cases (expected result)
1	Activating a workstation	
1.1	An activation code must be requested when booting the system on a deactivated workstation.	1. Boot WS (workstation) using the valid activation code (valid program start)
1.1.1	The activation code must be unique for that workstation. In order to activate two workstations, two different activation keys must be required.	2. Activating WS1, then activating WS2 using the same key (WS2 cannot be activated) 3. Verification test: Activating WS2 with the valid activation key (WS2 can be activated)
1.1.2	Program startup must be rejected if the valid activation key is not entered.	4. Attempt to start using invalid activation key (program start not possible) 5. Attempt to start without activation key (program start not possible)

Figure 3.3 Test cases for individual requirements

GUI prototype

Generating multiple uses

Using a GUI prototype, the customer was given a demo of the steps to be completed by the user in the individual use cases. The GUI prototype consisted of fully implemented screen forms with no functionality. The prototype already incorporated the GUI element classes intended for actual use. Thus there was no additional cost for building the GUI prototype because the forms were reusable.

The build of the GUI prototype is the first opportunity for the developer to test system design ideas using a concrete procedure, and to think about functions needed later. At the same time, the GUI prototype represents the first visible "product" the customer can evaluate and approve. Very early on, the customer gets a good idea of what the program is going to be like to use in our example, of what the licensing module will look like to future licensees.

System Design

Modeling means simplifying

Before coding starts, important processes are modeled in activity flowcharts. This helps make the rather opaque internal processes and relationships of individual use cases more understandable.

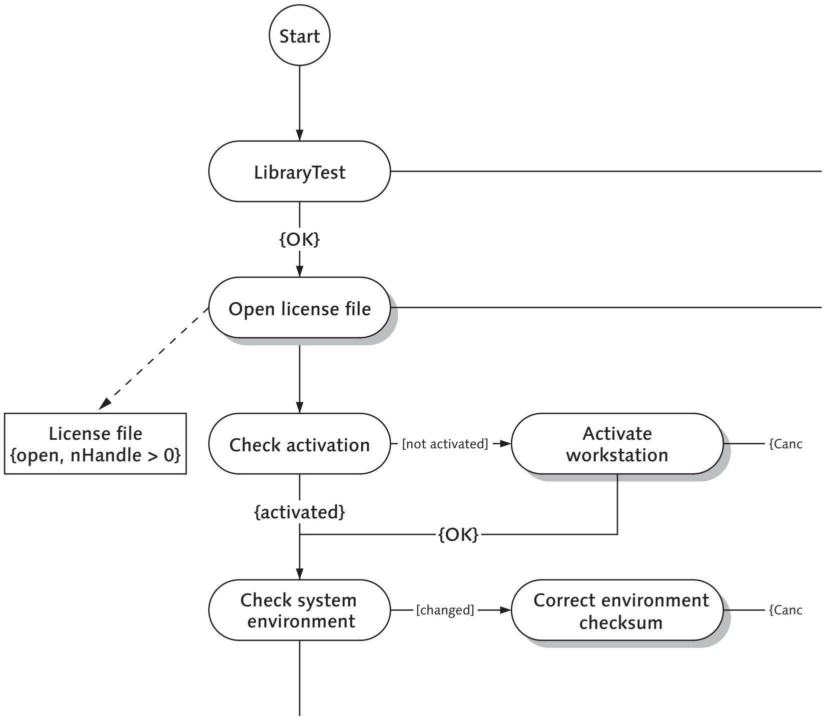

Figure 3.4 Activity flowchart of program start

Each individual activity is represented in the diagram by a rounded rectangle. If an activity in the diagram casts a shadow, this indicates that the details of the activity are illustrated in an additional activity flowchart. The arrows between activities represent the paths the program takes if the conditions specified in brackets are met. For some activities, dashed arrows indicate status changes in individual objects called by the activity. The example depicted in Figure 3.4 shows that the activity "open license file" changes the status of the object "license file" to "open," which corresponds to a value greater than zero in the "nHandle" attribute.

At this stage, activity flowcharts do not document actual, existing systems. Rather, they serve as tools for developers to formulate more detailed concepts of the program they are building. Many developers use this method to model only parts of the system, if at all. They model complex components that they cannot design in their head. Modeling becomes a creative process using pen and paper, or mouse and screen.

Going through scenarios

An activity flowchart for acting out various scenarios helps to check whether the modeled activities actually produce the desired system state.

Program walkthroughs can take place even before the first line of code is written. Regardless, the scenarios can be acted out very realistically using the activity flowchart, and the results can be checked and reconciled with the desired results.

To determine a testable result, current values of individual attributes are tabulated. Figure 3.5 shows an excerpt of a table from a model walkthrough. First, the scenario to be checked is described. At this point, one defines only the context that should apply to the walkthrough. In the "results" field of the table, a detailed description of the results from individual activities is entered.

2.1 Scenario: Starting and Exiting a Program, Best Case

The license file has been correctly installed, the workstation has been activated, the expiration date has not expired and neither the system environment nor the system date has been changed. The license file is stored in the program directory. The program is started, the program is used and the program is subsequently exited.

2.2 Sequence:

Step	Activity	Result	NHandle	lValid	License file status
1	Program start		0	.F.	closed
2	Library test	OK			
3	-> Open license file				
3.1	Search for license file	Program directory			
3.2	PP_LFOPEN license file		>0		open
3.3	Check activation	WS is activated			

Figure 3.5 Table of activities in a model walkthrough

Steps are serially numbered so that the branch level can be immediately identified, even in longer tables. In Step 3 of the figure, the program branches out to the activity "Open license file," which is described in its own activity diagram. The subsequent steps (Steps 3.1, 3.2, etc.) are atomic activities within the "Open license file" sub-activity.

In Step 3.2, a function is invoked from one of the DLL files used to run the encryption system. The results of this invocation are then recorded in the attribute fields "nHandle" and "License file status."

If you want to test an activity flowchart in this manner, it is best to create a unique field for each object or attribute whose condition is to be tabulated in the walkthrough. This is where every change in value resulting from an activity should be recorded. At the end of the walkthrough, all objects and attributes should match the predefined description of a correct result.

Testing design

A program model walkthrough allows the designer to check the design's validity. Acting out processes using scenarios and activity or sequence diagrams is always advisable for cases where relationships are not straightforward. Here are a few more tips on using models for quality assurance:

- Use models for important program aspects. Mandatory use of models makes little sense. If you want to use models as technical documentation for your program, the source code should be able to produce the models automatically.
- Models are abstractions. Do not attempt to reproduce every single detail in the model. Concentrate on the essentials. Specify only the attributes, methods, and links that are important for the activity depicted.
- Using the model, check your own understanding of each task and its solution. The need to flesh out ideas on paper textually or graphically often helps indicate weak points in the concept or where something is not one hundred percent understood.

- Do not lose sight of the big picture. Any good diagram fits on a single physical page. If your diagram runs over, combine the interrelated areas into sub-diagrams, minimize details, or rethink the program architecture being displayed.
- Use the communication possibilities afforded by models. All development team members should at least have a basic mastery of Unified Modeling Language (UML). UML allows ideas, analyses, and concepts to be easily incorporated into an ongoing review process.

Everything that helps

One key characteristic of the method described above is that none of the steps are mandatory. Thus, the development of the licensing module did not involve preparation of every possible document, model, or diagram, but rather only those that proved helpful in a particular situation. By helpful, we mean facilitating a broader understanding of the task at hand or providing means of communication or testing.

The two methods that follow were not applied in the licensing module.

Business model

For task analysis, it is important to understand the commercial environment of the software in production. The program must fit into this environment and add value, for an improved environment produces better data for processing. The best way to test your own understanding of the commercial environment is to produce a business model that furnishes the necessary explanations and present it to the customer for evaluation.

In our licensing module case, a business model would not have been much help. That is why we need an example from another project (see figure 3.6).

Checking analyses

Business models are produced as entity-relationship diagrams or as class diagrams without methods. Core data from previous analysis discussions should already have been assigned as attributes to entities (classes). Thus, the customer can recognize whether you have correctly understood the origin and meaning of the information occurring in the commercial environment. Since in most cases diagrams mean nothing to the customer, an explanatory text is both sensible and necessary.

Example of a Business Model

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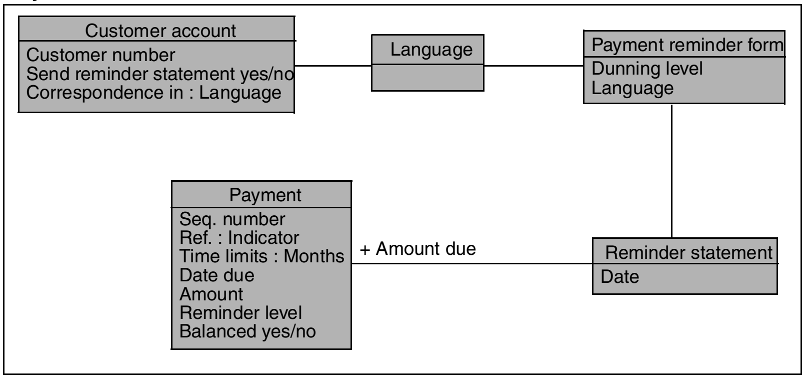
Payment Reminders



Reminder statement

Reminder statements are generated based on payments which are overdue and not yet paid. The billed amount becomes the accounts receivable balance.

Reminder statement

The reminder statement to be used is determined based on the dunning level and the language ID set for correspondence with that particular customer. The current dunning level is recorded in the payment total.

Figure 3.6 Excerpt from a business model with comments

Of all of the models, business models have the longest shelf life. If significant changes occur in the commercial environment, you will most likely need to change the program as well. Creating and maintaining a business model is always useful if the commercial environment exerts significant influence on the processes of a program.

Providing details on use cases

Providing detailed descriptions of use cases using a GUI prototype is another method for checking your own understanding, for discovering potential problems early on, or for sharing your thoughts with others or submitting them to testing. Here is another example that does not come from the licensing module.

Complex procedures are best outlined in activity flowcharts or sequence diagrams, and are best checked with scenario walkthroughs (see above).

Complex interfaces are best depicted in a detailed GUI prototype. The best way to check the logic of the interface and the efficiency of the workflow it controls is to describe all inputs, mouse clicks, and program responses in detail. The best place for such a detailed description of the GUI prototype is the use case's textual description. Since it is no secret that the devil is in the details, providing details on the use cases brings you a step closer to all the ifs, ands and buts of the development work to come. To be sure, you haven't yet had to grapple with coded legacies. Here, you can still change everything without a lot of effort by adapting the GUI prototype as you acquire new knowledge.

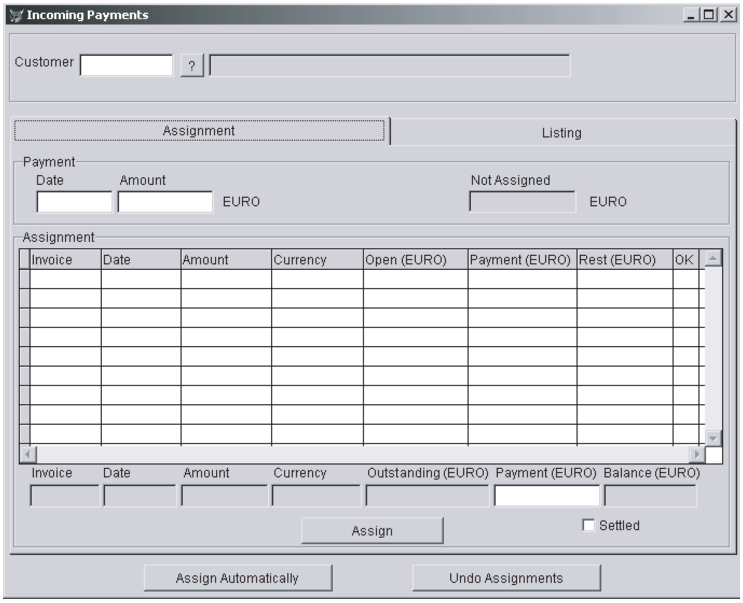
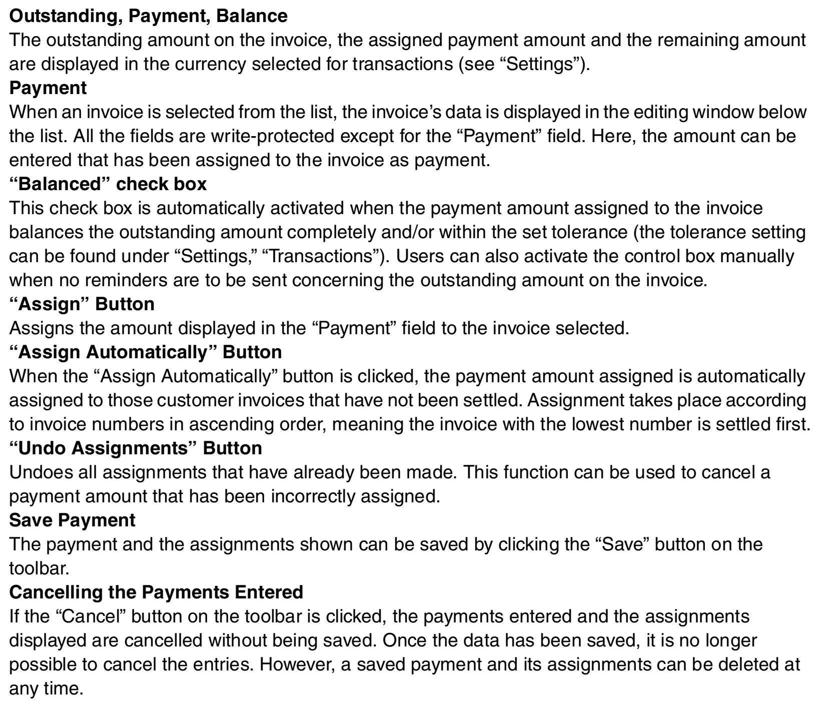


Figure 3.7 Screen form from the GUI prototype

Checking procedures

Like the scenario walkthrough, providing detail on more important or difficult use cases is one possible form of testing within the development process. This type of test can be conducted long before the application under test actually exists. You can already use some of the test models described below when describing possible inputs and the program responses they produce. For example, you can focus on lowest and highest possible inputs, required fields, optional inputs, and so on. This way, you get a much clearer picture of the required program functions than you would solely from the use case analysis.



Outstanding, Payment, Balance
The outstanding amount on the invoice, the assigned payment amount and the remaining amount are displayed in the currency selected for transactions (see “Settings”).
Payment
When an invoice is selected from the list, the invoice’s data is displayed in the editing window below the list. All the fields are write-protected except for the “Payment” field. Here, the amount can be entered that has been assigned to the invoice as payment.
“Balanced” check box
This check box is automatically activated when the payment amount assigned to the invoice balances the outstanding amount completely and/or within the set tolerance (the tolerance setting can be found under “Settings,” “Transactions”). Users can also activate the control box manually when no reminders are to be sent concerning the outstanding amount on the invoice.
“Assign” Button
Assigns the amount displayed in the “Payment” field to the invoice selected.
“Assign Automatically” Button
When the “Assign Automatically” button is clicked, the payment amount assigned is automatically assigned to those customer invoices that have not been settled. Assignment takes place according to invoice numbers in ascending order, meaning the invoice with the lowest number is settled first.
“Undo Assignments” Button
Undoes all assignments that have already been made. This function can be used to cancel a payment amount that has been incorrectly assigned.
Save Payment
The payment and the assignments shown can be saved by clicking the “Save” button on the toolbar.
Cancelling the Payments Entered
If the “Cancel” button on the toolbar is clicked, the payments entered and the assignments displayed are cancelled without being saved. Once the data has been saved, it is no longer possible to cancel the entries. However, a saved payment and its assignments can be deleted at any time.

Figure 3.8 Detailed description of a use case in the text document

Involving users early on

By creating detailed descriptions of program sequences for individual test cases, you have simultaneously drafted the most important (or most difficult) parts of the user manual. The idea of creating the user's guide before creating the program is certainly not new. If you provide users with the de facto user's guide together with the GUI prototype, you give them a chance to get to know the program's most important interfaces—the user interfaces. They can "get it" and then give feedback.

The first units

Once you have described tasks, developed concepts for solutions, clarified use cases, and set the most important parts of the interface, the hard part is already behind you. Now, you "only" need to program the functions that can be invoked by the interface and all the invisible little helpers that work away behind the scenes.

Top-down approach

The top-down approach described here begins with analysis, proceeds to the GUI and then focuses on functions invoked by the interface. I am certain that the approach taken in this test case is not suitable for all task groupings. I have previously found this approach very helpful for avoiding serious errors in analysis or in design, or for discovering them in a timely manner.

Before we tackle the big topic of unit testing below, I would like to touch on two further preliminary aspects: risk assessment and patterns in debugging.

3.2 Risk assessment

Risks were already mentioned in the use case. Testing deals with risks in many places. Certain aspects of a program may be so important to the customer that messy programming would pose quite a risk in these areas. A program must be safeguarded against quirks in the technical environment such as communication routes posing specific problems. Errors that emerge in truly unproblematic areas can provide important clues to risks which have not yet been recognized. The selection of program segments to be covered by regression testing is also a risk assessment issue.

3.2.1 Setting Priorities

Except for very trivial programs, it is no longer possible to test a program completely. The issue is not just cost or the limited time allowed by the project plan. The number of possible paths and input combinations in an event-driven program with a graphic interface is simply too great. Even with the best will in the world, nobody could check the billions of possible combinations.

Priorities must therefore be set. But how does one procede? Which criteria should be used to set the right priorities? Setting priorities always means assigning importance to things. The most important test cases should always be checked, and the less important ones as thoroughly as possible. Unimportant test cases are never checked. But what is an important case? Does everybody use the same criteria, or are different approaches used within the project team?

Rapid Application Testing is risk-oriented testing. The program segments that pose the highest risk should be checked most intensively. First of all, the risks that particular program segments or constellations of hardware or software may harbor must be identified, particularly when it comes to requirements and use cases needed. We will also need a method that enables us to sort and evaluate the risks we find. Our goal is to assign testing priorities in a transparent, testable way.

Identifying risks

It is certainly not equally important on all projects to perform a formal risk assessment. Often, one has a "gut feeling" about what must be done and where the greatest risks lurk. However, testers or QA officers should know about and have experience with formal methods, at least in order to hone their sense of possible risks and corresponding testing priorities.

3.2.2 Various Risk Types

Before we begin evaluating risks, we need to be clear about the types of risks that exist. Risks can take various shapes:

1. **Contract risks**
   - Contractual partners can interpret ambiguous and unclear task descriptions differently.
   - Unrealistic timeframes can cause the entire project to fail.
   - Misunderstood requirements can lead to a conflict with the customer.
   - Leaving a requirement unfulfilled can also lead to a contract penalty or even a lawsuit.
2. **User satisfaction**
   - When a functional property is missing or faulty, this could significantly disrupt the prospective user's workflow.
   - Inadequate usability or a departure from the system environment's informal user standards can cause the user to reject the program.
   - Confusing error messages and a missing or inadequate Online Help function can lead to user frustration and can ruin the program's reputation among users.

3. **Image risks**
   - An obsolete interface can have harmful effects on the customer's and on the software vendor's image.
   - Outdated program architecture can damage the reputation of a vendor or a project team, at least in the eyes of the customer's IT specialists.
   - Failure to comply with implicit requirements can damage your image (see the section "What is Software Quality?" on page 25), and potentially lead to a conflict with the customer.
4. **Complexity risks**
   - A calculation can be so complex that the risk of error is great.
   - A multitude of rules can lead to a lack of clarity and make it difficult to see through the program's behavior.
   - Parameterization can make installation, support, and maintenance more complex.
5. **Integration and configuration risks**
   - The interaction between multiple components can create interface problems and cause configuration errors.
   - The impact of disparate hardware resources and operating systems can also cause problems.
6. **I/O risks**
   - Input data may be unreliable.
   - The input and output channels (printer, E-mail server, network connection) may be intermittently unavailable or prove unstable.
7. **Time and synchronization risks**
   - Some workflows may have to be completed within a certain period of time.
   - Different areas of the program may have to be activated separately.
   - Access to common data by multiple users must be secure and synchronized.

8. Quantity risks

- Certain data can accumulate in very large quantities.
- Procedures must be executable within a certain timeframe (i.e., the workday) at a pre-defined rate (i.e., per unit of material).
- There are times during the day when many users access the program. During these periods, system response times must remain acceptable.

9. Security risks

- Certain data may only be accessed or modified by authorized users.
- Hostile attacks on the system must be anticipated.

Project-specific risks

This list is certainly incomplete. When you assess the risk of your current project, you will probably have to add specific risks. But the list does make clear that we must distinguish between acceptance and technical risk. Acceptance risks are primarily contract risks, risks related to usability and image risks.

3.2.3 Risk Assessment Based on User Priorities

This approach may be used when establishing testing priorities based on user acceptance risk. A comprehensive presentation of this method can be found in [McGregor et. al., 2000]. The authors assume that users will be more disturbed by errors in frequently used functions than by errors in lesser used functions. Thus, frequency of use should be factored into testing priorities along with the combined degree of user acceptance risk.

Frequency of use

To do this we need information about the prospective users and the program features they would use most. We can get this information from the use case analysis. This document lists all prospective users (actors) and the program features they will use (use cases). Usually, the textual descriptions of the use cases also provide information on frequency of use. However, they frequently fail to indicate what influence an individual use case might have on user satisfaction and contract compliance. If no information is available anywhere (for example, in the functionality specifications), we will have to make do with estimates.

Consistent scale Both the frequency of use and the risk of acceptance (user satisfaction, contract risk) will be graded using a scale. We will use the same scale later on in the second step to establish priorities for testing technical risks. The scales that we use to measure the degree of frequency and risk, as well as the resulting levels of priority, should all have the same granularity. The following six-point scale has proven useful:

Level	Frequency	Risk	Priority
0	Never	Not available	None
1	Seldom	Very low	Very low
2	Seldom	Low	Low
3	Sometimes	Medium risk	Medium
4	Frequently	High	High
5	Very frequently	Very high	Very high

Table 3.1 Six-point scale for frequency, risk, priority

Using a scale with fewer levels often produces imprecise test priorities. The addition of more categories makes classification more difficult without adding much significance.

In the example below, the program has been divided into very broad functions: Data collection, user administration, data backup, and reports are more like function modules than individual use cases. However, it still makes sense to establish testing priorities at this level. High-priority function modules can be divided still further into individual use cases as needed. To keep things simple, we will stay at the higher level.

First, the users and the program features they use are summarized in a table indicating the degree of frequency. The degree of frequency is assigned a number from the six-point scale above; this indicates how often a given feature or feature module is executed by each individual user group (or role).

Function User	Data collection	User administration	Data backup	Reports
Operator	5	1	1	3
Administrator	0	2	5	0
Management	2	1	1	5
Executive management	1	0	0	2

Table 3.2 Frequency of program use

To make the information in the table clearer, here is a summary.

- **Operator**
  Operators will collect data very frequently and sometimes generate reports. Operators will very rarely use administrative functions, i.e. only to change their password or user profile. Only in exceptional cases will operators also complete a data backup.
- **Administrator**
  Administrators never come into contact with data collection or reporting features (at least not in their role as administrator). They seldom access user administration, for example to add or delete a new user account. Data backups occur frequently, that is, twice a day.
- **Management**
  A management level employee frequently generates reports, but is seldom involved in data collection and completes user administration tasks or carries out backups only in exceptional cases.
- **Executive management**
  The data collection and report features could both be accessed by executive management, but direct involvement occurs only seldom if ever. Executive management are never involved in user administration or data backup.

Determining average scores

The second step is the determination of average degrees of frequency for each program feature and the degree of risk in relation to user acceptance risks. The average of these two figures allows you to prioritize test cases based on acceptance risks. All average scores are rounded up to the closest half unit.

Function User	Data collection	User administration	Data backup	Reports
Operator	5	1	1	3
Administrator	0	2	4	0
Management	2	1	1	5
Executive management	1	0	0	2
Average	2	1	2	3
Degree of risk	3	1	2	5
Testing priority (acceptance)	3	1	2	4

Table 3.3 Average frequency and degree of risk

In this risk assessment step, all user acceptance risks are combined into a general valuation of risk. But that is also this method's Achilles heel. If no explicit individual risks for software acceptance can be determined, or if the individual risks are in general not very great, a combined degree of risk could adequately represent all user acceptance risks. But if the user acceptance risk for a function module is "very high," as is the case for reporting in our example, it would be worth knowing more precisely where the risk lies in order to concentrate on this point during testing.

It is also doubtful whether the feature's frequency of use plays any significant role when the risk is "high" or "very high." For example, an annual financial statement must still add up, even though it is produced only once a year.

Individual assessment

When individual user acceptance risks can be identified, or when the user acceptance risk in individual cases is above average, it is advisable to conduct an individual assessment of the applicable degree of risk.

3.2.4 Function/risk matrix

We always conduct individual assessments of technical risks. It is important to use the same functional categories as were used in assessing user acceptance risks. In functional testing, we incorporate the testing priority established by user assessment testing as an individual risk called "Acceptance." We should also stick to the established six-point scale to make sure the risk assessments are comparable. We record the assessment results in a function/risk matrix.

Function User	Data collection	User administration	Data backup	Reports
Algorithm	1	1	2	4
Integration	2	2	2	3
I/O	2	1	3	1
Performance	3	1	2	4
Workflow	3	1	1	1
Security	2	5	2	5
Acceptance	3	1	2	4

Table 3.4 Function/risk matrix

To decide which risk groups belong in the matrix, we first assess all possible risks. It is always best to start with a matrix that specifies all the risks that come to mind. If a couple of risk types produce an entire row full of 0s and 1s, these can always be deleted from the matrix later.

Since we are estimating degrees of risk as an exercise in order to identify the most important test cases, it does not make much sense to calculate averages at this point. Using the matrix, we simply observe that we should test the reporting module most intensively, and in particular the security aspect the risk of users gaining unauthorized access to reporting data. The same risk (level 5) applies to security of user administration. If a user manages to manipulate his access rights using administrative functions, then obviously reporting data is also no longer secure.

Test results influence risk assessment

Risk assessment provides an initial approximation of what we need to concentrate on during testing. But keep in mind that the test results also bias the risk assessment. In extreme cases, a single test result can mess up the entire risk assessment. This happens when an unsuspected error reveals that we have underestimated an entire risk type.

3.3 Testing Patterns, Patterns for Debugging

Informative test cases

The risk assessment results indicate what we should test first. But how we approach the tests is still unclear. What we need are ideas on individual, concrete test cases. Regardless of the test item, there are some models that frequently produce informative test cases. Several authors propose and discuss models for test case selection or test implementation. Delano and Rising present general models for system testing [Delano and Rising, 2002]; Binder devotes an entire chapter to patterns in his comprehensive volume on testing object-oriented systems [Binder, 2000]. Bret Pettichord's testing hotlist [Hotlist] includes numerous articles containing models for test design and implementation, as well as best practices, tips and tricks.

3.3.1 Best, Minimal, Maximal and Error Case

A useful model for finding concrete test cases is the specification of each

- ▶ Best case
- ▶ Minimal case
- ▶ Maximal case
- ▶ Error case

test item or test scenario.

Best case

Best case first

"Best Case" is the case in which all of the conditions needed to run the program apply, and in which all parameter values are available and valid. All other conditions (such as open files) are also met. Conditions are normal—no stress—life is good. Your function should work without a hitch and return the proper results. Always check the best case first, because it does not make much sense to tackle other cases when even the best case does not work.

Minimal case

What happens if...

In the "minimal case," you are checking your program's minimum conditions. When calling a function, specify only the parameters that are absolutely necessary and leave out all others. Choose minimal values for parameters that must be passed. For example, if your function expects a date value that is not limited in the past, try entering January 1 of the year 1! If that is nonsensical, it is worth considering whether this parameter should in fact be restricted in your function's interface description.

All required files should also be closed in the minimal case. That is, unless the interface description for the function explicitly specifies that certain files are expected to be open.

The questions that generate "minimal case" test cases for application analysis and design usually sound like this: »*What happens when that isn't there?*" What should the program do when data is missing? What are the default values?

Maximal case

The maximal case executes the program to be tested with maximal values. These values can be parameter values, records in database tables, file sizes, string lengths, and many others. In our date example above, the maximum value would be December 31 of the year 9999 (which raises the next millennium10 problem). Maximal case usually finds fewer and less important errors than minimal case.

Error case

In error case testing, tests are conducted with missing or invalid values, or under invalid circumstances. Crucial parameters are omitted, or more parameters are passed than the function expects (if at all possible). Parameters of the wrong data type are passed (if permitted in the programming language) or parameters that contain invalid values. Required files are not found, access to required drives is denied, and so on.

Imagination wanted

Testers really get to use their imagination in error case testing. Experienced developers have an easier time because they have already made many mistakes themselves. They can tap that store of experience and try to imagine the kinds of errors that might have slipped past the developers of the program under test. This method is known as "error guessing." Error guessing is a completely legitimate tool for assembling test cases.

3.3.2 Equivalence classes

Analysis of input data

Test cases can also be found by examining input data. Input data is subdivided into so-called equivalent classes (equivalent partitioning). An equivalence class is a set of values for which is posited that any value in the set will invoke the same program behavior and thus expose the same errors. For example, take a function which is expecting one or more words as input values. If the function is expected to handle all words and recognize them in context, without any errors, then we have a quantity problem.

Words can be combinations of any of the 26 letters in the alphabet. In addition to letters, there are other characters used to abbreviate, punctuate, or combine words (among other things), all of which must be interpreted. It is clearly way beyond the scope of a test project to test all the combinations of letters. After completing an equivalence class analysis, it is probably also unnecessary. After analyzing the program, one can categorize the input characters at issue into the following equivalence classes:

- Letter (A to Z, a to z)
- Punctuation marks and special characters (comma, semicolon, hyphens, etc.)
- Apostrophe and hyphen characters
- Numbers (0 to 9)
- Control codes (ESC, CR, LF, etc.)

This method limits testing to combinations that represent an equivalence class, rather than an endless series of combinations. If you want to test how the program responds to a shortened or compound word, it is therefore sufficient to combine any string of letters with an apostrophe or dash. According to our equivalence class analysis, it is immaterial which letters are used or whether words contain an apostrophe or a hyphen.

Pay attention to the source code

An equivalence class analysis can only be completed by examining the source code underlying the function. That is the one and only way to find out whether an apostrophe and hyphen are equivalent input values, or whether the two are handled in two different branches of a CASE statement which can lead to differing results. This makes equivalence class analysis a classic example of the Gray Box testing approach. The interface is tested based on public interface inputs, but the required test cases are generated based on knowledge of internal structures. In this approach, of course, there is always the danger that test cases will no longer fit if the internal structure changes. When documenting test cases generated through equivalence class analysis, you should make a note of this. That way test cases can be checked if the program is modified.

3.3.3 Boundary Values

Boundaries are laden with errors

One further method for determining relevant input values is boundary-value analysis. Experience has shown that errors frequently occur when a program processes boundary values. In boundary-value analysis, one selects the following critical input values:

- A value just below the lower boundary value
- The lower boundary value itself
- A value just above the lower boundary value
- A value just below the upper boundary value
- The upper boundary value itself and
- A value just above the upper boundary value

and generates the required test cases. Here is a classic example of a boundary-value test case: salary tax brackets. If reported income of 50,000 is taxed at 20%, and at 15% below that level, while a reported income of 100,000 or above is taxed at 30%, then the boundary values matching this breakdown are:

- 49,999
- 50,000
- 50,001
- 99,999
- 100,000
- 100,001

This example also clearly illustrates why boundary-value analysis frequently does not generate fixed values for test cases. The boundaries for the income tax brackets are in all probability stored in parameter tables and written into the program code. Changes to these program parameters will also change the boundary values required for the test cases. This must be considered during boundary-value analysis.

3.3.4 Cause and Effect Diagrams, Decision Trees

Cause and effect diagrams convert specifications into graphics which depict the nodes that indicate cause and effect in the specification. The lines running between the nodes illustrate the cause and effect relationships. This diagram is later converted into a decision tree.

Analyzing complex specifications

The point of this approach is to subject complex specifications to systematic analysis in order to determine which test cases cover all requirements and specifications. For complex specifications, it is pretty hard even to produce a cause and effect diagram. It is also easy to make mistakes. Because those of us who design tests do not want to unnecessarily add errors, we do without cause and effect diagrams. However, the decision trees derived from them can be put to good use.

If the values A0 to A9 and B0 to B9 are allowed in a two-digit input field, the field validation rules can be illustrated using the following decision tree:

Rule **Condition** **Activity**	**1**	**2**	**3**	**4**	**5**	**6**
Character1 = A	0	0	0	1	0	1
Character1 = B	0	0	1	0	1	0
Character2 = digit	0	1	0	0	1	1
Accept field	-	-	-	-	X	X
Error message 1	X	X	-	-	-	-
Error message 2	X	-	X	X	-	-

Table 3.5 Decision tree with system responses

This decision tree tells us that we have to create six test cases and gives us expected outcomes.

Decision trees are well-suited for the review of more complex relations in the application specification. System responses should be clearly defined for each combination of conditions in the decision tree.

Incidentally:

If, after consulting the source code, we notice that when characters A and B are in the first position, they are treated in the same way and thus form an equivalence class, this reduces the number of required test cases to four.

Rule **Condition** **Activity**	**1**	**2**	**3**	**4**
Character1 = A or B	0	0	1	1
Character2 = digit	0	1	0	1
Accept field	-	-	-	X
Error message 1	X	X	-	-
Error message 2	X	-	X	-

Table 3.6 Decision tree after an equivalence class analysis

3.4 Unit testing

Now we turn to unit testing. Unit testing is primarily carried out by developers themselves. Therefore, when discussing possible test cases for unit testing, I assume that you are the developer of the unit under test.

Unit testing is concerned with functional correctness and completeness of individual program units, e.g. of functions, procedures or class methods, and classes or system components. Units can be of any size. They are continually produced in the course of a project, meaning that completed, discrete program segments will usually be available for unit testing. In the IT environment of some organizations, a completed program is also a unit.

Unit requirements

Unit testing is not a project phase. It is a perspective from which to evaluate and test software components. Unit testing is concerned with the unit requirements. It does not deal with how units interact that is an integration testing issue. Nor does it check how the unit is imbedded in the system environment or how it interacts with the system this is the province of system testing.

3.4.1 Functional testing

Unit testing cases cover the functional correctness and completeness of the unit as well as proper error handling, testing of input values (passing parameters), correctness of output data (return values) and component performance.

These types of tests fall into the category of Gray Box testing, meaning they cover unit functionality (the "black" aspect). However, in order to locate and assess the test cases, source code may be accessed (the "white" aspect).

Functions

Identifying influence factors

Functions provide a return value. Therefore, they are the easiest to cover in unit testing. The test cases derive from the combination of all input parameters. Input parameters include anything that has an impact on the output of a function. This means parameters that are passed when the function is called, but also factors such as system settings (date format, decimal separator, user rights, etc.). When devising useful test cases, start by tracking down all these influence factors.

In principle, we could calculate the expected result for any combination of input parameters. The return value of a function with a given combination of input parameters is the actual function output and this should match the expected output.

Volume problem

Difficulties which crop up in real projects are almost always related to an excessive number of potential input parameter combinations. Testing approaches discussed above such as equivalent partitioning and boundary value analysis, as well as the teaming approach discussed below in the section "Test Coverage" on page 130, all attempt to deal with these issues.

Any quick initial test of a function would definitely include the best case. Find out the minimum or maximum values of certain input parameters and ask yourself whether they could lead to problems. If you encounter a critical situation when considering the respective minimal or maximal case check it. This does not always need to take the form of a test. One look at the code will often tell you that something cannot possibly work. The most important thing is to hit upon the idea of examining the source code with this particular question in mind. Thinking in terms of minimal and maximal cases helps.

The proof of the pudding is in the eating

Also make sure that the function responds in a stable manner to error conditions. The rule of thumb here is: If it isn't obvious, it is worth checking. "Obviously" should mean just that. If a particular function behavior is not immediately clear from the source code, when you have to rack your brains about a function will behave in a fairly complex situation, it is always safer to test this behavior than it is to dream up a solution.

The best tool for this is a source code debugger. If you observe how the computer proceeds through a function step by step, periodically checking the values for local variables and executing branches, you will usually get a different perspective on the function than if you examine the source text in an editor.

Procedures

Procedures do not return a value, they do something. They change the underlying system data, send signals to other units which in turn trigger other events, or output data to a screen or printer, to name but a few examples.

Knowledge of procedure effects

Test cases for procedures generally have more complex expected outcomes than do functional test cases. As is the case with functions, test cases for procedures derive from input parameters. The expected outcome for a test case comprises all the effects of a procedure call with current input values. Thus a procedure named "PrintConsolidatedInvoice" can just as easily produce a pile of printouts as a series of data records with a date set to "ConsolidatedInvoicePrintedOn." When choosing test cases for procedures, just like with functions, you should determine all factors which may have an impact on the procedure. However, you must also be aware of all the procedure's effects.

Direct data access

If you want to compare the actual outcome and the expected outcome of a procedure, you need the technical capability to capture and analyze its intended effects. In order to find errors, you must at least have the capability to capture unintended effects. This all sounds rather expensive, but in practice it often means that you just need direct access to the application's system data.

How thoroughly the procedure outcomes should be tested is another question altogether. Does each and every consolidated invoice record require a check for the "PrintConsolidatedInvoice" procedure? In other words, do all items have to be totaled and the result compared with the net sum? Do VAT and gross sums have to be calculated and checked for each consolidated invoice? As is often true, the answer is a simple: "It depends."

Keep an eye on specific tasks

Each procedure should be checked to see if it completes its intended task. The "PrintConsolidatedInvoice" procedure's task is to create a summary of trade accounts receivable for a given period and to invoice these. Testing should focus on whether time periods are correctly processed, whether transitions between months and years (leap years) are handled correctly, whether previously billed periods are carried over properly, and so on. Other critical situations could occur if a customer receives goods or services on the exact cut-off date for consolidated invoicing; if the customer is entered into the system for the first time on or just prior to the cut-off date; or if deliveries straddle a period cut-off date. These are all scenarios related to consolidated invoicing and have less to do with invoicing.

Architecture determines test cases

The program probably also lets the user print out single invoices. When testing the generation of a single invoice, one should check all computing operations and other algorithms that apply to each and every invoice. Correct generation and output of consolidated invoices should be a function of correct generation and output of single invoices. I said "should" on purpose! Because the validity of this assumption is completely dependent on the application architecture. This is a further example of the importance of Gray Box testing in Rapid Application

Testing. If you cannot confirm your assumption by examining the program or talking with the developers, you can only guess that the consolidated invoice will be calculated correctly. It should be checked for accuracy in any case.

Component architecture reduces testing effort

This example also shows that the application architecture has a decisive effect on the quality of the application and the effort required to complete testing. In particular, the component architecture reduces the testing paths needed to cover programs to the point where testing of component interfaces can be considered complete.

Methods

Methods are also classified as functions or procedures; effective input parameters and intended effects must also be identified when picking test cases for class methods. In contrast to "free" functions and procedures, methods are provided for objects at run time when objects have a status attached.

Focus on the status of an object

The current status of the object containing the method is also always included among the input parameters of a method call. The status or state of an object is determined by the values of the object's internal variables. The values of these variables may be changed at each method call. The order in which the calls are made thus plays a role. However, the risk of an unintentional method call sequence is only relevant if the class contained in the method's source code has been released for use by other developers. As long as a class is used only by you or your core project team, you (the developer) can point out that certain things just aren't done—for example, calling a method at an inappropriate time.

Classes

If the release of a class involves unit testing of an entire class and not an individual method, testing will focus on the public interface, i.e. the class interface. Class testing is a form of Black Box testing. It checks the class interface methods as opposed to directly checking internal methods. For example, the interface methods must be callable in any order without any problems. If the object under test is in a state which prevents any meaningful execution of the method when called, the object must demonstrate a controlled response such as invoking exception handling, returning a bad value, and so on. The status of the object under test must not be changed by this response.

Setting properties

If the interface of the class includes properties, i.e. class attributes which are accessed directly and not by using setXXX and getXXX methods, then setting and retrieving these properties will lead to separate test cases. Unlike allocating values, setting and extracting class attributes can cause internal methods to be called that are attached to properties. Invoking these methods may of course lead to a number of other errors. That is why separate tests must be run on setting and retrieving properties.

Setting and extracting properties directly may tempt you to neglect the changing status of the object under test. To bring this point home, here is another short example from the area of trade receivables. In this example, a planned delivery of goods should be considered open as soon as a delivery note number is generated to enable the delivery.

Imagine that the delivery object includes a method called "SetDeliveredStatus(<DeliveryNoteNo.>)" which expects the delivery note number to be the call parameter. This will generate several test cases. The best case is that the delivery object has the correct status when called and that a valid delivery note number is passed. Minimal and maximal cases can be derived from the format or value range of the delivery note number. Error cases might involve situations where the delivery object does not have a deliverable status or where the delivery note number is wrong. All test cases derive from the purpose of the method and test against the expected outcome or desired effect of calling it. The danger of calling the method by accident or in the wrong context is fairly slim. If the delivery note number for a "delivery" class object can be directly set as a property, then developers have a lot more latitude. However, the odds also increase that the property will be erroneously or accidentally set somewhere in the program where it should not be.

Setting the property for an object will change its status

In other words: If you (the developer) set a property directly yourself, you have changed the status of that object. The risk here is that the change in status is not currently allowed. Setting a property directly can only be considered safe if an internal set method is attached to the property. The method validates the status change and possibly triggers any required activities that may come next.

When considering this issue, keep in mind who will use the class. If you (the developer) can look over the user's shoulder, many of the safeguards are not required. However, they will be needed for inexperienced, uninformed or even hostile users of your class. If you dispense with safeguards, you also do away with the tests that check them.

Avoid global values

Test cases for directly set (attribute/property) values are very difficult to cover by using external test cases. If at all possible, avoid global values which can be modified directly, such as global variables or structures or values in open files or local tables. These values are in constant danger of being inadvertently overwritten as a result of some action. Tests for such unintended changes are best deployed as embedded tests (see the section "Testing Strategies" on page 38). You can save yourself extra coding work by leaving global values out of the program design.

Required resources

The costs of unit testing should depend on the unit's degree of risk. However, subsequent use of the unit should also be considered. If you have developed a function which you will use many times over in the program, you may be able to do without an individual function test and simply trust that subsequent use of the function will expose any errors. As long as you are not required to release the function separately, it remains in a sort of internal beta testing.

Unit testing reduces integration testing

Each unit (function, procedure, class, etc.) that you make available to users should have gone through all functional beta case testing, as well as minimal, maximal, and error case testing of direct input parameters. No function is so unimportant that you can live without it. Functions that return critical values and those you are not prepared to treat as buggy should be subjected to comprehensive unit testing. As a general rule of thumb, careful unit testing will cut down on the test cases required to cover integration.

3.4.2 Structure testing

Source code validation

Source code validation, alluded to in our example test cases, is a completely different aspect of unit testing. The necessary test cases are derived from the source code structure and not from unit functionality. These are strictly structure tests of the unit.

Errors only visible at run-time

What does source code validation mean? Specifically in the case of interpreted languages which are not highly typed, typing errors in variable or function names may creep in that will not be discovered until run-time. Bear in mind, however, that highly typed languages also include expressions which use names that only become valid at run-time. This happens for example when accessing database fields, external files, and so on. Typographical mistakes may lurk in the names of external resources (and paths to these resources) which are not noticed while coding. They are only exposed when this part of the program is given a walkthrough. Source code validation thus means ensuring that every line of code is executed at least once during a test.

Structured basis testing

Structured basis testing is a relatively simple method for determining the test cases needed to validate source code. In this methodology, the source code structure is used to determine test cases. When generating test cases, the objective is to use the function to determine all possible source code branches.

Complete branch coverage

The test cases must ensure that each branch is covered at least once. All points at which the program's control flow graph branches will produce at least one new branch that does not form a part of the standard or ideal path. Each new branch will require a new test case which covers precisely this branch.

1. **Best Case**
   The first test case is, as always, the best case, i.e. all tests made in the function were passed and the ideal path has been covered in the function.

2. **Conditions**

   Every condition in the function generates at least one additional test case. This test case covers the situation when conditions deviate from the ones found in the ideal condition path.

   The same applies to FOR and WHILE loops. If one of these loops is covered in the best case at least once, then another test case is required for the variant which does not include the loop.

   REPEAT ... UNTIL loops are always covered at least once. Where the loop is only executed once, this is a special case. One should check whether the loop can always be exited, in other words, whether the UNTIL condition can always be accessed.

   You should pay especially close attention to combined conditions. When optimizing the compiler, it may happen that coverage of part of a condition expression is lost because the outcome of the total expression already exists. Here is a code example illustrating this:

```
IF  type("Alias") <> "C""
 or empty(Alias)
  or Alias = 1234
THEN
   ...
ELSE
   ...
ENDIF
```

Listing 3.1 Run-time errors caused by expression analysis

The code in listing 3.1 causes a run-time type mismatch error if “Alias” is of type “C” and not empty. If your "best case" test case does **not** expect “Alias” to be of type “C,” and in a variant test case the ELSE branch "Alias" is of type "C" but empty, then the third part of the expression will never be calculated. Either the first or the second part has already returned a TRUE result. This causes the entire expression to be returned as TRUE and therefore prevents further processing.

This is a frequent source of errors in programming languages that are not strongly typed. But strongly typed languages may also produce a run-time error with such a construct. All you have to do is picture a database field being accessed whose name has been spelled wrong.

3. **CASE Constructs**
   In addition to the best-case CASE construct, a separate case must be generated for each CASE branch. The same is true for instances of ELSE and OTHERWISE, regardless of whether they are explicitly executed in the source code or not. When a CASE condition is combined, then watch out for potential optimization of the compiler.

Schematic generation of test cases

With structured basis test cases, you can be sure that all lines of source code have been executed once. Creating structured basis test cases is fairly easy because conditions that deviate from best case scenarios can subsequently be recorded schematically for test case generation. We should give a source code example of this.

```
...
with THIS

   *---------------------------------------------------
   * check parameter
   *----------------------------------------------------
   IF NOT(
             type("tnFlags") = "N"

             and (tnFlags = LF_CREATE_MISSING
             or tnFlags = LF_CREATE_NORMAL)
             )
   ERROR __OCF_ErrWrongParameter
   RETURN .FALSE.
   ENDIF

   *---------------------------------------------------
   * control file must be closed
   *----------------------------------------------------
   IF NOT(.nControlHandle = 0)
   ERROR __OCF_ErrControlFileOpen
   RETURN .FALSE.
   ENDIF
```

```
*-----------------------------------------------------
* license file must be open already
*------------------------------------------------------
IF NOT(.nHandle <> 0)
ERROR __OCF_ErrLfClosed
RETURN .FALSE.
ENDIF
...
```

Listing 3.2 An example of a simple source code structure

For our best-case scenario, we set conditions that ensure that all parameters and preconditions are okay and debugging is not executed in the respective `IF` branches.

We therefore determine:

```
type("tnFlags") =  "N"
tnFlags = LF_CREATE_MISSING
nControlHandle = 0
nHandle <> 0
```

These are the values for the first test case.

In order to enter the first `IF` branch, you have to cause the `IF` condition to be true. The easiest way to do this is to ensure that `type("tnFlags") <> "N"` apply. But since you want to evaluate the combined expression as a whole, we decide that `tnFlags` have a value assigned, not equal to `LF_CREATE_MISSING` and not equal to `LF_CREATE_NORMAL`. That is the second test case.

The third test case is that the `nControlHandle <equals> 0`. This ensures that the branch of the second `IF` statement is covered.

The fourth test case leaves the ideal path at the third `IF` statement by setting the handle to `nHandle = 0`.

This process then carries on through the entire code structure ...

Very high cost This example demonstrates where problems arise in structured basis testing.

- ▶ The approach generates a large number of test cases.
- ▶ If conditions branch down to three or more levels, it becomes very difficult to create the testing environment that covers a particular branch.
- ▶ If a condition is based on the return value of a different function, this function must be made to return exactly the value needed. The worst case would be that the called function is replaced by a function stub which returns the desired value during testing.

Complications of this kind cause testers to dispense with exhaustive source code validation on many projects.

3.5 Integration Testing

If you are grouping several program units into a larger module, risks can arise related to the arrangement itself. These issues are dealt with in integration testing.

Integration testing is different from unit testing of the next larger program unit. Integration testing is less concerned with what the new, combined unit does than with whether the individual parts work together smoothly. The interaction of the individual parts of a unit or subsystem pose larger risks if the parts are physically separated, for example in different .exe and .dll files. If parts of a system are combined in an executable file, interface incompatibilities, missing files and other problems will appear immediately. If the parts of the program are physically separated, the first check of a component will be made only when it is called. The correct component version is checked, as well as the match between the interface and the function call, and so on.

3.5.1 Transactions

The functional correctness of transactions across multiple modules should always be tested first. These represent the best cases in integration testing. All components are present, correctly initialized and available. In a typical 3-tier architecture, this consists of the interface, processing logic and data storage. Best case testing checks if use cases are correctly handled across all three tiers.

Other constellations are also conceivable, such as program chains which include: a form editor, an application which prepares data for printing, and a printing program that merges the data with the forms and prints.

Maximal case

In addition to best cases, it also makes sense to carry out maximal case tests. These are tests which pass maximum values through all data channels. Try entering maximum values in the input fields of the application interface, for example. When entering numerical values, use the maximum number of digits but vary the values. Here are useful entries for fields with six places before the decimal point and two after:

1. 123456.78
2. 234567.89
3. 345678.90

and so on. Use them only to the extent that the program accepts these values, of course. Having 999999.99 in all fields would exhaust the maximum planned capacity this would certainly be a meaningful unit test case if two of these values were multiplied together. But integration testing is more concerned with interaction. In our example, the question is whether all values are being passed through the various modules and tiers correctly. It is vital that the input values at one end of the transaction chain can be readily associated with output values at the other end. If you had the same maximum values in all the inputs, you would not notice if two values had been accidentally switched somewhere along the line.

Assuming the input does not exceed the required field length, we can work with alphanumeric input data using the name of the data field and a character that signifies the end of the field. Here is reasonable input data of 40 characters in length for three address lines:

```
Address1------------------------------->
Address2------------------------------->
Address3------------------------------->
```

At the end of the processing chain, you can recognize whether all the input data has the correct length in the correct field.

Minimal case

Minimal cases can also make sense for integration testing, but these deal more with user-friendly behavior and minimal configuration than with data loss.

One example of user-friendly program behavior would be that the interface already "knows" what the application layer needs. Each time a user enters information, or at the latest submits it, a plausibility check is carried out automatically. If the user tries to enter or submit incomplete or faulty information, he or she is immediately notified instead of receiving an error message later from the server. Sometimes this level of plausibility checking cannot be maintained for more complex validations that also have to access the application's data pool. But there are still some Web sites that do not check simple required fields, which forces the user to reenter an entire set of information after an error message from the server. Here, minimal case test cases verify whether the obvious input data required to begin a transaction chain is also sufficient to complete processing.

Minimal configuration

Another type of minimal test case checks whether the application can get by with a minimum of installed components. For example, third-party products may have been installed that are required to perform certain functions, such as report generation, outputting graphics, compression tools, e-mail clients, and the like. What happens when one of these products is not installed? Could it be that the program does not even start? Even though the user could work reasonably well without the uninstalled components? Or does the program act as though everything is just fine, and then crash when you click the right button? The anticipated result of such a test would be that the program functions even without the third party components, but that the functions dependent on these components are clearly deactivated in the interface.

Error case

When error-case testing is included in integration testing, it checks how the program reacts when one of the components it always needs is unavailable or faulty.

▶ Does the program check for the strictly required components when started? When launched, the program probably cannot check whether all required components function properly. However, it can certainly check whether the components are available and whether the minimally required version is installed.

- Can transactions be properly cancelled if processing is interrupted at some point along the chain? Or, if so intended, can a transaction be resumed where it left off after the error has been fixed?

3.5.2 Linking to the Interface

A special kind of integration testing, which also makes sense for single-layer applications, checks the interplay between menus, toolbars, function keys and the program units they call.

- Are currently unusable menu items and toolbar buttons shaded in gray?
- Is the widget's display range sufficient to display all values?
- Are all error messages received during processing correctly passed on to the interface? Does the user understand the message when it appears?[1]
- By the same token, only the error messages meant for the user should be passed along to the interface. The message "OLE Error Code 0x8000ffff: Unexpected Error." means precious little to most users.

3.5.3 Synchronization

Further integration testing may be required to test how a particular program segment responds to events in other program segments.

Multi-user operation

For example, one segment could modify or delete data which is being used by another segment or displayed in a list. Here, the anticipated program behavior depends on the locking mechanism used. Pessimistic table or record locking means no data can be edited as long as other program segments are using the data. However, if the data is only being displayed in a read-only list, the list should be updated once the data has been modified. With optimistic locking, modifications can take place even if the data is in use somewhere else. The question of whether or not

1 At the start of a well-known financial accounting software program, the message "This is a duplicate check number. Are you sure?" appears without any accompanying information.

to update the data being used must be answered separately for each individual case. Information in a voucher should not be changed after it is created, otherwise the voucher is no longer a voucher. If a given document must be recreated, however, it makes a lot of sense to pass modifications such as address corrections.

Referential integrity

Deleting data that is simultaneously being used elsewhere should be a no-no. When using relational database systems, synchronization that takes place during data deletion is most often governed by referential integrity (RI) rules stored directly in the database. RI rules dictate what should happen if a linked data set is modified or deleted. The rules can be set to allow modifications to be passed along to linked sets or to prevent modifications to the database if linked sets exist. The same is true for deleting. Deleting a data set can also cause linked sets to be deleted as well. For example, if header information in a voucher is deleted, in most cases the line-item data will be automatically deleted as well. One alternative would be to prevent the deletion of header information as long as line item data is present.

The database design determines which RI rules apply. If RI rules are stored in the database, they must also be tested. Here, we do not check whether the database will adhere to its set rules. We can and do assume that the relational databases now on the market will do this. More importantly, the tests must ensure that all rules are set correctly and completely.

Synchronization often affects quality

Test cases for data synchronization, as well as data processing across multiple program segments or layers, depend significantly on the application's design. At the same time, these questions are often not addressed in the analysis because, after all, they are *obvious* to *everyone*. If a customer record is deleted, the customer's outstanding items must *certainly* also be deleted, right? Or is it better to prevent the deletion of customers if outstanding items exist? Does that always work? Must the user be able to override this?

As you can see in these simple examples, it is precisely questions of data and process synchronization that often determine the perceived quality of a program. If you are looking for test cases to analyze documents or design decisions, or to test integration, pose these questions of dependence and necessary synchronization to yourself or to others.

3.6 System Testing

System tests deal with issues related to the complete system. Finding test cases for system testing is easiest if you think of software as something in a box that gets sold somewhere.

"Can the software do everything I need it to do? Is it compatible with my hardware and operating system? How do I install it? How much space does it use up on the hard drive? Can other users get access to my data?"

These are the questions that produce test cases for system testing. Of course, the questions will not sound quite so casual or personal (you are not comparing online banking tools). But the gist is about the same.

3.6.1 Functional completeness

What interests the customer most about the system as a *whole?* Whether the program's (or add-on module's) functionality is actually there. Therefore, the first system tests or checks should answer this question if nothing else: "Have we thought of everything?" This question generates the best-case test cases for system testing. If parts of the system or add-on modules are missing, it is difficult to test the system as a *whole*.

Are the requirements satisfied?

How can we determine whether the system or the particular add-on module functions as required? By using the requirements specification, of course—assuming one exists and is up-to-date. If you have reliably managed requirements and modifications all along, you can possibly skip the testing for functional completeness. If not, you must find some other way to detect the explicit and implicit requirements of your system.

Use Cases and Scenarios

The systems' requirements can be derived from the description of use cases and scenarios, if such a description exists. If no use cases and scenario descriptions exist because, for example, the nature and scope of the task analysis only became clear during development then it is advisable to create a short, ad hoc description of use cases to prepare for system testing. For one thing, you can use this description to check whether every feature categorized as useful, or marked for implementation, was actually built successfully. In addition, you can use this description as a starting point for regression testing of the next round of program enhancements or modifications.

Implicit requirements

Correspondence, including e-mail, often contains implicit requirements that one has agreed to implement during the course of the project. These requirements tend to get lost. Discussion notes are also a rich source of functionality ideas that somehow never quite get implemented. Search through your inventories for such broken promises, at the latest during system testing. This gives the customer confidence in your organization's reliability even if you did not quite manage to do everything that you promised.

Menu items, buttons, check boxes

The program itself should also be fine-tuned for functional completeness. Menu items that call nothing, buttons that do not react or are always deactivated, and check boxes that do not noticeably affect program behavior when selected, are all signs of missing functionality. Perhaps something is not absent, but rather superfluous. These interface items could be hold-overs from prototypes or call functions that will not exist until the next release version.

User manual

The user manual must satisfy two general requirements. It should be **a)** available and **b)** accurate. Therefore, checking the functional completeness of an add-on module also includes checking the program against the user manual. Is everything important covered? Has everything described in the user manual actually been implemented?

Has everything been tested?

The **correct** implementation of requirements should be checked during unit and integration testing. During system testing, you must ask whether the requirements defined for your specific add-on module are **completely** implemented. Here implementation means: Solutions for all requirements have been programmed and tested! In this sense, system testing also confirms the completeness of the functional tests.

Software normally has points of contact with real life, and "completeness" is very hard to achieve at these points. Use cases describe a best case; executable alternatives or alternate scenarios describe cases that diverge from the best case. The best case and each separate scenario should (in theory) get an individual test case. However, with scenarios we once again quickly encounter a volume problem. As long as you have no reliable information about actual use, you must use your imagination and your experience to figure out which scenarios are important and should therefore be tested.

Describing use cases in detail

In the case study at the beginning of this chapter, a use analysis was conducted which GUI prototypes later fleshed out. If you have completed these sorts of tasks, you have already contemplated fundamental scenarios. You can now take advantage of all that by checking whether these scenarios have yet been covered during testing. If not, you can now make up for the missing tests during system testing.

3.6.2 Run-time Behavior

If the program should run on various operating systems, system testing will obviously evaluate the software's run-time behavior on these systems. Normally, no new test cases will be needed for this. Instead, appropriate unit, integration, and system tests are performed on all target platforms. Which test cases these are depends on the influence factors for the operating system (also see "Coverage of System Scenarios" on page 141).

System versions

Program behavior does not only vary across operating systems which belong to different system families such as Unix, Linux, Windows, DOS or Mac OS. There are also serious differences between versions in a system family. These can still have an effect on your program's behavior, even if you use a programming language that is supposed to protect you from such version differences. This is largely due to the system components that your program uses. Statements in your code might call the system interface directly, constituting an explicit use. Or the use could be implicit: The operating system interface is called from your language's run-time system or the code produced by your compiler.

Effects of the operating system

In the event of explicit use of operating system interfaces, you can determine which operating system components might be influencing your program by inspecting your code. This is not so easy for implicit uses of operating system interfaces from the run-time system or from compiler-generated code. The run-time system version and the compiler version are also important here, along with the OS version. Even the compiler status that translated the run-time system can be a decisive factor. For example, code produced by older compilers often cannot deal with today's standard processor speeds.

So far we have been discussing various OS versions, run-time systems or compilers, and we do not mean program versions with varying version numbers. Software vendors and development tools do not increase the version number with each modification. The deciding factor is always the number of the so-called "build." Builds can be performed as often as several times a day. One of these builds then makes it onto the next CD or into the next service pack. By contrast, new version numbers are set by the marketing department in cycles.

Keep smoke tests in reserve

By making only controlled upgrades and installing service packs only when needed, you gain some protection against modifications in the development environment. In most cases you cannot do anything about a customer's chaotic operating system environment. Therefore, you should compile a series of smoke tests that you can perform on each new operating system version as needed. These smoke tests should cover the basic functionality of your software. Accordingly, they do not discover involved problems with a specific OS state, but they do indicate whether the software's basic features function correctly.

Hardware resources

Hardware may also have an effect and must be checked during system testing. The user manual for your software might provide instructions on the minimal configuration required. Check these instructions at least with each major upgrade.

Drivers

Drivers fill the gap between hardware and operating systems. When errors occur that cannot be reproduced, the drivers used should be examined more closely. Drivers are always of interest in system testing if your program communicates with a hardware component more intensively than required for normal use. For example, the driver can have a decisive effect if communication protocols are used, if status information is called, or if outputs must be precisely positioned.

Timing problems

The ever-increasing speed of today's computers can lead to timing problems. If your program uses timer objects, needs wait cycles, or even uses its own timeout control system with "FOR" loops, you should conduct system tests on the fastest computers available. Timeouts which were adequate in the past may very well no longer work for the newest computers.

3.6.3 Installation

Test cases that evaluate installability and configurability should also be included in system testing. When conducting installation tests, it is important to use a testing system unrelated to the system under development. That is the only way to ensure that the development environment does not exert any influence on the installation process.

Minimal system requirements

Test the best case here as well using a properly configured "bare bones" target machine. "Bare bones" means that no other software is installed besides the operating system. If absent, all components required by the program should be automatically installed during installation. Testing can only be done reliably if the target machine has had a clean install with minimum system requirements. The best case here is also the minimal case.

Conflicting components

Sometimes the installation best case is the one that never occurs in the real world. "Out there" installation conditions can be quite the opposite: chaotic, or even disastrous. Though rare, it does happen that two programs from different vendors cannot be installed at the same time. This is most likely to happen when both vendors use the same components from the development system or the same software from third-party vendors but in different release versions. Unfortunately, not all of these components are upwardly compatible. It is also unfortunate that the installation check in the operating system sometimes does not function correctly with component versions. Many vendors have tried to bypass conflicting versions by using a rigid installation configuration, by tweaking general Registry information, by configuring paths to their version or by other contrivances. Browsers, data access components, and graphics libraries are well-known examples of this highway to DLL hell.

The usual suspects

If your program utilizes such risky components, you should look into using maximal case along with best case. This could consist of trying to install your program on a computer where all the usual suspects are already installed. However, it is not always so easy to identify them. For this particular type of test, it would be worthwhile to join various user groups, discussion forums. Conduct a compatibility test at the earliest opportunity as soon as you suspect a source of problems. If you notice for the first time during system testing that your program cannot be installed alongside another widely used program, it is probably too late to do anything about it in the current version.

Upgrading previous versions

Along with reinstallation, upgrades of earlier program versions may also have to go through system testing. Which of the many outdated versions are upgradable? This can only be decided on a project-specific basis.

Configurations

Highly configurable programs also run into a volume problem when testing upgrades to prior versions. Which program configurations should be checked? Must all upgradable versions be tested in every possible configuration? Precise analysis of various configurations and their effects can save a great deal of work here. Perhaps a reasonable compromise would be to limit testing to scenarios that are also used elsewhere. Check if the various configurations of your program are already available for smoke or regression testing before updating them manually. The test scenarios used prior to releasing the last version can thus be reused when testing upgrades. The best approach is to record all test scenarios in your source code control system or configuration management from the start.

At the same time, do not be too extravagant with installation options. Each installation option is a factor in the number of required test cases and these add up. If you count the large number of supported operating systems, the number of upgradable prior versions of your program, and a handful of various installation options, you will quickly come up with dozens of installation tests that really ought to be performed. The "Coverage of System Scenarios" section below offers some tips for how to combat this kind of exponential surge in testing without sacrificing too much security.

Installation options

Uninstallability

Installation and deinstallation programs are rarely made for specific applications these days. Instead, people fall back on ready-made installer programs. These programs are able to cleanly install and uninstall software packages. The current general policy is not to delete altered files, but to advise the user that the files must be manually deleted.

Using an installer

If you rely on a common installer program to perform your installation routine, you will not, in most cases, need to worry about being able to uninstall your software.

3.6.4 Capacity Limitations

Further system test issues include potential capacity limitations and overall system performance. Do you know the maximum file sizes allowed by your program? Or the maximum number of data records, simultaneous users, and the like? Probably not. These limitations are probably not very critical in many cases.

Warranted characteristics

That is, unless you are required or want to provide this information in the software manual, PR material, or on the packaging. You would be well-advised in this case to regularly verify this information using system tests. Otherwise, you run the risk that such a warranted characteristic becomes unrealistic. Upshot: this can be construed as a serious flaw and can even lead to your being sued. Key test cases for system testing in this case are: stress testing and robustness or capacity testing.

Stress testing

It is now common practice to test high-traffic Web applications by using stress testing. The fundamental approach to this method is described in the section below on performance testing. For a systematic approach to stress testing an application's individual components, see [FröhlichVogel01]. [Nguyen01] offers a comprehensive introduction to Web application testing.

3.6.5 System problems

The next category of test cases for system testing centers on how an application under test responds to problems in the programming environment, when the system crashes, network access is unavailable, the disk is full, or the printer is not ready or possibly even non-existent.

System errors

By combining the operating system, the programming language being used and its methods of dealing with problems, the application programmer should have enough resources to at least catch unexpected system failures before data gets lost and enable the application to be restarted in a controlled manner. In many applications, the error handling routines for this are more likely the subject of design reviews rather than explicit testing. In most cases, you can limit system testing for one of the first versions to a single test that generally checks for the proper interception of system errors. These general tests can be left out of system testing on subsequent versions. However, this presupposes that source code reviews are regularly conducted to ensure that the developers are sticking to the stipulated error handling strategy.

Impact on workflow

Yet it's a whole different story if a hardware component has more than the usual impact on the workflow. To find relevant test cases for this, locate situations in the program where the workflow depends on flawlessly functioning hardware. For example, ask yourself the following questions:

- ▶ Are there places in the program flow where something is outputted that cannot be repeated as such?
- ▶ Was data altered after an output operation without the user having approved the correct output?

- Does the workflow specify somewhere that data be fetched by another computer over the network? What happens if the network is unavailable?
- Do steps in the workflow depend on data being saved, e.g. on removable data media?

Is repetition possible?

Generally speaking, all places in the workflow are considered critical that cannot automatically be replicated when a failure occurs. Examples of this are: importing data, end-of-the-day routines, print job page numbering and the like, any type of automatic number assignment, and reading from or writing to removable media such as floppies, CDs, or tape.

If you have identified places like these in the workflow, during system testing you should check that the program enables the operation to be repeated if a hardware error occurs.

3.6.6 System Security

The final group of test cases for system testing consists of prevention against a hostile attack on data and the program. These tests cannot, and should not, answer the question of whether the user's IT environment is sufficiently safeguarded against hackers, viruses, data theft, sabotage, and the like. This is the responsibility of a company's security experts, network administrations, and IT managers. The application-based tests for security should therefore be limited to aspects of the application and the data used by it.

User authentication

When an application performs user authentication, the test cases generated for the application can only be used once the system is complete:

- How many failed login attempts does the system allow? What happens then?
- Is a password required? Does a password have to be changed at regular intervals?
- Can a password be changed and then changed right back to the previous one?

- Do users adhere to password specifications such as length and characters contained, etc?
- Is a user account disabled if a password has been entered incorrectly several times? Who can re-enable the account?
- Does changing the password make the old password invalid?
- Does changing the user ID make the old user ID invalid?
- Are deleted user accounts safely removed from the system?
- Are user IDs and/or passwords saved without encryption or sent over the Net?
- Is an account cancelled after being inactive for a certain amount of time?

Data security

Further test cases cover instances where protected data is accessed.

- Have access rights been assigned consistently throughout? Is access to restricted data via detours through other modules also prevented?
- Do products and add-ons purchased additionally also comply with the assigned rights?
- Can the database be accessed directly, e.g. using report generators, system tools, or other tools from the database vendor?
- Which data is deleted? Is data actually deleted, or does it simply end up in the system's Recycle bin? Who has access to the contents of the Recycle bin?
- Is critical data overwritten when deleted? Or is it simply flagged as deleted, yet can still be detected in the disk image?
- Who can modify the database being used? Who can save or modify stored procedures?

Targeted Attacks

The knowledge and tools required for a targeted attack on a system via the Internet or an intranet generally exceed the resources available to developers and testers. Knowledge of this kind is seldom learned—it is more likely to be gained through trial-and-error practice instead. If you want or need to conduct penetration testing, you should get help from an expert.

An enormous increase in these types of attacks has gone hand in hand with the Internet's resounding success, with the potential for security breaches having grown to such an extent that several universities and other public institutions have now also taken up the issue of Internet security. A good introduction to Web sites on this subject can be found in German in [TUBerlinSecurity] and in English in [Cert].

3.7 Performance Testing

The most important tests come last. There is one situation that frequently leads to delivery deadlines not being met or programs being supplied that, although they contain all the requisite functions, cause problems in real-world use or are unusable for all intents and purposes. It is poor performance under heavy loading.

Predictable maximum load

The performance of individual program parts, assembled modules, and entire systems or enhancements should be checked in the course of unit, integration and system testing. Performance or load tests check whether the program can handle the anticipated or predicted maximum load. This means whether the program functions reliably and at an acceptable speed under maximum load. Load or stress testing goes beyond the maximum load to the point where the program or one of its components ceases functioning. The component that failed is then investigated in order to identify possibilities for optimizing its performance or for early detection of the overload situation.

3.7.1 System Parameters

Performance and stress testing is carried out using the minimum recommended hardware configuration. In so doing, the following system parameters are taken to their design limits or beyond, either in real-world or simulation testing:

- **Number of concurrent users**
  The number of concurrent users of an application is systematically increased particularly in the case of client/server or Web-based

systems. The section "Stress Testing for Middleware" on page 127 contains an introduction to the technical background of such tests and the procedures used.

- **Memory use**
  Physical, virtual and temporary memory is artificially reduced by running other programs or stubs, thus reducing available memory. If possible, multiple instances of programs requiring large amounts of memory are created. Functions are repeated or carried out continuously to check that memory is released properly so as to test its availability. In Windows operating systems starting with Windows NT (NT, 2000, XP), the /maxmem switch in boot.ini can be used to reduce the amount of RAM used by Windows. For details, refer to [MSDN].
- **Computing time**
  Here, too, an artificial shortage is created by the use of other programs or stubs. Where possible, processes are carried out in parallel in order to trigger deadlock situations.
- **Network capacity**
  The network is operated at the minimum recommended bandwidth. Available network capacity is reduced on the hardware side or artificially by running competing programs.
- **Data access**
  The number of competing data requests is increased. Here, too, continuous testing is useful for detecting deadlocks.
- **Data volume**
  The size of the entire database or the amount of material requested in database queries is increased.

Performance and stress testing performed by reducing system resources mainly checks response times and the robustness of the program under load conditions. The simplest tool used for this is a stopwatch that measures the response times of the program being tested. However, a number of very effective (and expensive) testing tools have been developed for this job.

3.7.2 The Quadratic Effect

Another quasi-predictive type of performance testing focuses on the "quadratic behavior" of programs. These tests can be carried out at any time without much effort.

What is the quadratic effect?

The time needed by a part of a program to complete a task can often be expressed as a polynomial. A polynomial is an equation with only one variable of the following form:

$k_0 + k_1n + k_2n^2 \dots + k_mn^m$

k_0 to k_m are constants. The subscript m indicates the degree of the polynomial. For the purposes of performance testing, n is equal to the amount of input data.

If, for example, we first consider a program that always takes 400 milliseconds for a particular action (k_0=400) plus an additional 100 msec. for each block of input data (k_1=100), the total time for 10 data blocks is:

$400 + 100 \times 10 = 1400$ msecs. = 1.4 secs.

A different algorithm for the same task might require only one tenth of the time for k_0 and k_1 (k_0=40, k_1=10), but an additional 1 msec. for the square of the number of input data elements. For 10 data blocks the processing time is calculated as follows:

$40 + 10 \times 10 + 1 \times 10^2 = 240$ msecs. = 0.24 secs.

For 10 data blocks the second algorithm (A2) is thus significantly faster than the first (A1). It is also faster for 20 data blocks:

A1: $400 + 100 \times 20 = 2400$ msecs. = 2.4 secs.

A2: $40 + 10 \times 20 + 1 \times 20^2 = 640$ msecs. = 0.64 secs.

For 100 data blocks, however, the situation looks different:

A1: $400 + 100 \times 100 = 10{,}400$ msecs. = 10.4 secs.

A2: $40 + 10 \times 100 + 1 \times 100^2 = 11{,}400$ msecs. = 11.04 secs.

The fact is that with a sufficiently large data set a program whose processing time is represented by a polynomial of degree m (in the case of A2 $m = 2$) is always slower than a program whose processing time is derived from a polynomial of degree $m - 1$. To be sure, the constants k_0, k_1, k_2 influence the size of the data set required to confirm this fact, but not the fact itself.

Revealing the Quadratic Effect

How can this relationship be utilized in performance testing? Should we determine the appropriate polynomial for every program in order to determine its degree? No. There are simpler ways to identify programs whose performance corresponds to a polynomial of the second degree and which consequently exhibit the quadratic performance effect.

The first example above was based on 10 data blocks, the second on 20. In other words, the amount of data was doubled. However, the processing time was more than doubled — from 0.24 secs. to 0.64 secs. Whenever you observe this phenomenon you have most likely discovered a program exhibiting the quadratic effect.

Thus, you should always carry out at least two performance tests, in the second test increasing the data input by a factor of X big enough to yield significantly different results. If the processing time increases by more than a factor of X, you have landed your fish.

But why is the quadratic effect so dangerous? What is the situation with third or fourth degree polynomials?

Programs whose performance reflects a higher degree polynomial ($m > 2$) are already so slow, even with small amounts of data, that the program developers themselves usually notice that something is wrong. However, when only a single test is carried out the program developers frequently fail to notice the quadratic effect because they are only working with small or minute amounts of data in this case.

How does the quadratic effect occur?

When part of a program requires a processing time that is proportional to the amount of input data n, and this part is activated n times, a quadratic effect occurs in the whole program. An example is an array to which elements are added in a loop which are inserted at the beginning of the array. The time needed for the insertion of an element at the beginning of the array depends on how many elements the array already contains. Consequently, the entire loop exhibits a quadratic effect. If the individual elements are appended at the end of the array the quadratic effect does not occur since the addition of each new element involves the same amount of time, regardless of the number of elements in the array. A similar situation applies when new records are added to database tables with existing indices. When the number of new records to be added is sufficiently large, inserting new indices into the existing structure will always be slower than deleting existing ones and starting over.

For a detailed discussion of the quadratic effect in C++, refer to [KoeMo00].

3.7.3 Stress Testing for Middleware

When users concurrently work with the same program, the issue of where the program of an individual user is executed has to be dealt with. There are basically two possibilities (with as many classifications in-between as you like):

The program runs entirely in the memory of the user's workstation and only accesses the data it needs from a server (fat client).

The program runs entirely on an application server, with the user's workstation only providing the GUI (thin client)

Middleware

Middleware refers to applications running on the application server between the GUI unit (the user's workstation) and the data storage unit (the database server).

The performance of applications using thin clients (typical Web applications are the best example) depends on the crucial question of how many concurrent users the application can support without being overloaded. Or, to put it differently, what effect an increase in the number of concurrent users has on the program's performance.

Applications are considered well scaled if they demonstrate performance only marginally affected by the number of concurrent users or are completely unaffected by user numbers.

Scalability How can the scalability of an application be tested? The answer is actually very straightforward: start the application on an application server and allow a number of users to work with it. Measure the response times of the application. Increase the number of users by a factor of X and measure the response times once again. If an application scales well, the response times should increase by a factor less than X (see also the previous section on the quadratic effect). The best outcome is when there is no increase in response times whatsoever.

User profiles In order to obtain a realistic impression of the behavior of an application in real time, users should not be carrying out the same action at the same time. It is better to distribute the actions of the users in the way this normally occurs. If no previous knowledge about this is available, estimates have to be used. If 20% of the users of your Web application will be submitting orders, 40% examining the price list, and the others simply browsing the site and looking at banner ads, divide up your virtual users in the same way during the load test.

A further comment is made here regarding the underlying technology:

State-dependent vs. state-independent The scalability of an application depends strongly on using as few state-dependent objects as possible. State-dependent objects are those that maintain an internal status that has to be preserved between two uses of the procedure. This necessity means that a dedicated area of memory in which the actual state of the object is stored has to be set aside for every such object. State-independent objects, on the other hand, store all values that have to be retained in a database as soon as they complete a task. As a result they do not possess any variables of their own for which an area of memory would have to be reserved when the object is loaded into RAM. They operate in their methods with local variables only. Since the code of objects of the same class in RAM is normally present only once, only a minimal amount of RAM is occupied when objects are state-independent, i.e., do not require their own address in RAM.

The question as to how many state-dependent and state-independent objects are used can be answered in a review. In so doing, it is possible to work out the application's scalability by examining the application design.

Implementation

I said that scalability testing is "actually very straightforward". Why this qualification? Problems that arise during the load testing of middleware are mostly connected to the implementation of the test environment. The application server has to be equipped approximately the same as the server that is actually used later on. In order to test concurrent access by 1000 clients, 1000 PCs would be needed that are simultaneously connected to the application server, something that would be unrealistic (at the very least in the case of the second test with 10,000 clients). That is why it is necessary to simulate a large number of users on a single computer. Of course, this computer also has to be appropriately configured to accommodate a large number of processes concurrently. Different drivers have to be written for the various user profiles, and so on.

Tools are now available which support test procedures of this kind, especially the simulation of a large number of concurrent users.

3.7.4 Database Access

The performance of procedures for obtaining access to relational databases is highly dependent upon whether the database search engine is capable of optimizing access or not. Today's databases possess various possibilities for optimization, consequently the design decisions that support or hinder access optimization are in turn dependent upon the particular database being used. Generally speaking, access procedures that can be carried via indices perform significantly better than those that operate without an index.

Querying the level of optimization

Many databases nowadays offer the possibility of checking the level of optimization achievable (completely, partly, or not at all). It is advisable to subject all access procedures used by your application to this simple test in order to be certain that all the necessary indices are available and that nothing else is standing in the way of optimization.

Two variables have to be taken into consideration when testing a database's performance. The first is the size of the database, i.e., the number of stored records. The other is the number of competing access attempts, i.e., how many other users are concurrently trying to access the database. Both variables influence system performance.

Data generation tools

In database performance testing, a data generation tool that generates the desired number of records is very useful. You can create this tool yourself. If you need test data only for a special application or a special table within the application, writing your own small program is usually sufficient to generate the necessary data. If you frequently need test data of varying structures or quantities, it is advisable to buy a tool specifically designed for the job.

Virtual users

For database performance testing you also need drivers that act as virtual users accessing the database. As in the case of stress testing middleware, when selecting a driver it is advisable to ensure, if possible, that all the different kinds of access (insert, update, delete, select) are carried out at realistic frequency levels.

3.8 Test Coverage

In selecting test cases for unit, integration and system testing, you will want to avoid unnecessarily testing the same procedure more than once. You'll also want to be certain that as many of the procedures as possible occurring in the program are tested. This leads to the problem of test coverage. Many authors addressed this issue early on in discussions of software quality assurance and testing. Five indices are commonly found in the literature, C0 to C4. The C stands for "coverage."

3.8.1 Classic Coverage Indices

The level of coverage achieved with structured basis testing is referred to as C_0 statement coverage. C_0 is the ratio of the number of statements tested by the procedure to the total number of statements. Additional indices are:

- C_1 branch coverage: the ratio of the number of branches tested to the total number of branches.

- C_2 Condition coverage: the ratio of the evaluated expressions in conditions to the total number of expressions in conditions (see the coding example in the discussion of structured basis testing in the section "Structure testing" on page 104).
- C_3 Combinations of conditions coverage: ratio of the number of combinations of conditions to the total number of possible combinations.
- C_4 path coverage: Ratio of the tested paths to the total number of possible paths.

Branches and paths

The difference between branch coverage and path coverage is illustrated by the following activity flowchart:

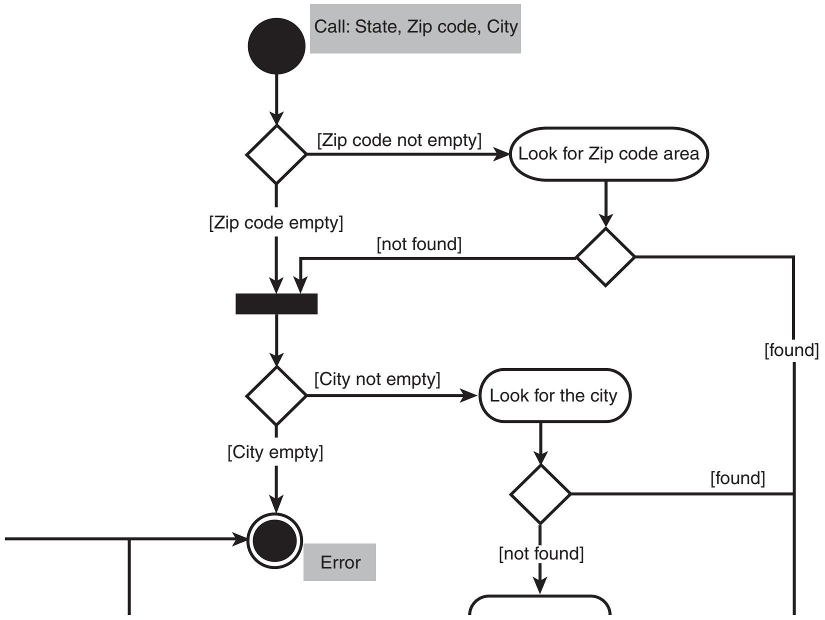


Figure 3.9 Activity flowchart for finding a destination

The flowchart above shows an extract from the activities for reaching a particular airport with the help of specified state, zip code and/or city names. Only the section up to the activity "Look for the city" or up to detection of an error is of interest here.

Two paths are sufficient if complete coverage of the branches in this area is required:

1. Zip code not empty/zip code not found/city not empty
2. Zip code empty/city empty

For complete path coverage, however, it is also necessary to test the following paths:

3. Zip code not empty/zip code not found/city empty
4. Zip code empty/city not empty

It is obvious that the number of possible combinations of conditions or paths in particular can quickly become very large. As a result, a 100% coverage of C3 and C4 cannot be achieved in most cases. Consequently, the task of test management is to specify realistic values for the indices that need to be attained.

3.8.2 What Information Do Code Coverage Indices Contain?

Coverage indices are snapshots

Classic coverage indices focus strongly on internal program structures right down to the source code structure. This closely correlates with the idea that testing begins when the program has been written. However, this notion no longer applies today. Today's approaches places more emphasis on the alterability of software. The program organization and the source code structure can be changed at any time via refactoring measures. That is why the classic coverage indices are regarded nowadays merely as snapshots of specific sections of the software and the test situation.

Of course, it is always interesting to see what percentage of the source code is even covered by testing, especially in the case of regression testing. When a tester notices that a particular routine is covered only to a small degree by testing, or not at all, it is probably a good idea to check out what this routine actually does. Every unchecked line of source code can contain a more or less serious error. However, whether undetected errors are more or less serious is not indicated by the coverage indices. A risk analysis is required for this.

Coverage indices are deceiving

The classic coverage indices provide hints about untested code. As long as the test coverage remains below 50% the tester is right to feel uneasy. But what is the situation when testing reaches a coverage level of 90% or more (extremely unlikely in the case of C3 and C4)? Does this make you, the tester, feel better? Don't kid yourself! How do you know that the program is doing everything it is supposed to? Coverage indices refer only to the code that's there, yet say nothing about missing code.

Take a simple example from [Marick97]. Let's assume that a certain function contains the following section of code:

```
return_Value = doThisAndThat()
IF (return_Value == FATAL_FERROR)
   EXIT(3)    // exit with error message 3
ELSE
   // everything OK
ENDIF
```

Listing 3.3 Example of missing code

If tests are carried out that cover both the IF branch and the ELSE branch, we have done everything that is required from the point of view of code coverage. However, we have not identified the real error. This code is, quite simply, incorrect. Actually it should be like this:

```
return_Value = doThisAndThat()
IF (return_Value == FATAL_FERROR)
   EXIT(3)    // exit with error message 3
ELSE IF (return_Value == RECOVERABLE_ERROR)
   // eliminate error cause,
// new attempt
ELSE
   // everything OK, continue
ENDIF
```

Listing 3.4 Completed code

Errors of omission like this are not discovered when the focus is exclusively on code coverage indices. Source code reviews are the best way to find such errors. When doing this, the most common errors should be checked off using a checklist.

Errors of omission can occur in the course of analysis, design, and coding. They affect documents, models, and source code, and manifest themselves in missing code, an excessively simple view of things, failure to take account of real situations, etc. Anybody involved in the creation or usage of a document, model or section of source code in the course of software development can contribute to the detection of such errors. Always ask things like:

- Are these all possible variants or aspects of the problem?
- What possible special cases are there? What would happen if …
- Is there a different way of looking at this? Could someone come up with the idea of doing it quite differently?

3.8.3 Function Coverage

When it comes to questions of coverage and risk estimation, rapid application testing focuses on the functions of the program being tested. The first and decisive question is always: "What is the program actually doing?"

Function coverage involves the ratio of number of functions tested to the total number of functions. However, this doesn't refer to functions within the programming language. As was pointed out above, these internal functions are either the subject of specific unit tests or are tested implicitly on account of their use in other functions.

Outwardly oriented functions

In the case of function coverage, the functions are examined that the program offers when viewed from the outside. The level of function coverage is derived from the total number of such functions in relation to the number that have already been tested. Of course, the ideal is a value of 100%; however, this value is seldom reached due to cost or time considerations, meaning priorities have to be set. The criteria to be taken into account in deciding these priorities are discussed above in Section 3.2 on Risk Assessment.

When the function coverage of actual or planned testing is examined, the question soon arises of which functions are to be covered. What granularity forms the basis of testing? Is it better to look at large function blocks or modules or remain at the level of small individual functions? Where are the functions located that are relevant for determining the degree of function coverage? These questions can be most readily answered by referring to any analysis and design documents you might have. As soon as you have specified the required program capabilities in the form of a use case analysis, you have a good basis for determining the functions to be covered by testing. Use case analysis is confronted with the same granularity problem. For more detailed descriptions of use case analysis and tips for determining granularity in use case analyses, refer to [Oesterreich98] and [Borrmann+Al01], for example.

Determining granularity

3.8.4 Generating Test Cases on the Basis of Use Cases

The use cases derived from object-oriented analyses provide a highly suitable basis for case testing. Every use case describes a form of application of the program. Since the use cases are part of the analysis and design documents to be agreed upon with the customer, they are much the same as the program specifications. If the program functions differently from the description in the use case the customer is justified in lodging a complaint.

Positive tests

Test cases constructed from use cases are based on the program specifications and are thus positive tests. They show that the program is functioning in the way described in the use case. If this is not the case, either the program or the use case is altered.

Use cases and the people applying them are summarized in diagrams or flowcharts. However, the use cases rendered as oval symbols in the diagrams aren't the functions for which complete test coverage is required.

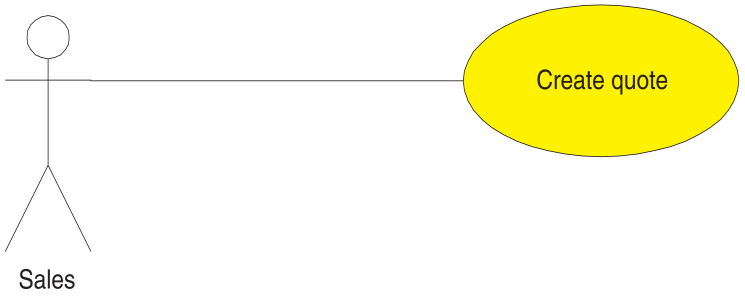


Figure 3.10 Extract from a use case diagram

The normal case and variations thereof

In order to determine the functions to be covered it is necessary to consult the written descriptions of the use cases and, where possible, the activity flowchart produced for the use case. The procedure for the use case under typical and atypical conditions is laid down in the written description at minimum. The normal situation and the variations on it define the desired functions of the program that need to be covered by the planned test cases or those actually performed. The normal case defines the best case path through the use case. Every variation produces a new path. The paths that a use case can follow are more obvious when an activity flowchart is constructed.

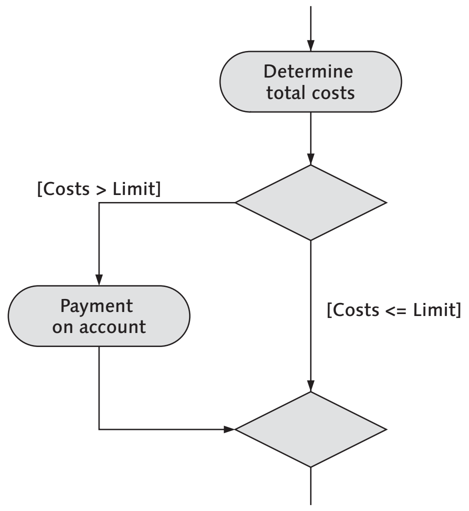


Figure 3.11 Extract from an activity flowchart

Viewing the activity flowchart enables the possible paths to be discerned directly and the program functions to be identified. If the section above is regarded as part of the "Create quote" use case, we see that the program provides an additional function in one special situation, namely when costs exceed the allowable limit. In this case, payment conditions specify a payment on account.

Function/Test Case Matrix

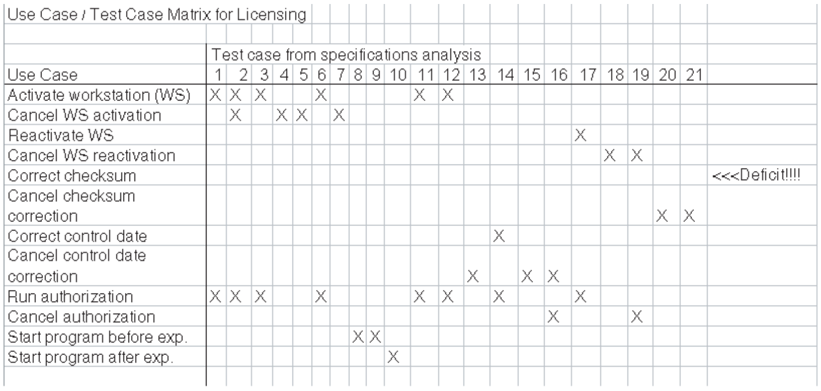
Since a test case frequently covers several functions simultaneously, it is interesting to see which test cases need to be carried out at minimum in order to cover all functions. This is what the function or test case matrix does.

Test case **Function**	**New**	**Paste**	**Edit**	**Copy**	**Cut**	**Delete**
Create record	X	X				
Save record	X	X	X			
Delete record					X	x
Record editing	X		X			
Copy/cut record to Clipboard				X	X	
Paste record from Clipboard		X				

Table 3.7 Function/test case matrix

Table 3.7 shows a simple function/test case matrix. This matrix shows that the "Edit" test case is also covered by the "New" test case if it is assumed that "New" does not cause an empty record to be saved but rather a new record containing data. Likewise, the test cases "Copy" and "Delete" can be omitted when the "Cut" test case is executed.

In real life such comparisons between identified program functions and planned or already completed test cases are somewhat more complex.



Use Case / Test Case Matrix for Licensing

	Test case from specifications analysis																				
Use Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Activate workstation (WS)	X	X	X			X					X	X										
Cancel WS activation		X		X	X		X															
Reactivate WS																	X					
Cancel WS reactivation																		X	X			
Correct checksum																						<<<Deficit!!!!
Cancel checksum correction																				X	X	
Correct control date														X								
Cancel control date correction													X		X	X						
Run authorization	X	X	X			X					X	X		X			X					
Cancel authorization																X			X			
Start program before exp.								X	X													
Start program after exp.										X												

Figure 3.12 Function/test case matrix of the licensing module

Redundancies and shortcomings

The function/test case matrix of the licensing module from the case study at the beginning of this chapter depicted in Figure 3.13 not only shows which test cases are superfluous with regard to use cases, but also that one use case has not been considered. The use case "Correct checksum" was not covered by any of the test cases in the test plan derived from the requirements analysis.

3.8.5 Test Coverage and Object-Oriented Languages

The classic test coverage indices are more difficult to work out for systems developed with an object orientation than for those with a procedural orientation. This is due mainly to the mechanisms of inheritance and polymorphism of object-oriented languages.

Polymorphism and delegation

In object-oriented languages branching occurs not only by virtue of structural commands such as IF – THEN – ELSE, but also by virtue of polymorphy. In addition, programs designed with an object orientation can change their behavior during run time through the delegation of tasks.

For instance, when the "Save" method of object A is activated a completely different code can be put into operation as compared to the "save" method of object B. Which of the two objects is activated in a particular situation may only be decided at run time. Consequently, in order to determine the degree of path coverage C_1 it is necessary to check which classes offer the "save" method, whether the "save" method was inherited from a higher class, and whether it might have been overwritten.

Basic and framework classes

The coverage indices C_0 statement coverage to C_4 path coverage are also significantly affected by whether or not the basic or framework classes used are considered. Basic and framework classes can be:

- Used without specific testing (no effort)
- Subjected to a code review (low effort)
- Present in integration testing by virtue of specific tests (moderate effort) or
- Tested by means of individual tests (considerable effort)

Reusability

Here, too, the decision on the testing approach depends upon a risk analysis. Apart from the acceptance risks and technical risks described above, reusability also plays a role. In most cases additionally purchased class libraries and frameworks are not tested separately—unless as part of the evaluation prior to the decision to purchase. The higher the assumed number of users of these libraries and frameworks, the lower the probability that serious errors have not yet been detected.

State-based Path Coverage

The methods of a class can only be tested by creating an object of this class. By creating such an object, however, processes occur that determine the state of the object and can impact the test results.

In the same way, the order in which methods are called changes the state of an object in a known way. If the methods of an object are called in a somewhat different order a completely different state can result. However, as was shown above, the current state of an object is always one of the preconditions for testing a specific method.

State flowcharts

In object-oriented analysis the confusing multiplicity of different states, method calls, preconditions, and changes of state is depicted in state flowcharts.

The state changes brought about by the various method calls are described in a state flowchart.

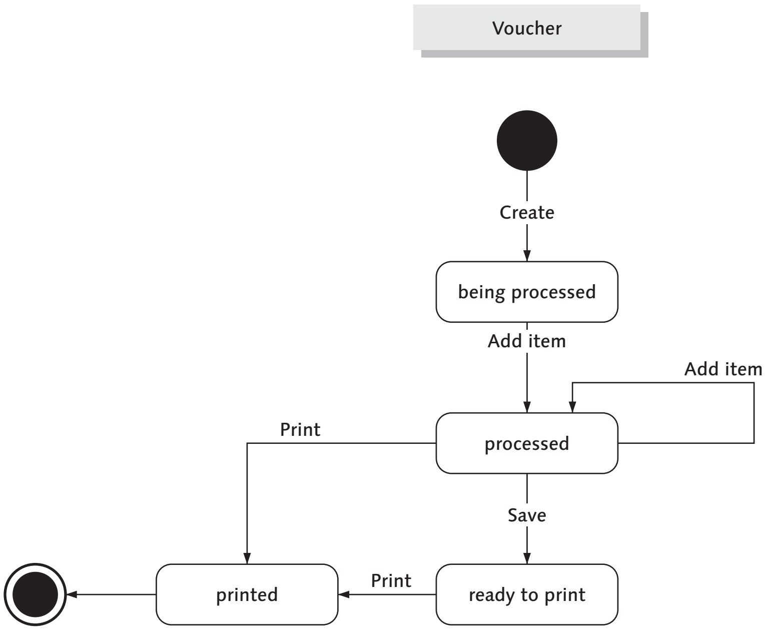


Figure 3.13 State flowchart for a voucher

Figure 3.13 shows that the voucher object is in the state "being processed" after being created. If the "add item" method is called, the voucher object switches its state to "processed". Subsequent calling of the "add item" method doesn't produce a new state and the voucher remains in the "processed" state. Not until the "print" or "save" methods are activated does the voucher move into the "printed" or "ready to print" state. In the same way, activation of the "print" method moves the voucher into the "printed" state.

One test case per path

In order to determine the test cases, the possible paths are established and the test cases designed that correspond to these paths. An individual test case then no longer involves running a single method, but rather consists of a series of methods whose activation results in the object assuming the states corresponding to the path to be tested.

Such a test case is most readily comparable to a workflow test case of a procedurally developed program. This means that testing doesn't merely involve a single step, but a series of steps, i.e. a work process.

Object-oriented analysis and design methods thus offer the test planner the opportunity of structuring the set of possible work processes and making a sensible choice based on the state changes of an object or a group of objects. Once a state flowchart describing the way an object functions is available it can be used to establish the test cases and the state-related path coverage for the object.

3.8.6 Coverage of System Scenarios

Apart from the issue of function coverage, the question as to which system scenarios have to be covered is very important in rapid application testing. As was mentioned above in the discussion of the possible test cases in system testing, system scenarios are a factor that can quickly drive up the number of tests required, especially when it comes to heterogeneous system structures as commonly seen in Web applications. That is why, as a rule, it is not enough to test Web applications in the uniform environment found on a company intranet. Testing often has to be conducted under real-life circumstances with firewalls, differing browser types, different Java Virtual Machines (JVM), and other components. This leads to a large number of possible combinations. One way of reducing this number to a manageable level is setting up pairs.

Teaming

Setting up pairs can be done when combining the current values of influence factors is restricted to pairs in order to obtain a manageable number of combinations. "Restricted to pairs" means that, of all possible combinations, only those are selected that guarantee that all pairs of influence factors appear once. Are you with me?

An example of pair setup

An example shows most clearly what this is all about.

Let's take another look at the licensing model used in the case study at the beginning of this chapter.

In case you've forgotten: the licensing module was concerned with software licensing and the detection of unauthorized use. The first time the licensed program was loaded its use could be authorized for a limited period only or permanently by entering an activator key for its use with the current workstation involved. At the end of the licensing period this could be extended, and so on.

Influence factors The licensing module makes use of a control file that can be stored in a dongle or under a hidden key in the Registry. For your testing of the activation of the software when started for the first time, two important influence factors were established, namely the operating system and the memory size of the control file. Since we are concerned with a Windows program for professional users, we want to restrict use to the Windows 98, NT, 2000 and XP operating systems. As a result, the following scenarios have to be tested:

Number	System	File
1	Win 98	Dongle
2	Win 98	Registry
3	Win NT	Dongle
4	Win NT	Registry
5	Win 2000	Dongle
6	Win 2000	Registry
7	Win XP	Dongle
8	Win XP	Registry

Table 3.8 All combinations of two determining factors

As along as you are only dealing with two factors, the total number of pairs of influence values is equal to the total number of all combinations of possible values. Starting with the third factor, however, the situation is different:

Number	System	File	Time limit
1	Win 98	Dongle	Y
2	Win 98	Dongle	N
3	Win 98	Registry	Y
4	Win 98	Registry	N

Table 3.9 All combinations of three determining factors

5	Win NT	Dongle	Y
6	Win NT	Dongle	N
7	Win NT	Registry	Y
8	Win NT	Registry	N
9	Win 2000	Dongle	Y
10	Win 2000	Dongle	N
11	Win 2000	Registry	Y
12	Win 2000	Dongle	N
13	Win XP	Dongle	Y
14	Win XP	Dongle	N
15	Win XP	Registry	Y
16	Win XP	Registry	N

Table 3.9 All combinations of three determining factors (cont.)

Combinations and pairs

The new factor "time limit", which distinguishes between limited and unlimited activation, causes the total number of combinations to rise to 16. However, the total number of value pairs is only 8, as the following table shows:

Number	**System**	**File**	**Time limit**
1	Win 98	Dongle	Y
2	Win 98	Registry	N
3	Win NT	Dongle	N
4	Win NT	Registry	Y
5	Win 2000	Dongle	Y
6	Win 2000	Registry	N
7	Win XP	Dongle	Y
8	Win XP	Registry	N

Table 3.10 Reduced combinations of three determining factors

Consequently, restricting combinations to value pairs substantially reduces the number of scenarios to be tested. When the number of factors and their possible values increases, the effect quickly becomes overwhelming. Under [Pairs] you will find a small Perl script that contains a table showing all the value pairs of the influence factors in a given table of influence factors and their possible values. In his documentation, James Bach, the author of the program, states that with 10 influence factors, each with 26 possible values, his program can extract 1,094 pair combinations from the 141,167,095,653,376 possible.

Influence Factors, Test Cases, and Test Scenarios

Nonetheless, 1,094 test scenarios is still a large number that can scarcely be dealt with. That is why it is very important to recognize which influence factors really exist and which test cases can be influenced by them. In the example of the licensing module, two factors were sufficient. However, only the one test case "Activation of the software upon launching it for the first time" was dealt with, whereas the range of functions of the licensing module suggests many further test cases that also have to be run. The question is: Do they really? Do the operating system and the way the control file is stored really have a different effect on the test case "Activating the software" than on the test case "Reactivation of the software after expiry of the license"? Or does the operating system even have a different effect on every single test case? Where exactly are the differences? It isn't necessary to put both test cases through all the scenarios unless the effect can be expected to be different in two different test cases. Consequently, it is well worth taking the time to closely examine the exact kind of effect.

Analyzing effects

In the example of the licensing module, the effects of the operating system and storage location for the control file result from the fact that each operating system uses a different .dll file. When the control file is stored in a dongle a different system-specific DLL procedure is used than when the data is stored in the Registry.

All program functions that use a system-specific DLL procedure are affected by a change of the operating system, not just the storage of the control file. As a consequence, of the two influence factors for which we want to cover all variants, the operating system has four variants, the DLL procedure 19. When combined this yields 4 * 19 = 76 test scenarios that have to be covered.

Checking function coverage

There is no need for further analysis if full coverage of functions using 19 or fewer test cases is the objective. In this case, all that needs to be done is to carry out all the test cases in the four scenarios resulting from the four operating systems. However, when full function coverage can only be achieved with substantially more than 19 test cases, it is worthwhile taking the time to conduct an analysis based on the DLL functions that actually occur.

In order to decide which test cases should be carried out on the different operating systems, a function/test case matrix indicating which DLL function is covered by which test case has to be constructed.

DLL function	Test case from specifications analysis																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	etc.
Checksum		X			X					X	X	X						X		X	
CeNum			X		X								X		X						
CompNo	X	X	X			X				X	X						X				
CopyAdd				X			X		X		X			X					X		
etc.																					

Table 3.11 Function/test case matrix

In this matrix we look for the minimum combination of columns sufficient to yield an X in every line. If you can't work out the minimum combination immediately, use this easy procedure:

1. Mark the column that currently has the most X's, e.g. in color.
2. Delete the X's that are in the marked column(s) from all the other (unmarked) columns.
3. Find the unmarked column that now has the most X's and mark it as well. Return to step 2 and continue repeating the procedure.

When all columns are either marked or empty, the marked columns show the minimum combination of columns. This way you have located all the test cases that need to be carried out to guarantee a satisfactory level of coverage.

4 Methodologies and Tools

A fool with a tool still remains a fool.
(R. Buckminster Fuller, inventor, engineer, philosopher, and poet)

4.1 Debugging—Another Use Case

After covering the range of potential test cases for unit, integration, system and performance testing and considering the coverage possible, we may be able to get a firmer grasp of the issues by exploring an additional use case.

The following sections discuss finding bugs (as many as possible), eliminating these and ensuring that they are in fact removed from the system. The use case also demonstrates how bugs are located exactly, isolated and described in order for them to be forwarded to the development team. The process as a whole is called debugging. Debugging is not just tracking down bugs by using a debugger. Debugging consists of more than this and can be broken down into these steps:

1. Performing a test case where a bug is pinpointed
2. Isolating the bug
3. Documenting the bug
4. Fixing the bug
5. Verifying that the bug has been properly removed

These steps in the process are not necessarily divided up between tester and developer. Even when the developer has checked a module prior to release, he or she carries out these steps—mostly without any superfluous formalities and, more often than not, in a woefully haphazard way. When "testing and improving" (see Chapter 2, "Testing: an Overview"), documentation may be limited to a brief remark or an entry in the development environment's ToDo list.

Systematic debugging

The formalities concerning documenting bugs and the test cases performed are set by those running the project. This chapter will be devoted to considerations surrounding systematic debugging.

The following use case provides a simple illustration of the process of debugging, from first detecting a given bug to checking that it is eliminated:

Test case: *Stock Transaction Posting with Printout of a Delivery Note*

Expected outcome: *Delivered quantity is withdrawn from warehouse stock*

4.1.1 The Test Case

It is probably clear to most people what a stock withdrawal or posting is as well as what a delivery note has to do with this type of warehouse transaction. That is why I will only provide a brief description of what happens in the test case.

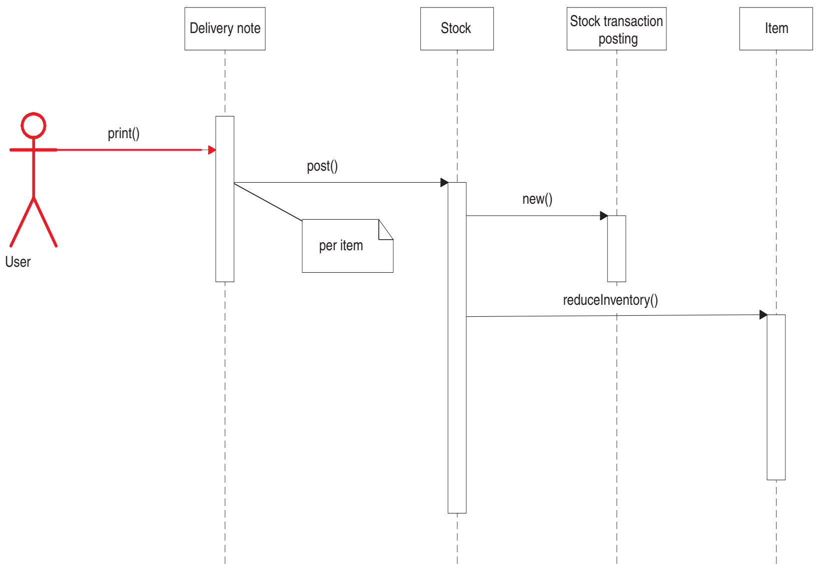


Figure 4.1 Warehouse transaction posting with printout of a delivery note

The user calls an as yet unprinted delivery note and begins the print job. One posting is made by the stock transaction module for each item on the delivery note, resulting in the creation of a new posting record and a reduction of inventory for that item. (Even if this is a redundant approach, it is often handled this way due to performance issues.)

We are already in the midst of daily testing routines and are testing a stock transaction posting accompanied by a printed delivery note. When a test case is performed, the expected outcome is compared with the real outcome. To be able to draw this comparison, you need a specified original state and some way of analyzing the final state. But, let's start at the beginning:

Performing the test

You complete the test case, i.e. you print out a newly created delivery note. Then you start the materials management program and check your inventory level for the item on the delivery note. But, because you forgot to make a note of your inventory before printing out the delivery note, you make a note of it now and then perform the test again. While checking the inventory of that item on your second try, it occurs to you that the posting record in the inventory ledger should match the expected outcome for "quantity delivered has been withdrawn from stock". The inventory ledger can only be printed out and not displayed on screen. So you print out the inventory ledger and notice that the ledger only prints out using whole numbers without decimal places. You had entered a quantity of 1.5 KG on the delivery note. At the same time you notice that there are no totals included in the inventory ledger. Congratulations, you found two bugs with a single test!

4.1.2 Detecting Bugs

This simple yet realistic example provides ample evidence of what is needed for successfully detecting bugs:

A Specified Original State

The system state prior to the test must be known (item inventory level prior to the posting). Only then can you see what changes have been made to the system when conducting the test case—in other words, what the actual result of your test is. The actual result of the test includes all changes to the state of the system!

If you want to rerun your tests, you must be able to return the system to the same state as it was prior to the test. This applies to all aspects of the system that can influence the outcome of the test. In our example this primarily concerns restoring the data. It is important to create a data set outside the programming environment to be used for testing purposes only. This data should also be included in your version control system where possible. As a developer occupied with testing and improving the system under development you probably do not have to resort to the backed up database every time. However, you should make a point of keeping a complete backup of the verified dataset somewhere nearby. Just in case that a test destroys part of the data by accident.

Of course your system state involves many ancillary conditions which have no effect on test results. But a caveat must be included here: "... will presumably have no effect!" Many times it is possible to know what factors impacted the outcome only after finding out the cause for the error. Be prepared to completely restore the system to its original state when carrying out critical tests—this will include hardware and operating system specifications, hard-disk partitioning, and so on.

Appropriate Methods of Analysis

In the example above, the error was discovered on the inventory ledger printout. The inventory ledger may be home to even more bugs you have simply overlooked. In your pursuit of bugs, an analysis of the data the inventory ledger is based on provides a greater sense of security and efficiency than merely carrying out visual checks. You need tools which allow you to access return values such as a database interfaces or programming environment enabling you to create programs for analyzing return values.

If you choose to automate or partially automate your test runs, you need to be able to view the result from within your testing script. This is not just a question of having the right tool, but also of designing your application to be test-friendly. For a detailed discussion of this aspect, see "Test-driven Application Development" on page 191.

Attentiveness

The total quantities missing in the inventory ledger do not really have anything to do with the test that was run.

It is frequently the case that anomalies crop up during testing which are not related to the test being performed. Sometimes these are minor things which catch eye as you are completing a given test. You should be on the lookout for signs like this. Do not ignore these signs just because they may be unimportant at the current time. Make a note of the anomaly and pursue the matter after you have completed running the test you were working on. Along with strategic thinking and taking a systematic approach, attentiveness is also the sign of a successful tester.

Self-confidence

You have a mental picture of what the program does. And then the program goes and does something completely different! "Oh, so that's why," you say. "What I was imagining was not true—I'll try to change how I view the program."

Stop for a second! You may be in the process of overlooking an error. What did this false conception trigger in you? Was it a program name, function name or menu item? Or was it the layout of entry fields on the screen, an icon or a combination of these? There was something funny which meant you had the wrong mental image of what the software does. This is what you need to pin down. Because whatever it was, the next user will also be led to thinking the wrong thing.

4.1.3 Error Accumulation

As a rule of thumb: if you've found one error, there are likely more. In most cases it's worthwhile to carefully review the circumstances of a randomly detected error later on. But, as I said. Later. First, complete the current test your are running. You should try to avoid working against your own risk assessment. If there is an overall test plan identifying certain parts of the program over others as especially in need of testing, then these critical areas of the program should continue to have priority. On the other hand, errors which turn up unexpectedly may also lead you to reconsider the assumptions you made in your risk assessment. This is especially true if the error is exposed in a part of the program which you had previously considered non-critical.

A case in point: A cursor-based record (local table with the result of a database query) in a program is passed through various independent modules, each of which makes specific changes to the record and writes the updated version to a system log. When testing one of these modules, you notice inconsistencies in the system log entries. In some cases the changes to the record made by the previous module are missing. The error is attributed to a refresh problem in the data access layer when the record is positioned in the cursor in a certain way. Clearly, once you have become aware of this issue, this will easily shift the distribution of risk, because now you have to find out which parts of the program may also be affected by this refresh problem.

4.1.4 Isolating Bugs

Isolating bugs means determining the factors which produce the bug. The first step is being able to reproduce the error. After this, you begin to eliminate those things which could not have contributed to occurrences of the error.

If you are a tester and have to forward a found bug to the developers, you can certainly make the programmers' lives easier by providing specifics on how to reproduce and isolate the bug. You are then protecting yourself from the favorite response to bug reports: "Not reproducible." Do not mix up the process of isolating bugs with the process of finding out what caused it. Any information provided on isolating bugs can be of help when trying to find out what is causing them. This information is primarily used to isolate bugs, enabling them to be recorded and described more precisely.

If you are both a developer and tester, isolating bugs is often the first step when investigating the cause of errors. The more precisely you can localize an error and the more confidently it can be reproduced, the easier it will be to determine its cause.

Reproducing errors

In order to isolate and pinpoint where a bug is, you must try to reproduce it. You should make a note of how the bug can be reproduced and what needs to be taken into account. Something like:

1. Enter delivery note, enter the quantity using decimal places.
2. Print the delivery note.
3. Print the inventory ledger; the quantity is output with no decimal places.

As you can see, the step where the item inventory level was checked has been omitted. This step does not have anything to do with reproducing the bug and can therefore be left out.

If a bug cannot be reproduced, this may be because the initial situation has changed from the time it first occurred to subsequent attempts to repeat it. Perhaps the totals in the inventory ledger are only left out when there is only one posting record in the ledger.

Or there may be something wrong with your test evaluation. Pursue this matter in any case—the first faulty inventory ledger is right in front of you. There's got to be something wrong somewhere.

Recording bugs

In our case example, the inventory ledger had to be printed out because displaying it on screen was not possible. Even if this restriction were not imposed, it would still be better not to limit investigation of a document or report to the print preview but also to print it out. For one thing, the print job forms a part of the workflow; on top of that, this print out is documentary evidence of the bug. This is also shows that it is not you who has made a mistake if it turns out that the bug cannot be reproduced. In other cases, screenshots have been of help in pinpointing the source of the error.[1]

Localizing errors

You have reproduced the error and determined that the same behavior is also present when other stock items are used. It is apparently enough to enter a quantity including decimal places.

Could it also be a problem with the stock transaction module and not related in any way to the printout of the delivery note?

In order to find out, start the stock transaction module and create a posting record directly in the module. You will, of course, enter a quantity with decimal places. After printing out the inventory ledger again, you note that the decimal places are still missing in this posting record. But since you have a tool for accessing the underlying data in the database, you can then check the stock posting table. There the decimal places are still present. You may be getting on to something ... could it be a print output issue?

1 If you want to save paper, it may be worth spending some money on a PDF printer driver.

You're done. You've localized the bug. You shouldn't assign any special meaning to the fact that you discovered a bug in a module you were not even testing. After all, a test case in later testing phases rarely focuses on only one module.

Completing test cases

But what about our original test case *Stock Transaction Posting with Printout of a Delivery Note*? If you do not have enough ways to analyze the case, there is no way for you to judge this test case. You have noted that printouts of the inventory ledger have something wrong with them. The inventory ledger must be omitted from the evaluation of your original test case.

This leads us to a very useful insight: **You should not rely on the output of programs you are testing to evaluate test cases!** You must have an independent means of checking the application being tested in order to safely determine what the real outcome of the test is.

By analyzing stock item data and the stock transaction data at the database level, you can state that all the data has been correctly posted after the printout of the delivery note. You should therefore finalize this test case, by giving it your OK.

4.1.5 Creating Bug Reports

Once bugs have been found and isolated, they are normally forwarded to the development group. This means you have to write a bug report.

Minimum information required

There is a minimum level of detail required when submitting a bug report.

- ▶ A description of the bug
- ▶ Steps required to reproduce the bug

Any knowledge gained while producing the error must be included where possible. Even if you are not sure how the bug was produced, any information about the current system environment or other factors of potential importance will be helpful to the developer when fixing the bug.

A bug report for the bug discussed above could look like this:

Description:

The inventory ledger does not output decimal places for stock posting quantities.

Can be reproduced by:

1. Starting the stock posting program
2. Entering a posting record including a quantity with decimal places
3. Saving the posting record
4. Printing the inventory ledger
5. The quantity in the inventory ledger is output without any decimal places

The error was reproduced five times in five attempts.

Isolation:

The decimal places are still present in the stock posting table. The error occurs for all posting types. Decimal places are also not output when the inventory journal is summarized and output by stock item groups.

Figure 4.2 Sample bug report

If necessary, include the program version and your name and telephone number in case there are any questions.

Keeping bug reports

If you are the development team yourself or the person responsible for bug fixing, should you still write a bug report? Yes—provided you cannot fix the bug immediately. It is often enough to write a brief note of this during the testing and improving phase. I have made it a habit to keep notes in my project folder even if all recorded bugs recorded have been dealt with. It provides me with a record of what I have checked already and where I may need to run a further test.

4.1.6 Bug fixing

We now reverse roles and step into the role of the developer who receives the bug report. As a developer you will initially attempt to reproduce the bug. This will ensure that you aren't tracking down bugs which for one reason or other do not occur in your development environment. If the error cannot be reproduced, then sit down with the tester and try to establish what differences there are between your system and the test system. This exercise may provide insight on what types of things can affect the way software works.

Working from the inside out—or vice versa

Once you have reproduced the error, you can then begin to search for what caused it. From the outside in or from the inside out. "Outside" is the inventory ledger, "inside" would be the last place you are aware of in the program workflow where the data is still correct, the stock posting table. The bug has to be located somewhere between these two points.

We'll start on the "outside" and take a look at the inventory ledger first. The ledger is created by a report writer tool. There is a formatting function linked to the quantity field preventing whole-number values with zeroes after the decimal to be output. For example, the value 1.23 is output in the report by this formatting function as 1.23, whereas the value 1.00 is displayed as 1. This formatting function appears to be working correctly. You check it one more time by using a single test record containing a quantity with decimal places you have entered manually.

The inventory ledger is printed from a temporary table holding the values ready for the print queue. This table is automatically deleted after the print job, so you set a breakpoint in your debugger right after print formatting is complete to allow you to check this table after printing. Then you start the program in debugging mode, complete the posting and call the inventory ledger. After the program stops at the breakpoint, you take a look at the temporary table. Here the decimal places are missing. The bug must be located in print formatting.

Is everything alright?

You have isolated the bug to print formatting and can now fix it. When you start your program in debugging mode again and stop after print formatting, you will see the temporary table now has the correct decimal places in the quantity field.

Is everything alright? Probably. To be safe, you should repeat the entire process up to where the ledger has been printed out. The spot between print formatting and the printout itself may include additional bugs which have eluded you thus far, because the print formatting already had bugs.

4.1.7 Verification

After the bug has been fixed, the new version of the program is resubmitted for testing. The tester is now expected to verify that the bug has been fixed. The test which uncovered the bug is repeated.

Repeating tests

As experienced testers, we must be able to ensure that a test can be repeated. You are in a position to recreate the test environment and complete all steps in the correct order because you have closely tracked the procedures used during the first test and have kept a record of all steps required to reproduce the bug.

If the error has occurred during an automated or partially automated test, then you're sitting pretty. In this case all you have to do is restart the test in question and check the result.

So, you repeat the test and note that the bug no longer occurs. Decimal places are now being output correctly.

Do not repeat isolation tests

What about the other tests you carried out to produce the error? As can be seen in the bug report, you tried performing various stock postings for different posting types (stock putaway, stock withdrawal, breakage, etc.) but found no differences. Should these tests also be repeated? No, there is no need for this. Tests carried out to produce an error are too vague and unstructured to merit being repeated. You could just as easily have tried out different posting types (which would have been a good idea) and different stock item groups and quantities. There are just too many possible combinations—which was clearly evident earlier in the chapter. Do not undermine test management decisions made for your test case priorities when finding a bug or verifying that it has been fixed.

4.1.8 Regression Testing

After all the bugs found to date have been fixed, development of the software can go on. Months down the road, you get a bug report from your hotline saying that the inventory ledger does not have decimal places! What happened?

It could be this easy: A developer may have inadvertently linked the buggy print formatting module into a subsequent version of the program.

These things happen. However, the use of source code control systems are designed to safeguard against this and can be relied upon to do so in almost all cases.

Regression testing is needed to detect such lapses. Regression testing should not only check if bugs previously fixed show up again. This type of testing should also verify that functions which worked correctly in the past are also working correctly in the new version.

Generally speaking, all completed test cases are likely candidates for regression testing. Much like bug fix verification, the goal of regression testing is to repeat a test which has already been performed. This often leads to cries for automating most testing procedures. Do not underestimate the effort required to set up and maintain automated tests. Including all test cases in regression testing is very likely to make any testing or development go over budget. Specific advice on regression testing and the selection of appropriate test cases is covered in Chapter 2, "Testing: an Overview." I take a closer look at Automating Testing Procedures in everyday testing in the following section.

Introduce a source code control system!

As a general rule, when using source code control systems the risk involved is so minimal that it is not a good idea to use regression testing for all bugs fixed. Introducing a source code control system is a key step towards achieving higher software quality. This is true not only because of the regression avoided when obsolete sections of code are used. It is also a smart move because it allows differing versions of source code, documents, models, test scripts and test data to be managed systematically.

4.2 Automating Testing Procedures

There are different methods used for automating testing, as well as differing degrees of complexity. The possibilities range from simple scripts created by a tester for frequently repeated tasks, to test frameworks facilitating unit testing, all the way to completely automated test case generation based on a formal requirements specification.

4.2.1 Integration and Systems Testing

When looking at automation techniques, a distinction needs to be made from the very start between integration and systems testing on the one hand and automated unit testing on the other. Automated unit tests are written by the developer of the respective unit. The same programming language is generally used for both the test and the application. The test procedures are called from within the development environment or from the interface of a specialized testing tool or testing framework. For more information on unit testing, see Section 4.2.3.

Integration and system tests are not necessarily created and carried out by programmers. That is why in the past a market has sprung up offering tools for automated testing which do not require any programming expertise. According to a number of testing experts, this approach has failed (among other authors, see [Bach99], [Pettichord01], [KanerBachPetti02], and [Zambelich98]). However, many tool vendors continue to push this approach, perhaps because so much money can be made with it.

Should I use capture and replay?

Testing automation is frequently misunderstood to be primarily concerned with recording user actions and playing them back using the scripts created in the process. Test automation tool vendors are glad to lend credence to this fiction—it is a way to pitch to decision-makers and demonstrate well-prepared sample applications as they magically pass all test runs with flying colors. There is a fitting description of the record/ playback myth found in [Zambelich98].

Recording and playing back user actions (Capture & Replay) was an approach used in automated testing dating back to when testers could only use the GUI of applications being tested to control them. That is a far cry from what we have today—modular architectures and automated interfaces. A program developed today that does not have an automation interface already has major deficiencies because of this. That is why recording and playing back user actions is only necessary and should only be used if the application must be controlled from the GUI during the test. Automated testing is often much simpler and more effective if the application being tested can be controlled by a second program without requiring use of the GUI. If you are seriously considering automating program testing in the future, you should first say farewell to the idea of recording and playing back test scripts.

Test automation is software development!

Test automation is a programming activity. The execution of a test is recorded in a test script. To do this it is best to use one of the scripting languages currently available such as VBScript, JScript, Perl, Python, Rexx or something similar. The test script is loaded either at the system level or from a test management environment. The test management environment must be able to administer and start test scripts and obtain and record the results. The actions programmed in a test script are, in general:

1. Setting up the environment needed for the test
2. Executing the test by calling and controlling the application under test
3. Evaluating and recording the result of the test

A test script thus saves you from having to complete the unchanging and repetitious steps of setting up the necessary test environment and evaluating the results. In the case of repeated tests a great deal can thus be gained through automation. It is also a good idea to note down in a script how you set up the test environment for your individual tests—so that nothing is forgotten.

With a script that recreates the situation at the start of the testing from stored scenarios, you can simply return to "Start" at any time. This may necessitate copying the files you need into the appropriate directories or deleting any remainders of previous testing or even the alteration of system settings such as default printer, date or time of day and the like.

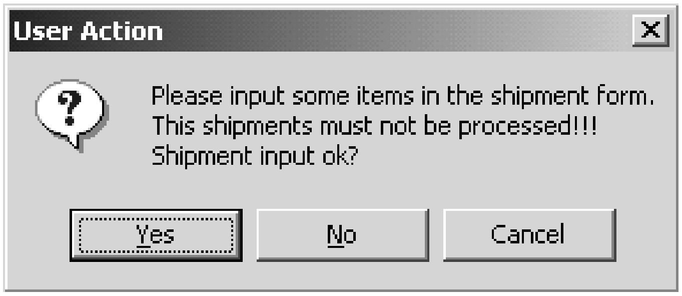
In the same way, the test script can spare testers the arduous task of checking repetitious test results by, for instance, comparing certain values in the database of the application with stored reference values or checking the correctness of the contents of newly created files.

Automated execution

Between these steps lies the actual execution of the test. When the interface of the application under test is needed for this, a recording and reporting tool that is started by the script will come in handy. However, a prerequisite for this is that actions at the interface must always be the same. Instead of setting down the required steps to be followed in a detailed flow chart or test plan ("File Menu - > New -> Customer, Customer No. = 4711, Customer Name = "Smith" etc), in this case an automatic recall from previously stored user inputs is certainly better. The tester dispenses with repetitive work that can become an onerous burden, and errors in entering data are avoided.

Semi-automated tests

However, where the actions that have to be carried out at the interface are not the same in every case, it is often simpler as well as more effective to entrust the carrying out of the actions to the tester. It is simpler because the script of a semi-automated test does not have to be modified to reflect each minor change in the user interface, and more effective because differences in execution offer a chance to discover errors that do not occur when the procedure is altered slightly. Semi-automatic tests are particularly appropriate for checking complete use cases. In this case the script serves as a checklist that uses Message Boxes and the like to call for certain user actions as well as checking and recording the success or failure of the test. The advantage of semi-automatic testing is that the preparation and evaluation of the test with its routine questions and schematic checks can be programmed, while the tester is guided through the actual execution and does not overlook any steps. During the process, the attention of the tester does not stray, something that is quite different when the complete test is carried out automatically.



Please input some items in the shipment form.
This shipments must not be processed!!!
Shipment input ok?

Figure 4.3 User interaction in a semi-automated test run

Scripting language

Because setting up the test environment as well as evaluating and logging the test results are tasks carried out by programmers, make sure you use a comprehensive and commonly used programming language. This can be a scripting language such as JavaScript (JScript) or the language you used in developing the application. Test frameworks for automated testing are always language-specific. As a developer you will probably be inclined to use your favorite programming language for preparing test scripts beyond unit testing. However, using a scripting language is often more effective because it involves less overhead. Overall, scripting languages are interpreted languages and less formal than compiled languages. However, modern scripting languages are almost as powerful as compiled languages.

Test-friendly design

Test automation is only truly effective when testers and developers work together. This cooperation should begin as early as possible. This is why Section 4.3 of this chapter is dedicated to test-friendly use design. By means of a test-friendly architecture and integration of interfaces required for testing (hooks), test automation can make significant contributions to increasing quality and productivity.

Because I mainly use Windows in my work, I will restrict myself to this operation system in my description of scripting and other operating system-related activities involved in test automation. Even if you work with a different operating system you should easily be able to apply these concepts and procedures.

4.2.2 Scripting under Windows

For a long time the situation for automated system-level scripting under Windows left a lot to be desired. The only option was using MS DOS batch files (.BAT). Compared to shell scripting on UNIX systems, scripting on Windows just didn't exist. Windows Scripting Host (WSH) now provides Windows with a scripting mechanism that can carry out common tasks such as copying files, cleaning up directories and much more.

The Windows Script Host is a language-independent scripting shell. WSH does not interpret the scripts themselves, but hands them off to a specialized interpreter instead. Scripts written in Visual Basic Scripting Edition (VBScript) and Java Script (JScript) are completely supported. Compatible interpreters for other scripting languages such as Perl, TCL, Rexx or Python can be added. Starting with Windows 98, WSH is provided as a standard feature of the operating system. Updated versions and detailed documentation can be downloaded at [MSScripting].

WSH uses the filename extension to determine the scripting language to use. Files with a .VBS extension are interpreted as VBScript files and those ending in .JS are interpreted as JScript files.

To create your first script, simply create a text file, using Notepad for instance, and give it a .VBS or .JS filename extension, depending upon which scripting language you want to use.

The popular Hello World! as a VBScript:

```
Dim WSHShell
Set WSHShell = WScript.CreateObject("WScript.Shell")
WSHShell.Popup "Hello World!"
```

Listing 4.1 Hello World in VBScript

And here's Hello World! in JScript:

```
  var WSHShell = WScript.CreateObject("WScript.Shell")
WSHShell.Popup("Hello World!")
```

Listing 4.2 Hello World in JScript

Scripts like this can be run by simply double-clicking on a file with a script filename extension.

Beginning with WSH 2.0, several jobs written in different languages can be consolidated into a single .WSF file. Job and language codes are entered as XML tags. Several jobs in a WSF file can be bundled into a package:

```
<package>
    <job id="DoneInVBS">
    <?job debug="true"?>
        <script language="VBScript">
           WScript.Echo "This is VBScript"
        </script>
    </job>
    <job id="DoneInJS">
    <?job debug="true"?>
        <script language="JScript">
           WScript.Echo("This is JScript");
        </script>
    </job>
</package>
```

Listing 4.3 Jobs in one package

When run, the job ID is entered as a command line parameter. Assuming that the lines above are written in a file called MultipleHello.wsf, starting `MultipleHello //job:DoneInJS` would run the second job, which is written in JScript. If several jobs are run, WSH executes them in the order they appear.

Test Preparation

The VBScript and JScript scripting languages do not provide any methods or procedures potentially required for setting up a test on the system level. These tasks are delegated to objects provided by the Scripting Host.

The most important object for working with the Windows file system is `FileSystemObject.` FileSystemObject is a COM object that is provided by the run-time environment in the Windows Script Host, the Scripting Automation Server. In a VBScript, COM objects can be created by simply using createObject(<Servername.classname>). In **JScript** you can create a new ActiveXObject with a line like:

```
var fso = new ActiveXObject("Scripting.FileSystemObject")
```

Scripting is the name used by the server for FileSystemObject. When the line in Listing 4.6 is run, the`fso` variable provides you with a reference to

FileSystemObject. Its methods can now be used for copying files, etc. For example, the following line copies all TIF files from a test scenario 1 into the tmp directory on the C drive:

```
fso.CopyFile("c:\\Tests\\Scenario1\\*.tif", "c:\\tmp\\")
```

You can just as easily copy or move complete directory trees, delete or create files or directories, or create text files for logging test activities and results.

The following JavaScript creates a text file that can be written and names it testlog.txt and enters the time the test began:

```
// Create FileSystemObject
var fso = new ActiveXObject("Scripting.FileSystemObject");
// Create TextStreamObject
var a = fso.CreateTextFile("c:\\testlog.txt", true);
// Variables for the line of text and time
var d, s = "Test started at: ";
var c = ":";
// Get system date
d = new Date();
// Prepare line of text
s += d.getHours() + c;
s += d.getMinutes() + c;
s += d.getSeconds() + c;
s += d.getMilliseconds();
// Write line of text
a.WriteLine(s);
// Close file
a.Close();
```

Listing 4.4 Creating a log file in JScript

The procedure for preparing lines of text also shows the automatic transformation of data types which is carried out by Jscript. The `getHours()` method returns a whole number (integer) that can be used in carrying out normal calculations. However, when such a whole number is assigned to a text variable, JScript automatically converts it into text.

Scripting.FileSystemObject provides the most frequently needed functions for preparing a test and setting up the test environment. In addition, the WScript.Network object provides access to attached network drives and printers. Registry entries can be read and modified with the WScript.Shell object. We also need the WScript.Shell object to control the program being tested.

Performing the test

Windows Scripting may also be used when running tests. The program being tested must be a working application or exist as a COM object. A working program can be started using the run method of the WScript.Shell object. The following sample VBScript starts the Windows machine and sends a sequence of keystrokes to the running program.

```
// Construct shell object
Dim WSHShell
Set WSHShell = WScript.CreateObject("WScript.Shell")
// Start program
WshShell.Run "calc"
WScript.Sleep 100
// Activate program
WshShell.AppActivate "Calculator"
WScript.Sleep 100
// Emulate keyboard entry
WshShell.SendKeys "1{+}"
WScript.Sleep 500
WshShell.SendKeys "2"
WScript.Sleep 500
WshShell.SendKeys "~"
WScript.Sleep 500
WshShell.SendKeys "*3"
WScript.Sleep 500
WshShell.SendKeys "~"
WScript.Sleep 2500
```

Listing 4.5 Sending keyboard inputs from a VBScript

Complete control of the program via the keyboard is useful for automatically running tests that carry out actions on the interface of the program. If this is not possible, an additional tool is required that can capture and replay mouse clicks. As in the example listing above, the `SendKeys` method of the `Shell` object can be used to send keystrokes to the program being controlled. In addition to letters and numbers, all function and control keys, except for the **Print** and **PrtScreen** keys, can be sent to an application. They can also be used in combination with the **Ctrl**, **Alt** and/or **Shift** keys.

Testing COM objects

If the test can or should be run without the program interface, you need a driver that can call the object or function being tested. If the object being tested is a COM object, this task can be accomplished by a WSH script. For the following example I developed a small Automation Server .dll file called `XmlTools`, which contains a class called `XmlString`. Among other things the `XmlString class` provides the methods `setContent(<Element>,<Content>)`, `getContent(<Element>)` and `countElements()`.

To test this class, I wrote a JavaScript combining all scripting options mentioned previously.

```
<job id="Test_setContent">
<?job debug="true"?>
<script language="JScript">
// Create FileSystemObject
var fso = new ActiveXObject("Scripting.FileSystemObject")
// Create TextStream object
var a = fso.CreateTextFile("testlog.txt", true);
// Variables for the line of text and time
var d, s = "Test run on: ";
// Get system date
d = new Date();
// Prepare date
s += d.getDate() + ".";
s += (d.getMonth()+1) + ".";
s += d.getYear() + " ";
```

```
s += d.getHours() + ":";
s += d.getMinutes();
// Write line of text
a.WriteLine(s);
// Create test object
var XmlString = new
ActiveXObject("XmlTools.XmlString");
XmlString.setContent("Test","This is a test");
// Check if saved correctly
if (XmlString.getContent("Test") == "This is a test")
{
   a.WriteLine("setContent and getContent ok");
}else
{
   a.WriteLine("setContent or getContent failed");
}
// Check for correct count
if (XmlString.countElements() == 1)
{
   a.WriteLine("setContent and countElements ok");
}
else
{
   a.WriteLine("setContent or countElements failed");
}
// Clean up
a.Close();
</script>
</job>
```

Listing 4.6 Xmltest.wsf file using JavaScript

The script is saved in a .WSF file, allowing me to use the XML extension to designate a job ID, the language to be used and to turn the Script Debugger on and off.

First, a text file is created and the date of the test is logged.

```
s += (d.getMonth()+1) + ".";
```

The `getMonth()` method returns a whole number between 0 and 11, so 1 must be added here.[2]

```
// Create test object
var XmlString = new ActiveXObject("XmlTools.XmlString");
XmlString.setContent("Test","This is a test");
```

This is where the test object is created. Finally, the `setContent()` method is called to place the "This is a test" value under the "Test" element name in the XmlString object.

```
if (XmlString.getContent("Test") == "This is a test")
{
   a.WriteLine("setContent and getContent ok");
}
else
{
   a.WriteLine("setContent or getContent failed");
}
```

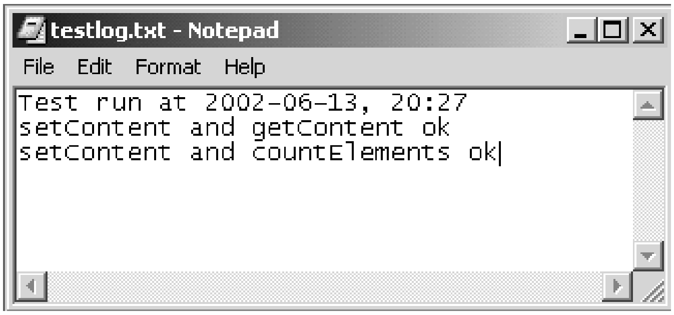
The `getContent()` method is used to check the content of the "Test" element by retrieving it and then comparing it to the expected result. The results of this comparison are then recorded in the test log file. Because two methods are participating in this test section, first `setContent()` and then `getContent()`, we can't know which one has failed without additional information. But this is usually not a big problem. If an automatic test like this fails, most of the time you can quickly determine which of the two modules is not okay.

```
// Check if count is correct
if (XmlString.countElements() == 1)
{
   a.WriteLine("setContent and countElements ok");
}
```

2 Because the year begins with month 0 and ends with month 11 (Oh, these programmers!).

```
else
{
   a.WriteLine("setContent or countElements failed");
}
// Clean up
a.Close();
</script>
</job>
```

Furthermore, the value returned by `countElements()` is checked, the log file is closed, writing the contents of the buffer to disk, and the script and job are completed with closing tags. You can see the contents of the test log file in Figure 4.4[3].



```
Test run at 2002-06-13, 20:27
setContent and getContent ok
setContent and countElements ok
```

Figure 4.4 Testlog.txt

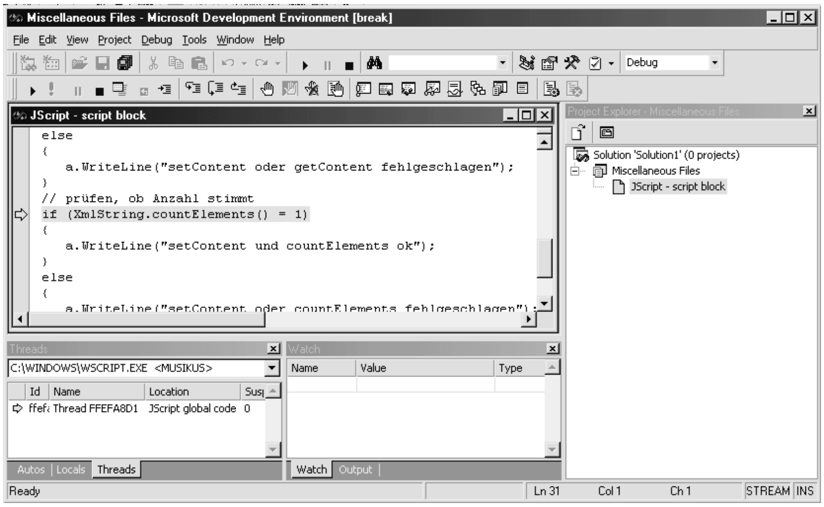
Note the doubled equals sign at the comparision point of the script. In JScript a doubled equals sign is a comparison operator and a single equals sign is an assignment operator.

Enter the Script Debugger

If you should forget this, the Script Debugger is useful for finding the mistake. `<?job debug="true"?>` at the beginning of the file tells the Scripting Host to start the Script Debugger when an uncaught exception occurs.

You already have the Script Debugger if Microsoft's Visual Studio development environment is installed on your computer. If not, you can download it for free from [MSScripting].

3 As you can see in Testlog.txt writing books also involves working at strange hours


Miscellaneous Files - Microsoft Development Environment [break]
File Edit View Project Debug Tools Window Help
Debug
JScript - script block
Project Explorer - Miscellaneous Files
Solution 'Solution1' (0 projects)
Miscellaneous Files
JScript - script block
Threads
Watch
Autos Locals Threads
Watch Output
Ready
Ln 31 Col 1 Ch 1
STREAM INS

```
else
{
   a.WriteLine("setContent oder getContent fehlgeschlagen");
}
// prüfen, ob Anzahl stimmt
if (XmlString.countElements() = 1)
{
   a.WriteLine("setContent und countElements ok");
}
else
{
   a.WriteLine("setContent oder countElements fehlgeschlagen");
```

```
C:\WINDOWS\WSCRIPT.EXE  <MUSIKUS>
```

Id	Name	Location	Sus
ffef	Thread FFEFA8D1	JScript global code	0

Name	Value	Type

Figure 4.5 Script Debugger with faulty scripting code

Evaluating the Test

Automating the evaluation of test results can make testing far easier. Nothing is more tedious than having to do things like going through the same printouts again and again, comparing numbers and checking records. Automatic evaluation of test results conceals the danger that comparisons are always made with a reference value. This reference value must be a 100% match—otherwise, the entire evaluation of the test would no longer correct without anybody noticing it.

Checking properties

When evaluating and recording test results you must be able to access the values that test results are based on. As shown in the previous example, it is no problem to query the properties of a COM object by using a WSH script, if the object provides a get method for this. In most cases, it is very difficult to access the values of internal object variables. The encapsulation mechanism prevents outside access to the internal values of an object. For this reason, the developer should always add functions to the program or object which enable such test results to be accessed. You can find more on this topic in the section "Test-driven Application Development" on page 191.

Database queries using ADO

If values important for evaluation are stored in a database, you can use an ADO object in a WSH script to access it.

```
// Create required ADO connection and RecordSet objects
var oConn  = new ActiveXObject("ADODB.Connection");
var oRS    = new ActiveXObject("ADODB.Recordset");
/*
The connection string declares the OLE DB provider
and the data source
*/
var sConnString =
 "Provider=vfpoledb.1;Data Source=.\\Data\\testdata.dbc";
// Open connection
oConn.Open(sConnString);
// Open RecordSet
oRS.Open(
 "select * from customer "+
 "where cust_id='CACTU'"
 ,oConn,3,3
// Get customer.company field
var sBuffer = "";
sBuffer = oRS.Fields('Company').value;
// and output
var WSHShell = WScript.CreateObject("WScript.Shell");
WSHShell.Popup(sBuffer);
// Close RecordSet
oRS.Close();
// Close connection
oConn.Close();
```

Listing 4.7 Using ADO to access a database

You can see how this is done in Listing 4.7. For ADO access you need a `connection` object and a `RecordSet` object. The connection object initiates the connection to the OLE DB provider. This is a driver program similar to the popular ODBC drivers. However, OLE DB technology is newer and according to Microsoft will be replacing ODBC technology in the long term. It hasn't reached that point yet, but OLE DB providers are available for most databases. In addition, an ODBC OLE DB provider is available for ADO access to databases that do not have their own OLE DB providers but probaby only an ODBC driver.

When the connection to the data source is open, you can open the RecordSet by using an SQL statement which specifies the connection to be used and thus gain access to the data you need to evaluate test results.

Working with ADO objects in a Windows script is relatively uncomplicated. However, you still need a basic knowledge of SQL and access rights to the database to be able to evaluate tests by accessing data directly.

Data State

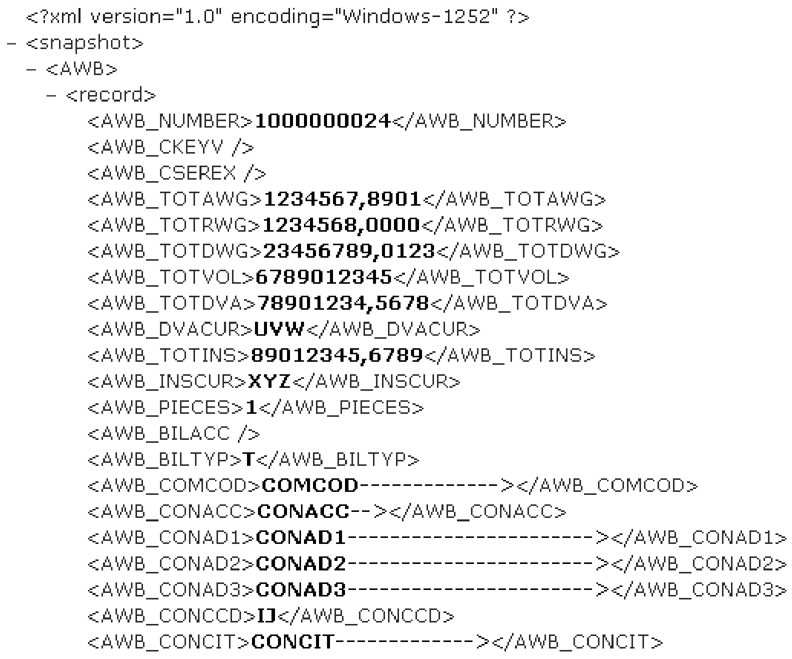
One difficulty in analyzing automated (and manual) tests is that there is often no way for you to know what things to check. There's more to a best-case test run than having it work perfectly and produce the desired results. It is also important that such a test run has no undesirable side effects. As we saw in the case study at the beginning of this chapter, printing out a delivery note should trigger a stock transaction with the implicit requirement being that all other data remain unchanged. A bug in printing delivery notes that causes a customer's address to be changed is probably not very easy to discover, because you would never anticipate a connection here and set up a test case for it.

How can such unanticipated side effects be discovered anyway? If the bug shows up somewhere in the data, you can track it down by comparing the state of the tested data with a data state that was backed up and verified beforehand. The data state is created by saving the current values for all data needed by the program

A saved and verified data state is needed to compare the data state after a test. This means that the data state matching the expected result must be accessible. Such a data state can be created manually or saved once a test of the program is completed successfully. Comparing saved data states is also particularly useful for automating the analysis of regression tests, because regression tests are typically performed after it is already possible to run the program successfully.

The data state should be saved as an XML file. XML provides a data format that contains both the contents of data and its structure. This allows visualization of component-container relationships on the object level and parent-child relationships in relational databases.

Many databases today can return query results in XML format without having to rely on a separate program to handle the conversion. A special program to compare the current data state with the saved data state is normally still required, because all values that depend on the system clock cannot be directly compared with one another.



```
   <?xml version="1.0" encoding="Windows-1252" ?>
 - <snapshot>
   - <AWB>
     - <record>
         <AWB_NUMBER>1000000024</AWB_NUMBER>
         <AWB_CKEYV />
         <AWB_CSEREX />
         <AWB_TOTAWG>1234567,8901</AWB_TOTAWG>
         <AWB_TOTRWG>1234568,0000</AWB_TOTRWG>
         <AWB_TOTDWG>23456789,0123</AWB_TOTDWG>
         <AWB_TOTVOL>6789012345</AWB_TOTVOL>
         <AWB_TOTDVA>78901234,5678</AWB_TOTDVA>
         <AWB_DVACUR>UVW</AWB_DVACUR>
         <AWB_TOTINS>89012345,6789</AWB_TOTINS>
         <AWB_INSCUR>XYZ</AWB_INSCUR>
         <AWB_PIECES>1</AWB_PIECES>
         <AWB_BILACC />
         <AWB_BILTYP>T</AWB_BILTYP>
         <AWB_COMCOD>COMCOD------------></AWB_COMCOD>
         <AWB_CONACC>CONACC--></AWB_CONACC>
         <AWB_CONAD1>CONAD1-----------------------></AWB_CONAD1>
         <AWB_CONAD2>CONAD2-----------------------></AWB_CONAD2>
         <AWB_CONAD3>CONAD3-----------------------></AWB_CONAD3>
         <AWB_CONCCD>IJ</AWB_CONCCD>
         <AWB_CONCIT>CONCIT------------></AWB_CONCIT>
```

Figure 4.6 Sample data state

In Figure 4.6 you can see a part of the resulting data state after a test was run using the highest possible values. The data state saved here is in XML format and contains data from the tables of a relational database. The first level below the "snapshot" root-level element is composed of the RecordSet. This is called AWB in this example. The second level consists of records from the recordset. And finally, the third level contains the fields for each record with the field names from the table used as the names for the elements.

Using a script such a data snapshot can be created and saved at any point while running the test. The next time the test is run you compare the current data state with the saved snapshot. The comparison should actually take place on the field level so that you can determine exactly which table, record and field has values which deviate from the saved value if there are any discrepancies.

Tools exist that create, save and compare data state files. With a little programming experience you can create such a data state tool on your own and place it in your testing toolbox.

Masked file comparisons

Another useful tool would be a maskable DIFF utility. This means a file comparison tool that you can tell which part of the file to ignore when carrying out a comparison. Files in text format are often output during a test run. These outputs should not vary between two runs of the same test—in reality they do, but only in the parts of the file containing the system date and time. A file comparison utility can be used to assign comparison masks that hide certain parts (date and time information) of an output text file. Text outputs of this kind could very well be used for automating the analysis of test runs.

On my search for such a tool I have come across various versions of DIFF for Unix/Linux and MS Windows and enhancements for WinDiff (see section 4.4, "Tools"). I couldn't find a maskable version of DIFF. Perhaps this gap has already been filled—it's likely that you'll have to write your own file comparison tool.

XML Diff

In addition to tools for text file comparison, there are now programs that can compare XML files and are aware of XML elements. To provide an illustration of what this means, let's have another look at the previous data state example. You can see that XML elements corresponding to the fields in individual records are not sorted. The order simply reflects the physical sequence of the fields in the record. But the physical sequence of the fields in a record is not a factor to be considered during a comparison. Using our example, this means that if, for some reason, in a new data state the "Awb_TotDwg" field appears before the the "Awb_TotRwg" field instead of after it, then the comparison of the data state with the saved version should not fail due to this change in sequence. What's important here are the contents of the fields, not their order in the record.

A program that compares XML files should also include an option for ignoring such changes in sequence on the same structural level. Even missing or "white space" between individual elements should be ignored, as well as carriage returns and interspersed tabs.

The last thing to ask for in an XML Diff tool used for automating test analysis would be the possibility of hiding individual elements from the comparison—for the same reasons stated previously for file comparisons.

Data Integrity Tests

Checking data integrity can be easily automated by a program as well. In addition to referencial integrity, checks of fields and records can also be carried out. Rules for validating the saved data by field or record can be created in many databases. The database checks these rules before saving and refuses to save data that contradict these rules.

Rules for field validation check the validity of each field. Typical examples are for date fields whose values may precede a certain starting date or fields containing prices that may not be less than zero. Rules for record validation check the validity of each record. Record validation is always important when the valid values for the fields in a record are interdependent. An example of this would be an order item where the discount and minimum quantity surcharge exclude one another.

This is also a way of preventing records from being created that have invalid references to other records or for preventing records from being deleted that are referenced by other records. This is prevented by the rules imposed to maintain referential integrity.

The rules set up in the database may be faulty or incomplete. So it makes sense to check the integrity of the data by using a separate program.

Reuse

There are some passages in the previous XmlTest.wsf sample script which are independent of the object being tested. Wherever possible, the parts of the script used for creating test log files and for logging results should be made reusable. These tasks can be moved to a separate script that can be embedded into a WSF file using a line like this:

```
<script language="JScript" src="createTestlog.js"/>
```

A script embedded in this way is run when the main script is interpreted. Embedding script files like this allows you to add additional functions to your main script. In the following example two functions from an embedded JScript are called in one VBScript.

```
<job id="HelloGoodBye">
<script language="JScript" src="WorldFunctions.js"/>
<script language="VBScript">
  hello()
  GoodBye()
</script>
</job>
```

Listing 4.8 The controlling VBScript

```
function hello()
{
  var WSHShell = WScript.CreateObject("WScript.Shell")
  WSHShell.Popup("Hello!")
}
function GoodBye()
{
  var WSHShell = WScript.CreateObject("WScript.Shell")
  WSHShell.Popup("... see you later!")
}
```

Listing 4.9 The JScript with functions

Scripting languages supported by Windows Scripting Host can thus be combined. A single job in a .WSF file can be composed of entirely different scripts in different languages. Scripting development on Windows has become a very good option for completely or partially automating tests. But you should be aware that this has to do with software development project. If you want to do more than just automate a testing task now and then, you should plan this out carefully. Test support libraries should be created and maintained for use across all parts of the projects and the infrastructure of your test environment should be set up with the entire project in mind. This involves considerations about where and when individual test cases are filed, where the test log files go, how to determine which tests were last carried out on which version, etc.

Test Cases and Test Suites

One way to organize individual test cases in WSH scripts is to create a job for each test case in a WSF file. When several test cases are joined together this combination is called a test suite. So, a WSF file containing several test cases makes up a test suite. If the test cases in the suite build upon one another, meaning that if the following test expects the test object to be in the state that was produced by the previous test, the test suite should be regarded as a unit, even when in reality it consists of individual test cases. You can no longer run individual test cases in such a test suite, because the test object is only in its proper state when all previous tests in the suite have been run. When possible, try to avoid suites which combine linked tests and initialize each test case one at a time, to also make single tests repeatable.

There is only one job in the previous XmlTest.wsf example and this is:

```
<job id="Test_setContent">
```

even if several values are being checked. This job should afterwards be regarded as a test case and not as a suite made up of a setContent() test case followed by getContent() and countElements() test cases.

Scripting Alternatives

If in real life you don't just test software but also write it, then you probably prefer to use a specific programming language in a specific development environment, and even use a favorite editor. So why learn an extra scripting language to automate integration and system tests? You can use one of the language-specific test frameworks for unit testing that I will describe in the next section. When doing unit testing there is often no need to make extensive preparations at the system level. Analyses are also frequently limited to checking the return values of a method call.

The power of scripting languages lies in their simplicity and above all their easy use. Nothing has to be compiled, most scripting langauges are interpreted and they are not strongly typed. This means that you simply declare a variable and give it a value, setting its type. Type transformations are often carried out automatically. This is a nightmare for developers who want every last bit under their control, but scripting languages are more suitable than compiled languages for automating test runs.

Using a single tool vendor's proprietary scripting language is not a viable option. Many vendors still base their testing tool on a "capture & replay" feature. A vendor-specific scripting language can be used to add process control, error and exception handling and similar things to the recorded script. But by doing this they are turning testing on its head. The interface-oriented "capture & replay" script should not control the test and provide additional scripting options. Instead, a scripting language that is not vendor-specific should take over control of the test and if necessary call a "capture & replay" tool.

4.2.3 Unit Test Frameworks

Unit tests are conducted by the software developers themselves. If testing processes can be automated, developers naturally fall back on the programming language in which the application itself is programmed. Using this procedure is tempting for unit tests since the unit being tested (class, function, procedure) must be embedded in a run-time system. Calling a single program function on the operating system level or from a script is not all that easy. Only a few development environments allow you to work directly and interactively with objects, functions, and procedures. In most cases, for testing to take place, the function being tested must be compiled with a test driver program in a testing environment. The testing environment starts the test and then invokes the test driver. In addition, the testing environment records the results of the test. The test driver invokes the units to be tested with all the variants and parameters that constitute the test case.

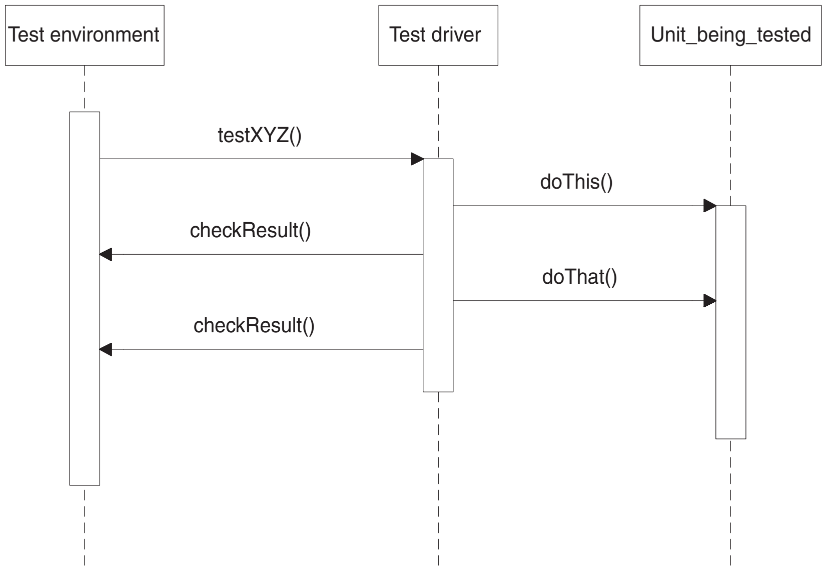


Figure 4.7 Sequence of calls in automated unit testing

The flowchart in Figure 4.7 illustrates the sequence normally used in an automated unit test. The test driver contains the actual test cases in the form of functions or methods that can be called. For example, the "testXYZ()" function represents a test case. The test case consists of calling one or more functions, procedures, or methods of the unit being tested. The results returned are transferred from the test driver to the test environment for checking. The test environment can then record these results.

Test drivers are written by the unit tester—that is, in most cases by the developer of the unit being tested. This leaves the test environment universally valid and usable for any kind of project. In addition to supporting embedded test drivers, most environments can also handle the creation of test suites, i.e. by combining test cases into a group that can then run at the same time.

eXtreme testing With the rise of the eXtreme Programming movement, automated unit testing has gained a lot of attention in the developer community. It's true that there have been many previous attempts to automate testing and to get developers to conduct unit tests on a regular basis. But it was eXtreme

Programming (XP) that first made automated unit testing a key element in programming work. In an XP project, developers write tests before writing the actual method code. In this approach, unit tests are essentially the same as the final specification.

The first person to use this approach was Kent Beck, who put together a test framework for Smalltalk programs [Testframe]. The JUnit [JUnit] test framework for Java unit testing developed by Kent Beck and Erich Gamma has since been adapted by other developers for use with additional programming languages.

An up-to-date list of free test frameworks is available for download at [xProgramming].

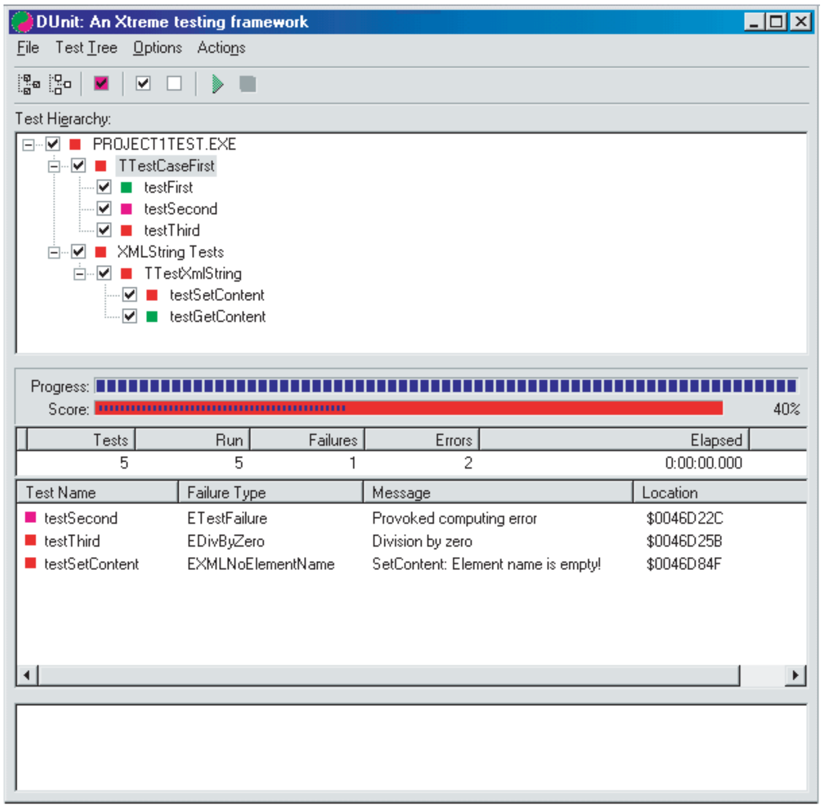
A DUnit Example

A test framework provides classes that can be used to create unit tests and test suites. The tests are processed by a TestRunner object. Test results are separated into successful tests, failures (deviation from expected and actual result) and errors (unanticipated errors during testing). A GUI is used to display and manage results in the test framework.

XUnit

All XUnit test frameworks are structured like the original JUnit framework. X is the language identifier, thus "J" for Java, "C" for C and "Cpp" for C++ and so on. Figure 4.6 shows the graphical interface for the DUnit Delphi test framework. The test hierarchy can be seen in the top section of the window. Test cases (e.g. TTestCaseFirst) and test suites (e.g. XMLString Tests) can be included in the test project. If the second level is a test suite, any number of test cases may be grouped within it. A test case can comprise as many testing methods as desired. In this example, the three test methods of the test case are "testFirst", "testSecond" and "testThird." Any of the levels in the test hierarchy can be included or excluded. In the next test run only selected tests are carried out.

Test results are displayed in the bottom section of the window. The types of results are "failures" and "errors."



```
PROJECT1TEST.EXE
  TTestCaseFirst
    testFirst
    testSecond
    testThird
  XMLString Tests
    TTestXmlString
      testSetContent
      testGetContent
```

40%

Tests	Run	Failures	Errors	Elapsed
5	5	1	2	0:00:00.000

Test Name	Failure Type	Message	Location
testSecond	ETestFailure	Provoked computing error	$0046D22C
testThird	EDivByZero	Division by zero	$0046D25B
testSetContent	EXMLNoElementName	SetContent: Element name is empty!	$0046D84F

Figure 4.8 DUnit TestRunner interface

Test frameworks can be easily integrated because they are written for specific programming languages and development environments. The following examples use Delphi and DUnit code. Since all adaptations of XUnit are highly similar, transferring them into your language should be easy.

First, a separate project for unit testing is created. The test framework is integrated into the project as a unit or package. Naturally, this includes every unit or package containing finished unit tests.

```
program Project1Test;
uses
  Forms,
  Test framework,
  GUITestRunner,
  Project1Testcases in 'Project1Testcases.pas',
  XMLStringTestcases in 'XMLStringTestcases.pas';
```

Listing 4.10 The uses clause integrates all required units in Pascal.

All test cases used are derived from the test case class provided by the framework.

```
type
  TTestXmlString = class(TTestCase)
  private
    TestObject : TXMLString;
  protected
    procedure SetUp; override;
    procedure TearDown; override;
  published
    procedure testSetContent;
    procedure testGetContent;
  end;
```

Listing 4.11 Declaring a specific test case in DUnit

The TTestCase class contains two virtual methods called `SetUp` and `TearDown`. For each test case, these methods are overwritten and are used to make the necessary preparations for a test run. In most cases, an object of the class being tested is created in the `SetUp` method and cleared by the `TearDown` method.

```
procedure TTestXmlString.SetUp;
begin
  TestObject := TXMLString.Create;
end;
procedure TTestXmlString.TearDown;
begin
  TestObject.free;
end;
```

Listing 4.12 SeatUp and TearDown methods for each test case

The allocation of a new test case to a test suite is handled differently depending upon options available in the language used. In Delphi, this takes place in the initialization segment of the unit.

```
initialization
begin
  Test-Framework.RegisterTest('XMLString Tests',
                              TTestXmlString.suite);
end;
```

Listing 4.13 Assigning to a test suite

Finally, testing methods are populated for each test case. This is where the actual test code is. In the following example, the `setContentAsString` method of the test object is called using an empty string as its first parameter. The method expects the name of an element here and it cannot be empty. If it is empty, an exception is triggered by the method. The calling method, here the test method from the TtestXmlString test case, must catch and handle the exception. As shown in the example, this is done in Delphi using a `try ... except` block. If the exception is not caught, we have an "error" result type (see Figure 4.8), meaning that the test has failed, even though the method being tested behaved properly.

```
procedure TTestXmlString.testSetContent;
begin
...
  // Error Case, no name specified
  try
    TestObject.SetContentAsString('','Testtext');
  except
    on e: EXMLNoElementName do
begin
      check(TestObject.getContentAsString('Testelement1')
         = 'Testtext');
      check(TestObject.getContentAsString('Testelement2')
         = '');
end;
    on e: Exception do fail('Unexpected exception type: '
                        + e.ClassName );
end;
end;
```

Listing 4.14 Exception handling in a test case

Checking the anticipated results occurs by calling the `check...` or `assert...` methods inherited from the test case class.

Advantages

Developers often search for a quick and easy way of testing freshly programmed functions. To do this, first create an object in the class that provides the function. Then, use a snippet of some sort of source code that calls the function. And finally, review the results. Because the infrastructure for this is not provided in most development environments, it is usually left out; the new functionality is tested only in conjunction with the use of this class. A test framework provides a ready-made infrastructure for unit testing.

If, as required by eXtreme Programming, the unit tests are written first and only then is the tested function coded, the function itself is viewed from a different perspective, from its interface and/or the specification. Unit tests represent the current status of the specification. The developer thinks about the specification first and only afterwards about its implementation.

The accumulated unit tests provide a sense of security should changes be made.[4] A function's internal structure can be revised and worked over as much as needed as long as its interface remains constant. Refactoring, continuous maintenance of and improvements to the structure of the source code, would be a very risky exercise without automated regression tests. Where in the unit hierarchy these regression tests are to take place depends on risk assessments, degree of reuse, test coverage through intensive usage of a function, and so on.

Limitations

Other methods from the same test object are often used to check results of unit testing. For this reason, it is not always clear what is actually being tested. In automated unit testing, far more effort is needed to satisfy the expectation that you are not relying on test object output when determining test results.

The amount of effort also increases considerably if external data is involved. External data must then be provided in a variety of potential scenarios with strongly divergent content. Plus, external test data must be maintained. If there is a change to the data structure, all external data scenarios must be modified to reflect this, otherwise there is no way that unit testing can be performed without errors. This is why it is highly advisable to avoid using external data wherever possible in unit testing, to have the test create the data and limit its use to a standard scenario.

The same is true for all required system resources. The developer's computer is rarely configured exactly like the target computer—if that decision has even been made yet. The developer's computer configuration may also be modified at one point or other. Who can claim to always bear in mind that a unit test uses specifically this or that temp directory? If the directory is then removed during the next big clean-up, and the test cycle suddenly fails to work, then a lot of time is wasting looking for the reason why.

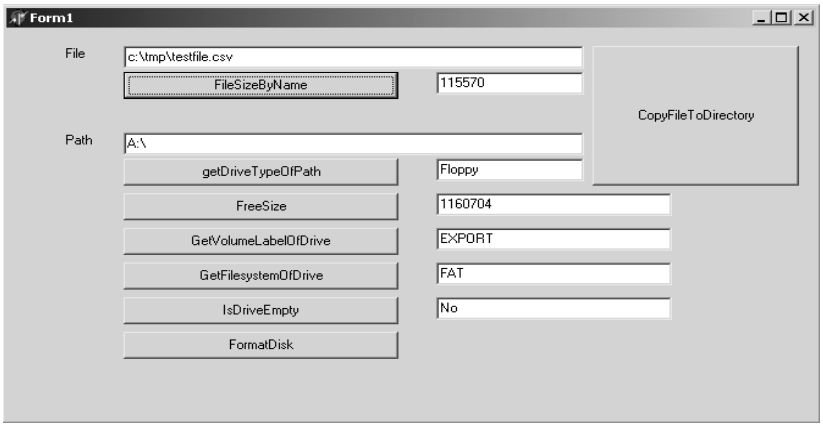
Developers are often pressed for time. That is why unit testing is almost never conducted beyond the best case and one or two error cases. Once

4 However, this sense of security can also be deceptive.

they are ready to be performed, the resulting tests normally catch only a few new errors. You quickly end up with a large number of fully automated, executed tests; unfortunately, they must be maintained and are mostly of little help. On the other hand, automated unit tests are generated without giving consideration to risk assessment. Many a Junit fan preaches test cases even for set- and get-methods that do nothing but conduct a value allocation.

Alternatives to Automated Unit Testing

Interactive unit tests, embedded tests, and testing by using constitute alternatives to automated unit testing. Can your development environment call a single function or method interactively or catch and provide a graphical display of a return value? If so, you should take advantage of this opportunity to perform interactive unit testing. If your development environment cannot do this, you may want to use wizards to quickly devise a test application that can help enter parameter values, call functions or methods, and display return values.[5]



c:\tmp\testfile.csv
115570
A:\
Floppy
1160704
EXPORT
FAT
No

Figure 4.9 Utility program for interactive unit testing

Figure 4.9 shows an example of a utility program for interactive unit testing that allows files to be written to various media (diskette, hard drive, network device, etc.) with simultaneous space availability verification, non-compulsory diskette formatting and other functions.

5 If neither of these options are available to you, your development environment doubtlessly has an abundance of other features going for it.

Theoretically, the number of test cases which can be derived goes into the hundreds. Not only must varying types of media be considered, but also the various operating systems, marginal cases, whether sufficient space is still available for the first copied file and directory entry but not for the next one, access rights, path expressions in UNC notation (Universal Naming Convention: \\Server\Share) or the drive letter, and so on. Nor can all these system conditions be ensured for the foreseeable future (Will the target computer still be networked? Does the test computer always have a B: drive?). This is compounded by the fact that the user interface must also be used with the system dialog when formatting floppies.

Interactive unit testing

Thus, the example above shows that automated unit testing is unfeasible, even for this relatively simple use case.[6] In such settings, there are definite advantages to performing semi-automated interactive testing for Rapid Application Testing. You should combine interactive unit testing with embedded tests in cases like these (see Design by Contract below), bearing in mind that certain subfeatures are automatically tested with the key features.

Conclusions

It's all in the mix

"There is no silver bullet!", wrote Frederick P. Brooks, Jr. in "The Mythical Man-Month" [Brooks95]. What he meant is that there is no "miracle" methodology that can provide a solution to every problem. The same holds true for automated unit testing and interactive testing, embedded tests, and testing by using. The key to a solution lies in using a mix of simpler but more effective techniques. Collaboration between developers and testers can yield highly effective results, particularly when it comes to unit testing. Here, integration and system testing tools can perhaps be useful in unit testing as well. By the same token, developers surely have a few tricks up their sleeve that might come in handy for testers.

6 If only interactive unit testing was as easy as fanatical purveyors of eXtreme Testing would have them be.

Conducting unit testing with the complete application only, however, is not an option. If you're having to start the entire application every time you test individual units, you should try to further decouple the individual parts of the application. In the latter stages of the development process, the presence of units that were inadequately encapsulated earlier on can lead to a situation in which the application can be tested from that point forward only as a "whole"— because somehow "everything" is implicated. When designing applications, bear in mind the importance of greater encapsulation; this will make your life easier during testing. Alternatively, tell your developers that they should provide unit tests for each unit they release. This can lead even the most prolix of software developers to start thinking in a terms of greater encapsulation.

Decoupling units

4.2.4 Application Interface Testing

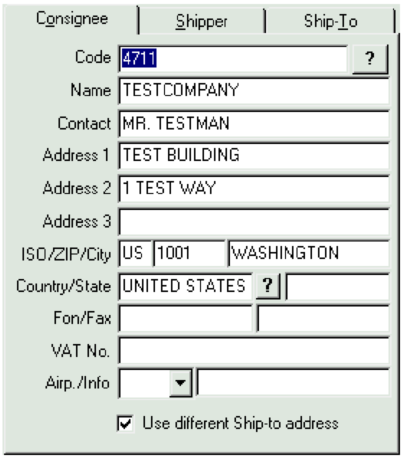
Testing an application interface should not be confused with functional tests, in which the application interface is used simply to control a procedure. Application interface tests are less concerned with flows than they are with determining the robustness of the interface. Some basic technical knowledge goes a long way when it comes to understanding the importance of GUI testing.

Event control

Nowadays graphic program interfaces are built with the help of event-driven programming. When the user clicks on a button, an event is triggered within the program. The developer can respond to this event by linking the event with a button's method. This link is already hard-wired in some development environments. The code contained in the linked method is run every time the event occurs (event handling). The most prevalent interface errors are attributable to event handling that is successful in most settings but fails in certain others. The developer needs to consider these exceptions when handling a given event. Settings in which three or more "ifs" occur can easily confuse the software, inducing an erroneous program response.

An example

I would like to illustrate this point with a brief example:



Code	4711
Name	TESTCOMPANY
Contact	MR. TESTMAN
Address 1	TEST BUILDING
Address 2	1 TEST WAY
Address 3	
ISO/ZIP/City	US 1001 WASHINGTON
Country/State	UNITED STATES
Fon/Fax	
VAT No.	
Airp./Info	

☑ Use different Ship-to address

Figure 4.10 Excerpt from a ship-to address dialog

An excerpt from a dialog for gathering address information is shown in Figure 4.10. In the normal procedure, the "Consignee" address is displayed after a key is entered in the "Code" field. The Ship-to page is not yet displayed at this point. Only when the user activates the "Use different Ship-to address" checkbox is the Ship-to page displayed, allowing the ship-to address to be modified. An error would have occurred if a) a new entry was active b) the cursor was inadvertently placed in the "Code" field after an address was called and the "Ship-to" page was displayed, and if the user then c) clicked on the Ship-to tab.

The error occurred in handling the "Code" field's "OnExit" event. Here, the software failed to detect an exception when the record was reentered. As a result, the "Consignee" data record was read in anew and the "Ship-to" address, which may already have been edited, disappeared.

The most prevalent events of this type include "OnExit," "OnEntry," "Click," and "KeyPress." Some developers deal with these events by writing several pages of processing code. Inasmuch as this code is also required at a later time by other events, several events are simply linked to the same method or the method is called by the program. This and other similar horrors happen without the event ever occurring explicitly. Nor are development environments totally immune to error. For instance, in certain settings the program might call a method linked to an "OnExit" event for an entry field either twice or not at all.

Error diffusion

What does this example show? In my view, it elucidates four key points:

1. In addition to synchronization and display errors, combinations of events during interface development (regardless of their degree of complexity) give rise to the most egregious problems. The errors they cause are scattered randomly throughout the program and often lie outside normal procedure paths. The program responds erroneously only when certain sets of conditions coincide.
2. You can find these bugs by using planned test cases. If the situations that cause the program to act incorrectly could be anticipated, the bugs would probably be caught. The most productive technique is to click or type "all over the place" without any regard for processes while consciously recording and analyzing all points where the program diverges from what is considered correct behavior. This is why tests are so difficult to automate properly.
3. Having a firm grasp of a program's internal processes greatly simplifies the task of ferreting out, isolating and describing any errors. If you know that successful execution of a broad range of code snippets depends upon whether you exit an input box with the return key, the tab key or a mouse click, it's much easier to reproduce and isolate an error that you happen upon.
4. The approach to programming and application design adopated plays a pivotal role in the common GUI errors described here. This is why tests on up and running graphic interfaces are "too little too late." Standardized, mandatory programming guidelines do far more for quality assurance than any testing of finished software.

4.3 Test-driven Application Development

Why should developers want to make life easier for testers? Because developers are themselves testers, because testers make a positive contribution to developers' work, because the whole project team wants to win the big game, because if testers have an easier time of it, debugging and even development are simplified, and so on.

Although there are at least a dozen or more good reasons for allowing for testing already in the application design phase, one of these reasons crowds all others off the playing field: money. In May, 2002 the National Institute of Standards and Technology released a study on the economic consequences of inadequate software testing [NIST] showing that software design errors, bugs, and other product defects cost $59.5 billion annually in the USA alone. The authors of the study assign a fair amount of blame for these economic losses to the vendors of software testing tools. The study advocates the institution of binding software testing standards, which ideally would be monitored by a federal software quality assurance agency. Would this help?

Paying attention to testability

The software industry likes to draw comparisons between itself and other sectors, particularly the auto industry[7]. But when it comes to testability, software products clearly lag far behind automobiles. While the diagnostic options and special tools that make life easier for service technicians are taken into account in the design of a new car, many software vendors pay precious little attention to the needs of their service staffs (testers, support staff, administrators) and customers. As a result, their work still must be performed manually, since most software products provide little in the way of diagnostic options, technical documentation, self-testing routines, online help or proprietary data formats.

Test-driven application development

This is mainly the province of software designers and architects, who should be endowing software with greater testability in the software architecture stage. If an application misbehaves, even the best testing tool in the world won't be able to fix it. The following elements come into play in test-driven application development:

- ▶ Ensuring the complete application can be operated without the interface
- ▶ Integrating functions that can supply a testing tool or script with the requisite information during run time

7 If Microsoft built cars…

- Providing self-tests during operation
- Providing a debugging mode with advanced event logging
- Using conventional data formats that are understood by a wide variety of tools
- Separating the application into components that communicate with one another using documented interfaces
- Providing add-ins and hooks for diagnostic tools for monitoring program operations
- Systematically prioritizing testability and developing innovative ways of achieving this.

4.3.1 Separation of Interface and Implementation

One design decision that can streamline the process of software testing and development is the clear separation of interface from implementation. This makes it possible to completely test implementation functions using code. The interface then only needs to be tested for proper display, workflow and the complex event control errors mentioned previously.

When xUnit testing frameworks (see unit testing frameworks) are used, the separation of interface and implementation basically becomes mandatory, because such frameworks provide objects, call the methods being tested and evaluate the results. Launching an application (normally a prerequisite for correctly drawing an interface) and then controlling the application using a capture & replay tool is scarcely possible within such a framework.

Inasmuch as program functionality tests that employ the program's interface are in fact integration tests, it follows that unit tests cannot be performed without separating the interface and the implementation.

Programming guidelines

The practice of separating interface from implementation unfortunately has not yet found broad acceptance among many developers, nor have development environment vendors been much help in this arena. It's generally a relatively simple matter to cobble together an application by conjuring it into graphical existence with a grid and a handful of entry fields, buttons and checkboxes that are then yoked to a database. But as soon as the application grows more complex, the simple implementation of the base application (which is of course retained in all instances) crumbles before your eyes. Coherent unit testing simply cannot be performed on an application design distributed across hundreds of Click, OnExit and LostFocus events. In such settings, quality assurance involves setting clear, timely programming guidelines which must be checked during review sessions.

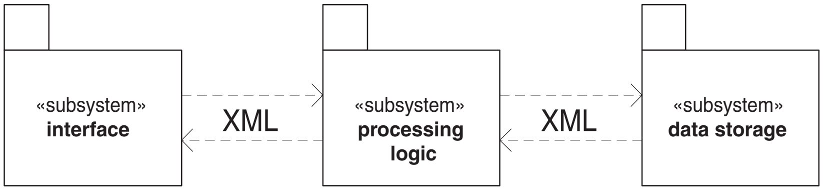


Figure 4.11 Classic 3-layer separation

Figure 4.11 shows the classic 3-tier separation of interface, processing logic, and data storage. Enabling communication between individual subsystems using XML structures is advantantageous from the standpoint of system architecture in that subsystems become more strongly decoupled. XML communication constitutes the optimal solution for automated testing because XML structures are composed of plain text only, which allows them to be scrutinized, saved and edited. The anticipated communication content can be compared with the actual content using XML DIFF tools. Standards such as SOAP (Simple Object Access Protocol), WSDL (Web Services Description Language) and UDDI (Universal Description, Discovery and Integration) are now available for such XML-based communication. Below you will find a case study on the use of SOAP, WSDL and UDDI at a financial computer center [DostalRieck]. But the use of XML for communication on a lesser scale, such as between the modules of an application also makes good sense.

Test adapter

If you are unable or don't want to port everything over to Web Services right away, a clean separation of interface and implementation still enables you to interpose a test adapter between the various subsystems for testing purposes.

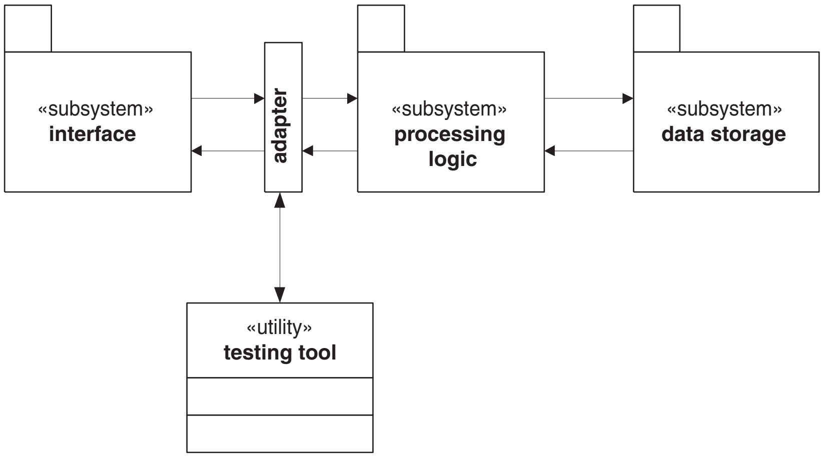


Figure 4.12 Inserted test adapter

Figure 4.12 shows such an adapter, which during the testing phase routes communication between interface and implementation via an attached testing tool. The adapter has two interfaces. It supplies the implementation interface with an interface subsystem (or a portion of it), while at the same time acting as an interface to the implementation subsystem. The communication data relevant to the test is directed to the testing tool between these two interface views. Commands that control processing can also be sent from the testing tool to the adapter. The interface subsystem can thus be omitted from the test if it is not needed.

4.3.2 Handling Printouts

Hard copy reports created by a report generator provide a special example of separating interface from implementation concerns. Report generators nowadays offer a wide range of options for making selections and doing calculations based on formulas which use their own programming language within the report generator. These report generator programming options should not be used to prepare reports based on underlying, normalized[8] basic data. Instead, the data for the report should be obtained from the processing layer and placed in temporary tables. This can then be denormalized (i.e. categorized by

8 Normalizing data involves eliminating redundancy from the data. Certain set procedures are used for this.

content) and can also be redundant if necessary. Machine-specific data types can be formatted for printing. Whether all data is completely denormalized of if, for instance two temporary tables (separated by header and item information) are created for a typical voucher structure, is not an overriding concern.

Checking the layout

The design decision to always output reports from temporary tables means that manual test evaluations can be limited to checking the print layout. The correctness of the output results can then be checked automatically by analyzing the temporary tables.[9]

Instead of temporary tables, you can use XML tables for the output data and XSL stylesheets for the layout. This solution is best for documents that are to be printed, but is less suitable for extremely long reports because the resulting XML file quickly becomes unmanageably large. The use of XML and XSL for reporting and printing documents is still in its infancy. Users currently have to develop their own general printing engine for XML data.

Another option is to use a printer driver that can create PDF files (Adobe's Portable Document Format). In some instances this can cut down on paper consumption and simplify the archiving of test results. PDF printer drivers are available from [Zeon]. The latest version of Acrobat Reader is available for free from [Adobe].

4.3.3 Interface-centric design

"Program to an interface, not an implementation" has become a watchword of object-oriented application design—and with good reason. For the more your classes are decoupled from your application and the less a class "knows" about the implementation of other classes, the more options you will have for testing such classes. Even in the early stages of software development, when some classes are still unavailable, the missing classes or the objects instantiated from them must often be replaced with placeholders called stubs. Outwardly a placeholder provides the interface to the class it represents. An implementation that

9 One advantage of denormalized data is that users generally have an easier time dealing with it. Trained users can create their own reports from the data provided in the temporary tables.

references a class to be tested does not even exist in this case. In order to use placeholders it is therefore absolutely necessary that classes communicate with one another via their defined interfaces only.

Unit testing supported by testing frameworks or testing codes (see below) constitutes black box testing in every instance. Such testing accesses the unit to be tested via its public interface only. If this does not occur, each refactoring operation within the unit will almost always result in a test that can no longer be run, meaning the test must also be modified.

Modularizing

In application design, interface-centric design and modularization basically amount to the same thing. Applications should be based on components, regardless of whether they are called COM objects, Beans or (as more recently) .NET assemblies. Components can be tested separately. However, this does not mean that an application composed of a constellation of individually tested components will necessarily work as a whole. To ensure that the application does in fact work, tests are still needed that encompass the entire processing chain, from the interface through the network to the different application layers, up to and including data management and back A testing chain that tests each component individually in advance will be far less prone to error.

4.3.4 Design by Contract

As described in the section "Embedded Testing" on page 47, the "Eiffel" programming language offers a design by contract approach that contains language constructs for testing preconditions, postconditions and invariant (always applicable) conditions for classes and class methods. If you program in Eiffel, you are certainly familiar with the use of the terms "require", "ensure" and "invariant" as they are used to define pre-, post-, and invariant conditions.

If you program in another language, you can emulate design by contract by using ASSERT and IF statements.

Assert statements

```
ASSERT !empty(This.cAlias) ;
  MESSAGE "XmlRecordSet._load: No Alias set!"
```

ASSERT statements check a Boolean expression and output a message if this expression is returned as FALSE. In the example given above, the `cAlias` class variable is checked to ensure that it is not empty. If it is found to be empty, a message is displayed indicating that no alias has been defined.

An IF statement can be used to achieve almost the same behavior:

```
IF empty(This.cAlias)
   ERROR "XmlRecordSet._load: Alias not set!"
   RETURN .FALSE.
ENDIF
```

The differences between these two kinds of checks vary from language to language. However, a common property of all ASSERT implementations is that ASSERT statements can be suppressed in compiled code and ignored outside of the development environment.

An example in MS Visual FoxPro

ASSERTs in Microsoft Visual FoxPro stop the program after unsuccessful tests and offer the developer the option of switching to debugging mode. But because this behavior is only valid in the development environment, ASSERT statements are automatically ignored in the run-time environment. If the bugs caught by ASSERT statements in the development phase can also occur in the run-time version of the code, an additional IF statement is always required.

An example in Delphi

ASSERTs are integrated into the exception handling methods of other languages such as Delphi. A call of the ASSERT function in Delphi generates an exception when the Boolean statement transferred is assessed as FALSE. These exceptions can be intercepted and handled like other exceptions. If you want the program to stop in the development environment when an assertion fails, you first have to set Delphi's debugger options to interrupt a program when exceptions in Delphi occur.

```
begin
  try
     doSomething;
  except
     application.MessageBox(
     'It didn’t work!','Too bad',0);
   end;
end;
...
procedure TMyClass.doSomething;
begin
   assert(Weekday() <> ‘Sunday’,'Today is a day of
rest.');
end;
```

Listing 4.15 Assert statements in Delphi trigger exceptions.

When setting ASSERTs in languages that act similar to the Delphi example above, you should protect each call of a function, procedure or method using `try ... except`. Only by doing this can you ensure that your program will successfully catch built-in run-time tests.

Preconditions

Use ASSERT statements to check all preconditions that must be met for each method. Apart from serving your own testing purposes, an additional benefit of doing this is that all preconditions for the method are documented.

Both ASSERTs and IF statements should be used to ensure that parameters have been passed correctly to a public method. Checking passed parameters is a mandatory task of every public method and should therefore not be deactivated during run time, as is usually done when ASSERTs are used.

The same holds true when an object must be in a defined state in order to carry out a certain method. If a voucher must be completed to printing, do not check this with ASSERTs when the print() method is called.

ASSERTs check preconditions that indicate an error in the program when preconditions are not met. In doing this the program of course must also be able to respond to any unanticipated errors that may arise. In the code examples given above, the program making the call must interpret a return value of .FALSE. as an error and catch and appropriately handle the exception thrown. If, having detected all bugs during the development phase, you are absolutely certain that the run-time error has been eliminated and will not recur, you can forego these additional checks. However, it is still advisable to leave ASSERT statements in the program outside of the development environment, even during run time . Bear in mind that there is a trade-off between achieving optimal operational integrity and losses in productivity engendered by numerous additional follow-up checks.

Postconditions

Except in the case of Eiffel, assertions are always used to check postconditions. While a method cannot be assigned the task of correctly passing parameters (this task falls to the method making the call), the actual idea behind this method is to always get a correct return value or, more generally, adhering to the postconditions specified. Anything that deviates from this can only be a bug in the program.

Postconditions are checked before the return from the method. If the method returns a calculated value, the latter can be verified by carrying out a reverse calculation. When data is changed, the data state can be checked using an alternative method or an access check.

Postconditions are preconditions for subsequent dependent functions. Ensure uses a somewhat different technique by consistently using a function in a precondition in place of ASSERTs. The function doesn't just passively assert that something is true so that it will work. It actively ensures this and assigns objects to do it. The source code then looks something like Listing 4.16.

```
Function startPreview(tcReport)
ensureReportingDate
ensureDatabase
report form tcReport preview
...
```

Listing 4.16 Using ensure to ensure the preconditions

This technique has several advantages over conventional ASSERT techniques. Programming for purposes of creating and checking a state used by several functions needs to be performed in one place only. To test the startPreview() function, only those constituents of the application have to be started that ensure the availability of ReportingDate and the database. Any changes that occur in database availability and the criteria used for checking likewise need to be realized in one place only.

Invariants

There are frequently many places in the source code where a state is checked, but the alternative state is not. For example, if the value of variable i resulting from previous processing can only be 1 or 2, hooks are frequently used with IF statements such as:

```
IF i = 1
   ...
ELSE   //  i = 2
   ...
ENDIF
```

The fact that `i = 2` must always be true in the ELSE branch is termed an internal invariant of the method. Such internal invariants can be very easily checked using short ASSERTs:

```
IF i = 1
   ...
ELSE
   ASSERT  i = 2
   ...
ENDIF
```

Listing 4.17 Internal invariants

Assumptions about the control flow in the program can easily be verified using a similar approach: Instead of

```
void doSomething() {
   for (…) {
      if (…)
         return;
   }
   // the program should never get here
}
```

it's better to write:

```
void doSomething() {
   for (...) {
      if (...)
         return;
   }
   assert false;
}
```

Listing 4.18 Checks in the control flow

Class invariants are implemented as testing methods outside of Eiffel. The methods in this class have no processing function and merely check the current status of the class. This checking method should simply return TRUE if everything is okay and FALSE otherwise.

A transaction posting class whose objects must always be balanced (regardless of the method used) can verify this state using an appropriate method:

```
// Returns TRUE, if balanced
Private Boolean balanced()
{
   ...
}
```

This method can be viewed as a class invariant. All other methods can use

```
   Assert balanced();
```

to check that the invariant states are maintained before and after processing.

Side effects

When using ASSERTs, you must make absolutely certain that no side effects occur adventitiously. The `balanced()` method from the example above should not be allowed to change the status of the class. If ASSERTs are removed from the final version of the program in the run-time environment, `balanced()` is not executed and the status of the class differs from what it would be in a walkthrough in the development environment.

Sometimes side effects are introduced intentionally—for example, when a comparative value is needed to check a postcondition no longer required in the absence of ASSERTs. To do this, simply create a) a local function or an internal class that saves the comparative value and b) perhaps a second function or method in the internal class that performs the comparison later on. In Delphi it could take this form:

```
procedure TMyClass.myMethod();
var cTmp:string;
cString: string;
// local function
function tmpCopy(a:string):boolean;
begin
  cTmp := a;
  result := TRUE;
end;
// Method code begins here
begin
cString := 'abcdefg';
```

```
// Assert with side effect, cString is saved
temporarily
assert(tmpCopy(cString));
// additional processing ...
// Comparison with saved string
assert(cTmp = cString);
end;
```

Listing 4.19 Assert statement with side effect

Temporary storage of the string is also carried out in an ASSERT call, thereby also suppressing this line once all ASSERTs have been removed from the code. During code optimization the compiler then automatically removes the local `tmpCopy()` function because it is no longer being called.

4.3.5 Test Code

Object-oriented languages offer developers the option of encapsulating object attributes. But using this seemingly quite helpful option may hinder comprehensive checking of the state of an object from the outside, e.g. preculde use of a test script. In some development environments, encapsulation is so extensive that protected attributes can only be accessed, even from the debugger, when you are directly within a method belonging to the class being tested.

You can circumvent this restriction in the class design stage by including one or more methods in each class whose sole purpose is to test the other methods in the class (test code procedure). Because all class-specific tests are carried out by a method in the class, all protected attributes in the class can also be analyzed during the test.

Naming conventions

The test code procedure is especially suitable as an alternative or enhancement to test frameworks for unit testing. One great advantage of the test code method is that the writing of test drivers only involves instantiating an object for each class, calling the test code method and writing each result returned by the tests into a log file. The testing environment and test driver can be combined because class-specific test methods are kept within the class. The test driver can locate the test method via a naming convention, as is done nowadays in some Xunit frameworks. Many programming languages provide mechanisms for querying the names of methods offered by a class. If each test method begins, say, with `testing`, the test driver can be set to call each `testing`... method in order.

Dump method

A class in integration tests can include a dump method that returns the values of all protected attributes or writes the current state into a log file. XML is a suitable format for such files. This method allows for generic representation of container hierarchies in an object dump.

The above-mentioned testing methods for class invariants can also be regarded as test code that can be called from the test driver when needed. Each of these testing methods should be removed from the production code using conditional compiling. The current test code is automatically administered and distributed with the class and is also automatically integrated into the source code control system.

4.3.6 Code Instrumentation

If your classes or the functions of your application recognize a debugging or tracing mode, you can easily trace the paths that run through an application being tested. This is a useful error analysis method for the testing phase. Here is an example of a homemade variant (pseudo code):

```
#ifdef DEBUG_CODE
if <ObjectName> in DebugTrace
   debugoutput <Object+MethodName>
endif
#endif
```

At the beginning of each method, such pieces of code write into a debugging output file or a window the name of the object or another identifying feature, plus the name of the method. It should be possible to confine this to individual objects in accordance with the IF statement.

Tracing code

Depending on whether the DEBUG_CODE constant is defined, the logging in the pseudo code example is either compiled or not. In some instances it is best to leave tracing code in the release version. Of course this is only an option if the tracing code does not slow the performance of a time-critical application. Using tracing code that can be activated and deactivated from the outside allows for the detection of bugs, even at the customer site.

A somewhat more elegant variant can be realized in languages that support `try ... finally` constructs and similar features. The `try` keyword can be used to introduce a block of statements that is closed by a `finally` block, regardless of whether the `try` block ends in an error or anything else via `return` or `exit`.

`Try ... finally` constructs are generally used for blocks of code that absolutely must be cleaned up after they are executed. Such constructs can also be used for code instrumentation, as the following example shows:

```
function TMyClass.doSomething(): boolean;
begin
{>>Profile} ProfilerEnterProc(N); try {Profile>>}
  // ... Method code
{>>Profile}finally ProfilerExitProc(N); end;{Profile>>}
end;
```

In this case tracing is delegated to a profiler class. The `ProfilerEnterProc` call is inserted before the actual method code. It informs the profiler that procedure or function number N has just been accessed. The actual method code follows `try`, which is also inserted. The `finally` block is inserted after the method code. It calls the profiler again and informs it that procedure number N is now being exited.

Each add-in is indicated by begin and end tags, thus enabling add-ins that are added automatically to be removed automatically as well.

4.3.7 Audit Trail

An "audit trail" is also a form of logging involving logging changes to data only. Databases often contain trigger mechanisms that allow certain procedures to be started when records are updated, inserted or deleted. You can log changes to data in these procedures.

Audit trail logs are used to track and assess changes to data that occur during non-transparent, nested transactions. They are particularly helpful when they log the procedure or method that made the change to each record. They allow tracing procedures to be tracked via code instrumentation and non-reproducible errors to be detected.

4.4 Tools

I will not attempt to cover all available testing tools in the following section; instead I will only indicate the wide range of tools available—or not available—as well as giving some pointers on how to use several of them.

An exhaustive, but partly outdated list of testing tools is available at [QAResource]. This page is certainly a good place to begin your search for the right tool. A list of affordable development tools in German, which also includes one or two testing tools, can be downloaded from [ZDNet]. [Sourceforge] is a central directory for a variety of open source projects.

German university home pages also offer an overview of a variety of program tools, among others [UniPassau].

4.4.1 File comparison tools, Diff, XML Diff

GNU Diffutils from the Free Software Foundation is available for download at [DiffUtils]. It is distributed as C source code, Makefiles, etc. for compiling Diffutils on Unix/Linux. Specialized Makefiles and .bat files are provided for MS Windows and DOS. A binary version of Diffutils (and a great deal more) for MS Windows can be found at [Sourceforge] as part of the GnuWin32 project.

The current version of the Diffutils cmp program can skip a specified number of bytes at the beginning of files being compared and can also be set to stop after a given number of bytes have been compared. By repeatedly running cmp, a developer of test scripts can exclude sections of the files from being compared in diff analysis.

If you want to use Diffutils or other GNU programs in WSH scripts you can use the Exec method of the Wscript.Shell object to do this. The following JScript example shows how you can access the cmp program.

```
// execute cmp with StdOut access
var Shell = new ActiveXObject("WScript.Shell");
var Pipe = Shell.Exec("cmp file_1 file_2");
// create results file
var fso = new
ActiveXObject("Scripting.FileSystemObject")
var a = fso.CreateTextFile("results.txt", true);
// read StdOut and write to the results file
while(!Pipe.StdOut.AtEndOfStream)
   a.WriteLine(Pipe.StdOut.ReadLine());
// close results file
a.Close()
```

Listing 4.20 JScript with StdOut access

Impressware [Snap] offers a tool by the name SNAP that can carry out masked file comparisons. In addition, SNAP is able to compare database tables or individual records directly or with the contents of data saved offline. SNAP is available for COBOL and Natural development environments.

A program for searching for and reporting differences between XML files is available at [XmlDiff1]. XMLDIFF is written in Python and can be downloaded and distributed for free under the GNU Public License (GPL).

An implementation of XMLDIFF in Perl can be found at [XmlDiff2].

4.4.2 Data Access and Evaluation

Database interfaces can easily be found on the Web. Simply enter "Database Desktop" in your favorite search engine and you will probably get two or three dozen hits. Some development environments come with their own database desktop, while database developers usually offer an interactive interface for their database.

All these interfaces offer interactive access to databases, and the better ones also offer the opportunity to search for or alter table structures or field types, if this is allowed. Access is obtained either by means of a native driver or via an ODBC driver. In most cases the database interfaces are only used interactively and cannot be programmed.

If you have to test in your MS Windows client a data intensive application that stores your data in a relational database that you can access via ODBC and you have no fear of programming in an xBase language, you should have a look at Microsoft Visual FoxPro (MS-VFP). You will not be able to find a better "data shovel" in MS Windows. VFP 6.0 ist part of Microsoft Visual Studio 6.0, but was not incorporated into Visual Studio .NET because this would have required replacing VFP's own database engine. You can obtain more information on the current VFP Version 7 under [MSVFP.]

Data access with VFP

VFP is a fully mature development environment and is also very useful for testing data intensive applications. The programing language is an object oriented extension of the widely known dBase langauge. All data can be manipulated and evaluated with xBase commands or in SQL syntax. The SQL commands are directly integrated into the language, but do not have to be set up as a string and entered as parameters of the loading procedure, as is otherwise usually the case. The results of an SQL search are stored in a local cursor that can in turn be searched and evaluated with xBase commands. With a single command `CursorToXml` you can convert the result of an SQL search into XML format (and with `XmlToCursor` back again), and so on.

For test purposes you can create your own views that do not put a load on the database or you can communicate with the target database with its own SQL syntax using SQL Pass Through technology.

Scripting with VFP

VFP uses a non-typed, interpretative language that is well suited to creating test scripts. A simple call is possible if the Windows Scripting Host is needed for system-level tasks. The "Hello World" example in the section "Scripting under Windows" on page 162 looks like this in VFP:

```
WSHShell = CreateObject("WScript.Shell")
WSHShell.Popup("Hello World")
```

It's just as easy as JScript or VBScript. In addition, VFP has very powerful and fast string processing functions that make it possible to use a test script to analyze even large text files simply and quickly.

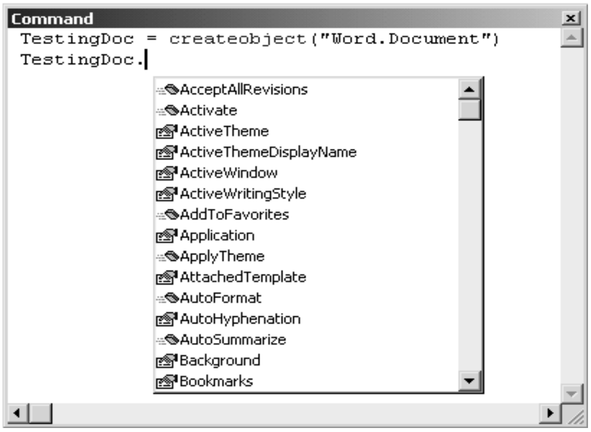
CAL in Munich [CAL] offers "FoxRunner", a program that uses VFP as a test platform for data-intensive applications on MS Windows. FoxRunner also permits the automatic generation of test data and the creation, storage and comparison of data snapshots for all ODBC-compatible databases.

4.4.3 COM Interactive

Microsoft Visual FoxPro 7 (VFP) is also suitable for interactively testing COM interfaces. The VFP interface permits interactive instantiation and manipulation of COM objects.

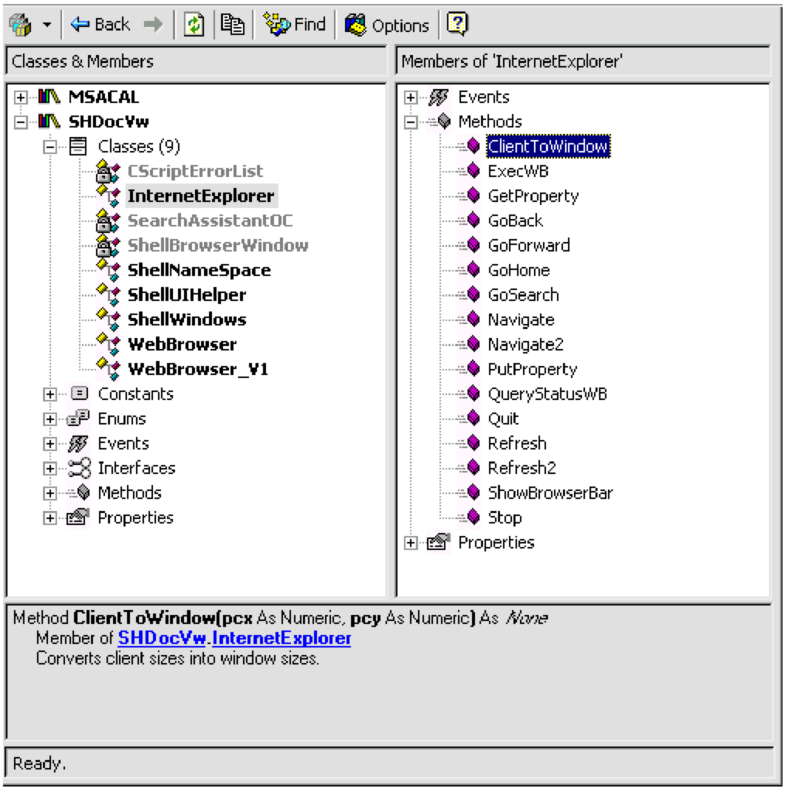
Figure 4.13 shows the Command window on the VFP desktop in which a Word.Document object has just been created for a test. This object can already be used in the second line, because every line in the Command window of VFP is executed immediately once it is closed by the Enter key. It is possible to navigate freely in the command window. Even command lines that have already been entered can be edited and repeated individually or in groups, and the return values of the method called can be shown on the VFP desktop.

In addition, the methods, properties, interfaces, etc. of a COM object can be examined using the Object Browser that is integrated into VFP7.



```
TestingDoc = createobject("Word.Document")
TestingDoc.
```

Figure 4.13 Command window of the VFP desktop



Method **ClientToWindow(pcx** As Numeric, **pcy** As Numeric**)** As *None*
Member of SHDocVw.InternetExplorer
Converts client sizes into window sizes.

Ready.

Figure 4.14 The VFP Object Browser

Figure 4.14 shows the methods of MS Internet Explorer as depicted in the VFP Object Browser.

4.4.4 Code Coverage, Logging, Tracing and Profiling

Code coverage tools can recognize which sections of source code were tested in a test run. Simple tools are limited to the statement coverage (C0), whereas more demanding tools also deliver information on branch coverage (C1) and coverage of conditions (C2). The significance of the coverage indices was spelled out in the section "Classic Coverage Indices" on page 130.

Logging and tracing both mean that log information from the program is recorded at run time. In the case of logging this frequently involves both contextual and technical information, whereas tracing generally involves debugging information only.

Profiling Profiling tools independently collect and log system information during a program run. This can involve different kinds of information. This frequently includes the time taken by individual commands or procedures, memory use, processor times for individual tasks, etc.

A continuously updated list of code coverage, logging, tracing und profiling tools can be found at [TestEvaluation].

Brian Marick [Marick] publishes a number of articles on code coverage and tracing on his Web site. You can also find download links on his site for freeware tools that he has written.

JProf is a Java profiler, written in C++, that traces memory use, synchronization and processor use. It can be downloaded for free at [jProf].

At [log4j] you can find the Logging Framework for Java from the Apache Foundation's Jakarta project.

GpProfile is a freeware profiler for Delphi [gpProfile]. The try ... finally example in the previous Code Instrumentation section comes from a project that was carried out using gpProfile. The output of the profiler is suitable for analyzing calling sequences and the times required per function.

Coverage and profiling tools are already integrated into some development systems. The current version of Borland's Jbuilder contains the OptimizeIt suite, consisting of code coverage, profiler und thread debugger [JBuilder]. Microsoft Visual FoxPro [MSVFP] also includes a simple coverage profiler.

4.4.5 Design by Contract

Here are two tools that implement design-by-contract procedures (see above) in Java.

Reliable Systems offers a free pre-processor at [iContract] that instruments Java sources with code for checking invariants, preconditions and postconditions.

ParaSoft has a tool called Jcontract that also makes design by contract possible in Java [ParaSoft]. It enters the conditions to be tested as invariants, preconditions and postconditions in comments similar to JavaDoc tags. A special compiler uses these to make the required Java code.

```
Public class example
{
    /** @pre month >= 1 && month <= 12 */
    static void setMonth (int month) {
        // ...
    }
    //////////
    public static void main (String[] args)
    {
        setMonth (13);
    }
}
```

Listing 4.21 Example of a Java class using Jcontract conditions

4.4.6 Load and Performance Tests

The list of stress and performance testing tools for is now almost as long as the one for GUI test automation (see below). A continously updated list can be found at [Stress]. Virtually all major GUI test automation tool vendors have enhanced their tools to include Web applications and provide integrated stress and performance testing tools or integration of tools that can be bought separately. See the section on GUI Test Automation below for more information.

Microsoft offers a free Web Application Stress Tool (WAS) for Win NT 4.0 and Windows 2000 at [MSWas]. Microsoft Visual Studio .NET contains a new Web Stress tool (no longer free).

PushToTest [PushToTest] offers free open source tools for testing, monitoring und automating Web Services systems. TestMaker 3.0 is a tool that tests Web Services for scalability and performance. It creates test agents that simulate real-world Web Services environments.

TestMaker 3.0 is written in Java and uses Python as its scripting language. Program and source code are available under the Apache Open Source License.

Red Gate [RedGate] offers ANTS, an "Advanced .NET Testing System". ANTS is used for stress testing Web applications that were created using Microsoft's .NET technology.

Scapa Technologies [Scapa] has a performance testing tool that is specialized for Citrix Metaframe environments. Scapa StressTest works together with other scripting environments and testing tools such as WinRunner and SilkTest.

Paessler Co Ltd [Paessler] is a German firm that offers a Web server stress tool at markedly lower prices than its larger competitors.

Applied Computer Techologie [Acomtech] is one of several vendors offering network performance testing tools.

4.4.7 GUI Test Automation

The largest number of test automation tool vendors is still to be found in this group. The majority of the tools permit interactive displays of user actions linked to editing and extending of the scripts that are created, mostly in proprietary scripting languages. A criticism of this approach from the standpoint of rapid application testing is to be found above in the section "Automating Testing Procedures" on page 158.

Many suppliers integrate additional load testing procedures for client/server and Web applications into their automation tools as well as management functions for the administration and automatic repetition of test sessions. The tools are too varied in their level of performance and too focused on certain details for a simple and unequivocal evaluation. However, a certain degree of classification into tools that mainly support testers and those that give more support to developers is possible. [Mercury] and [Segue], for instance, are certainly more tester oriented, whereas [ParaSoft] is mainly intended for developers and integrators.

Isolation layer

GUI test automation tool vendors attempt to master the problem of constantly and rapidly changing user interfaces by inserting or making possible an isolation layer between the test script and the application under test. Most tools have long since distanced themselves from the pixel oriented approach involving mouse clicks and so on, and are able to directly address the controls making up the the graphical interface. In the scripts it is not necessary to use only the object names that the developers gave the controls, but logical names that are assigned to the "physical" names via one or more mapping tables can also be used.

At [Nagle] you can find an interesting design for a "Test Automation Framework" that is "keyword and data driven" and uses the mapping tables from GUI test automation tools to develop a tool-independent framework for describing test cases. According to the author, construction of the frameworks took 18 months. The article shows clearly and unmistakably the large quantity of both conceptual and financial resources that is necessary for the automation of testing.

A number of GUI test automating tools are listed here alphabetically with explanatory comments.

- Android [Android] is an open source record and playback tool for the Unix/Linux environment.
- What does this example show?
- The Mercury Interactive Corporation [Mercury] offers "WinRunner" and "Xrunner", test automation tools for MS Windows and X-Windows interfaces respectively. "Astra Quick Test" and "Quick Test Professional" are offered for Web interfaces.
- PARASOFT Corporation [ParaSoft] offers a tool called "WebKing" that designed to support development and testing of dynamic Web sites.
- The firm Rational [Rational] offers "Visual Test" (acquired from Microsoft), a test automation tool for MS Windows programs that is closely integrated into the development environment of MS Visual Studio 6. Für die Steuerung von Web-Sites wird »Rational Robot« angeboten, das auch in die umfassenderen Pakete »Rational Test Suite« und »Rational Team Test« integriert ist.
- Segue Software [Segue] offers SilkTest für desktop, client/server and Web applications.

I have not succeeded in finding a simple Capture & Replay tool for MS Windows that does without its own scripting and can therefore be simply and effectively integrated into general scripting environments. [Unisyn] offers a bargain-priced tool for automating testing in Windows (starting with Windows 98) that also features Capture & Replay. If you operate your test automation with the help of the Windows Scripting Host and need Capture & Replay capability from time to time, a tool like this certainly sufficient.

4.4.8 Testing Distributed Systems

In testing distributed systems it is necessary to take the time required for transactions between a number of clients and one or more servers into consideration. Because in situations like this different processes with different speeds are constantly running, differences can occur in the sequence of events for clients and servers that only produce an error in special circumstances. In other situations with a somewhat different sequence of events the error may not occur at all. On the one hand this makes finding and reproducing errors difficult, on the other it means that close attention must be paid to seeing that the sequence of events is identical to the initial testing when the test is repeated.

A trace-based test method for distributed systems developed by a team headed by E. Reyzl at Siemens is described at [TMT01]. This method traces the exchange of information between distributed components and evaluates it. Recording is carried out either by monitoring network communication using a packet sniffer or by instrumentation software under observation. The message exchanges are graphically represented on sequence diagrams following the style used for UML sequence diagrams.

5 Agile Quality Management

The best laid plans of mice and men often go astray. (paraphrased from "To a Mouse, On Turning up her Nest with a Plough" by Robert Burns [Burns])

5.1 Keep It Flexible

Everybody is talking about agile methods. But what exactly does this mean? Agile methods are first and foremost the proven survival strategies of small, successful teams. Their secret of success is simple: Keep it flexible! The most important thing is benefiting the customer. It's not the plan, model or method which is important to the customer at the end of the day but rather the product. The software has to adapt to the conditions under which the customer works, not the other way around. Yet these conditions may be subject to constant change. That's why the key ingredient of a successful project is being able to react to these changes quickly.

Counter-movement

For a long time an attempt was made to overcome the software development "crisis" by employing increasingly detailed and rigid soft development methodologies. A countermovement sprang up whose members were successful, however they no longer wanted their success to be discounted just because they didn't follow a plan. In February of 2001, 17 of these "anarchists" got together and tried to synthesize their experience and principles. The result was The Manifesto for Agile Software Development [AgileManifesto].

The Manifesto consists of four declarations and a series of principles derived from them. Quote from the Agile Manifesto Web site (http://agilemanifesto.org/):

"We are uncovering better ways of developing software by doing it and helping others to do it. Through this work we have come to value:

- ***Individuals and interactions** over processes and tools*
- ***Working software** over comprehensive documentation*

– ***Customer collaboration*** *over contract negotiation*

– ***Responding to change*** *over following a plan*

That is, while there is value in the items on the right, we value the items on the left more.

Now let's try to apply these principles to testing and other quality assurance methods for the purpose of achieving agile quality management.

5.1.1 Individuals and Interactions

If we value *individuals and interactions* more highly than processes and tools, we will have to let go of the notion that there is someone in our project who assumes the burden of testing and is responsible for testing quality into the product. There also won't be a quality assurance group at the end of the line who decides on the fate of the finished product (i.e. deliver or not deliver). To be sure, everyone involved in the development process is responsible for the quality of their part of the product. In other words, quality management means ensuring that the necessary time, infrastructure and knowledge are available. All the team members should know the quality objective and current project risks. Everyone should be trained for their role as specialist, architect, developer or support engineer in testing techniques or—expressed in more general terms—quality assurance techniques.

Identifying individual areas of responsibility

Working autonomously is predicated on a clear-cut identification of the individual areas of responsibility and those in charge of them, e.g. by modularizing software and allocating tasks in the team. Chaos can be virtually precluded if a project is organized and carried out as follows: motivated, capable individuals; a team which is self-organized; and full support by management trusting that all participants will do their best. Added to which: a realistic schedule with short iteration cycles, regular reviews of what has been achieved, and the availability of knowledgeable contacts at the customer's or users' end.

An interaction occurs when someone uses someone else's product for his own work and doesn't simply have to accept it as is but may criticize it. Using the product in a real-world context enables most errors to be detected. The feasibility of a vision or the quality of an analysis of the proposed use can be best checked by attempting to transform them into a software architecture. The architecture ideas in turn can probably be best assessed by implementing them and deploying the resulting software. That's why short interaction cycles and frequent deliveries are a very effective quality assurance instrument. The completeness of the product is less important in this context. If creating the full-fledged functionality takes too long, produce a prototype first.

Joint assessment

An interaction also occurs through reviews of documents, schedules and completed program components; joint evaluation of intermediate work products; agreeing on the next steps to be taken; analyzing errors; and making suggestions for improving the process. Individual system components are subjected to more in-depth testing whenever this is suggested by the risk analysis. Interactions can't take place unless at least two individuals are involved in testing or a review. The individual who has engineered the product should be allowed to ask any other team member to review or countertest the product. The decisive thing is only the competence required for the test or review. The developer might say to the architect, "Why don't you take a look at this procedure and see if you see anything that might go wrong." By the same token, any team member can ask another member for intermediate results or meet in one-on-one talks for deciding on how to proceed further. There aren't any prescribed procedures or information channels, the team organizes itself. Any conflicts arising in the process are resolved in a personal exchange, whether one-on-one or in a group. In the process, the project manager frequently assumes the role of moderator.[1]

5.1.2 Working Software

It should come as no surprise that the real goal of a software development project is not a cupboard stuffed full of documents, schedules and models, but rather working software. That is why working software is the key yardstick of project progress. The authors of the Agile Manifesto include an example in their Principles: *"Too often, we've seen*

1 At the present writing, I am working as an architect in a team of about ten people spread across the country. In most cases phone conferences suffice for self-organizing the team.

project teams who don't realize they're in trouble until a short time before delivery. They did the requirements on time, the design on time, maybe even the code on time, but testing and integration took much longer than they thought." [FowlerHighsmith01] If a bottleneck is to be avoided at the end of the development process, quality assurance has to be integrated in that process. Each product or intermediate product in the process has to be linked to a quality assurance method.

- ▶ Documents and models are best linked via reviews. They can be ongoing reviews by working in teams of two, informal reviews through proofing by another team member, group reviews of central design decisions, analysis reviews by specialists, etc.
- ▶ Functions, procedures, classes, modules, components—all units of the program are integrated through automated or interactive unit testing or through embedded testing of the run-time conditions with the use of design-by-contract constructs.
- ▶ The assembly of components to form a complete product (build) is linked to smoke testing and automated regression testing.

The creation of a product or intermediate product is immediately followed by the process prescribed by the associated quality assurance method, meaning quality assurance occurs in-process and not right before delivery is due to take place. Of course, this takes time—just exactly the time you might otherwise not have right before you are due to deliver. It might even take less time since waiting to perform it right before delivery probably means having to get your mind back around individual program components.

5.1.3 Collaboration with the Customer

A new species — the software architect — has recently sprung up between the manager, programmer and user. In his book *Effektive Software-Architekturen* ("Effective Software Architectures") [Starke], Gernot Starke describes the role of the software architect as follows: *"Software architects form the interface between software analysis, design, implementation, management and operation."* Although not appropriately cast or not cast at all in many projects, this new role is of central importance for the success of a project. The architect is essentially responsible for the proper functioning of the overall system. Since he acts as the "customer's advocate" [Starke], he is also responsible for the feasibility of the customer's requirements.

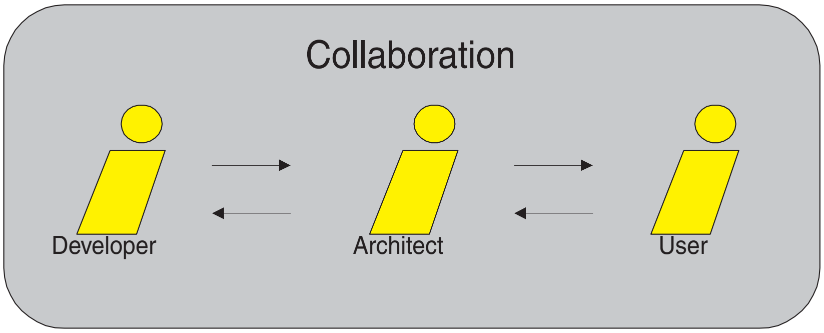


Figure 5.1 Collaboration with the customer

Agile quality management takes into account the growing significance of the software architect by appropriately casting this role in the project. Of course, the project risks always determine the appropriate role. In mini-projects the only analyst, programmer, documentor, and tester is probably also the architect. When projects become larger, the architect role very soon becomes a full-time job. Very large projects sometimes have to be divided among several architects.

Interface between the customer and development team

The architect forms the interface between the development team and the customer. The most important thing to the authors of the Agile Manifesto was that there be collaboration with the customer in a project. Agile projects should no longer be handled in the same old way with the customer not hearing or seeing anything for a long time after the analysis phase until someone all of a sudden appears at the door with the finished software product. To be sure, customer collaboration means collaboration on an ongoing basis. When the project has kicked off, someone has to be designated as the contact or liaison at the customer's end. During the project, this contact always has to be available and be able to provide information as needed. The contact should be a specialist and, if possible, a future user of the program being designed and engineered; in other words, the contact shouldn't be someone in purchasing who is in charge of software procurement. The reason for this requirement is that the contact also assumes a key role in agile quality management. This should be the individual who essentially assumes and/or supervises user testing.

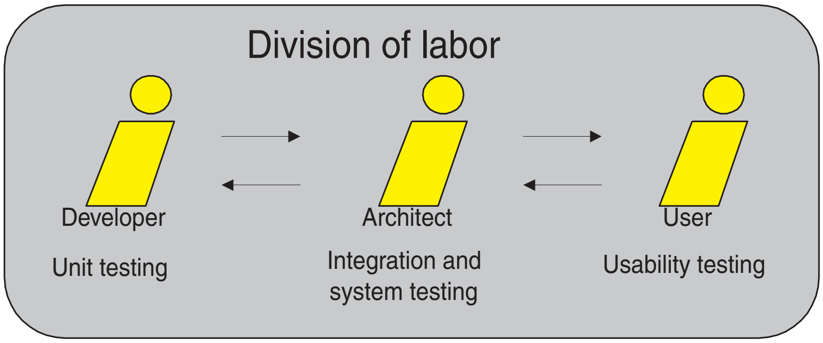


Figure 5.2 Division of labor during testing

According to this division of labor, the developer handles unit testing, the architect does integration and system testing, and the user carries out usability testing.

In so doing, the roles and tasks are to be understood in a very general sense:

A developer is anyone who produces a product or intermediate product of software development. This includes not only programmers but also team members in charge of analysis, design and documentation. For the sake of simplicity, "unit testing" refers to all testing impacting the finished product.

Sound architecture

Integration and system testing is the job of the architect in as much as the architect checks for the correct implementation and structural soundness of his own architecture. Of course, assigning this task to the architect doesn't mean that he is responsible for performing all integration and system testing by himself. This is hardly possible in a sizable project. In any event, he should monitor testing. This means first and foremost assessing the risk analysis, test plan and test design and contributing to laying them out.

Testing is concluded by the user's representative checking for compliance with the customer's requirements and usability of the program as a whole. Here, too, the task should be assigned to this individual on account of its content. In common practice in large-size projects, however, this task is subdivided into subtasks which can be delegated.

5.1.4 Reaction to Changes

Risk-oriented and agile procedures don't mean that planning can be dispensed with completely. It should basically be understood that no plan is written in stone but rather it applies as long as its basic premises apply.

The most important effect of planning is thinking about something in depth. The second most important effect is that there is an intention of doing something and possibly being able to estimate whether that intention is realistic. However, reality frequently gets in the way when it comes to this second aspect.

It is useful to frequently think about the following early on:

- What are the greatest risks, and how will we deal with them? One rule of thumb is to deal with the items posing the greatest risk first.
- Which system environment or scenarios have to be considered? Examples of this are the various operating system configurations which have to be included in testing, and others which can be discounted.
- Which processes does the program model? What are the application scenarios, and how can they be tested?
- Which quality assurance techniques are to be applied? Should we use a test framework? Or design by contract? Or both?
- Which types of tests are to be automated, which are to be performed manually? How can automated testing be supported? Which scripting environment should we use?
- Do we have the qualified people we need on the project? Do we need someone who is specialized in testing tools? Should a part of testing be farmed out to external testing contractors?
- What hardware is needed? How many and which workstations or PCs, printers, network hardware, cabling, phone lines are needed?
- Which tools are to be used? Is a bug tracking database to be sourced or developed in house? How is test case tracking structured, how are bug reports written and distributed? How is bug fixing reported?

A whole series of questions needs to be considered early on. However, very rarely does a detailed written plan need to be drafted. Many answers will change in the course of the project; risks constantly have to undergo reassessment. Any plan made soon has to be discarded. The fact that we haven't succeeded in keeping all the project records up to date for the umpteenth time is a source of frustration and dissatisfaction. That's why it makes more sense to internalize the principles of agile quality management and make them a cornerstone of everyday project work rather than write them down neatly and file them away in the nearest project folder.

5.2 Estimates of Effort

The general effort allocated to testing and reviewing (documentation, models, concepts) is put at between 30 % and 90 % of the overall project effort, a tendency which is on the rise [NIST]. Let's assume some value in-between and put the effort for testing and reviewing at 50 % of the overall project effort. Now let's combine the effort allocated to analysis, design, coding and documentation. You now have half of the project effort. The other half is spent on testing and reviewing.

Unit Testing

How much should the effort allocated to unit testing be in relation to the overall project effort? In his book *Code Complete* [McConnell93], Steve McConnel speaks of 8 % to 35 %, depending on the overall complexity. The share devoted to unit testing increases with increasing complexity.

Integration Testing

The effort allocated to integration testing increases with the increasing complexity of the overall system in relation to the overall effort. In most cases, it is put at between 5 % of the overall project effort for simple systems and 30 % for complex systems.

System Testing

Like integration testing, the effort allocated to system testing increases with the increasing complexity of the overall system, ranging between 5 % – 25 % of the overall project effort.

Regression Testing

The effort allocated to regression testing correlates closely to the test methods employed. If regression testing is exclusively manual, it can easily comprise 100 % of initial testing for each major release. According to [KanerBachPetti02], automating testing involves ten times the effort of manual testing. In my own experience, the effort required for the maintenance of automated regression testing steps amounts to an average of 30 % of the manual testing effort of the program components involved per major release. This value can be reduced substantially by employing a test-oriented design of the program components.

User Testing, Acceptance Testing

The effort required for user testing may amount to between 10 % and 30 % of the overall project effort. It increases in keeping with the growing complexity of the project.

5.2.1 Evaluating One's Own Projects

The above figures should not be understood as absolutely reliable limits in themselves, but rather simply as empirical values derived from evaluation of a series of projects. Try to evaluate your own projects and use the findings as a guideline for calculating the numbers for your next project.

The following breakdown might be applicable to a project with low to moderate system complexity, numerous individual modules, and high technical complexity:

- 5 % of overall effort for unit testing
- 15 % for integration testing
- 10 % for system testing
- 20 % for user testing

Of course, this effort can be dispensed with if you develop disposable software that no one seriously uses. If you intend to or must deliver a quality program, however, it is well to include testing and reviewing costs in your estimates. Otherwise a development period of one year can quickly turn into two or three years until the product is actually "ready for prime time", with no one really understanding why.

5.2.2 Software Risk Classes

Whereas we have made a flip distinction above between disposable software and quality software, the German Technical Control Association (TÜV) has published a classification scheme for software according to risk classes (quoted from [Wallmüller90]). Five classes are distinguished:

- **Class A:** no risk
- **Class B:** low risk, e.g. image loss
- **Class C:** moderate risk, e.g. financial loss
- **Class D:** high risk, high financial loss possible
- **Class E:** very high risk, personal injury possible
- The testing costs corresponding to the various risk classes are specified as follows:
- **Class A:** no effort
- **Class B:** only black box testing
- **Class C:** black box testing and usability testing, statistical program analysis (reviews, code checker, etc.)
- **Class D:** black box testing, white box testing, usability testing, statistical program analysis
- **Class E:** black box testing, white box testing, usability testing, statistical program analysis, additional risk assessments of the overall system such as environmental impact, organizational operations, etc.

Although this classification is not new it is remarkable that the TÜV association took such a forward-looking approach back then by thinking in terms of risk. Of course, "high financial loss" is very relative. Consequently, classifying your product according to one of the above categories is more or less subjective. Yet however you classify your product, decide what effort you want to spend on quality assurance.

5.3 The Test Machine

If at all possible, *don't* use the development system as your test system. Even if you install the program to be tested in a separate directory on another hard drive, the fact that the development environment is also installed on the machine will have serious consequences (Registry entries).

The test machine(s) should only be used for testing purposes. If various printer drivers, graphic cards, ISDN cards, etc. are to be tested, it is advisable to reinstall the entire machine without having to expend much time or effort.

5.3.1 Cloning Hard Drives

Cloning hard drives is much easier if you use the right software tool for the job. These tools enable the entire contents of a hard drive to be written to a file (i.e. cloned or mirrored). This hard drive image can then be burned onto a CD, for example. Together with the accompanying boot diskette you can copy the hard drive image on to the hard drive and thus avoid time-consuming installation work. A leading tool for cloning hard drives is Norton Ghost [Ghost].

5.3.2 Virtual Machines

An alternative to cloning hard drives is using virtual machines. Virtual machines are set up on your host operating system as guests. The current version of VMware [VMware] supports Windows (from Windows 2000) and Linux. Various operating systems and versions can then be installed on the guest systems. At present you can install the entire range of Microsoft OS versions as a guest system under VMware: from MS-DOS to Windows 3.1 to Windows .NET Enterprise Server (experimental). In addition, VMware Workstation 3.1 also supports all standard Linux distributions, FreeBSD and Netware 6.0 (experiments). The only prerequisite is that you have installable versions of these operating systems.

VMware uses virtual disks which can be stored as files on the hard drive of the host system. These files can be included in the normal backup process. It goes without saying that you can also back up the files of a virtual machine according to the basic OS setup and thus always be able to revert to this status. Virtual machines have become a highly recommended alternative to individual test machines when it comes to testing, particularly of various system configurations and installation procedures.

5.4 Administering Test Data

In some of the examples given in this book we have seen how important it is to run testing on secured data capable of being reproduced at any time. This data has to be organized and administered. The ideal thing is to do all testing using the same test data. This way, you only need one copy of your original test data which you can load into your test environment before testing. It is hard to put yourself in this position however. The data which influences testing also includes control data used by the application (parameter tables, INI files, etc.) or metadata (format descriptions, data dictionary, etc.). If your application uses control data and/or metadata, you will probably not be able to get around administering several versions of this data for different tests, with each version corresponding to a test scenario.

It is relatively easy to model the various test scenarios in the directory structure of your test environment. The structure might look like this:

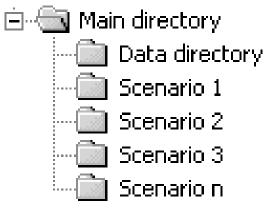


Figure 5.3 Directory structure with test scenarios

Prior to testing, the data of the respective scenario is copied into the data directory. The procedure of switching over the data directory to the required scenario by switching over the program parameters is not advisable. The test may undergo modification, making the initial test data unavailable for retesting.

When your test data reside in a server database, the various scenarios are either constructed as different databases whose data is then copied into the working database of the test environment prior to testing; or administered using only the SQL scripts that are required to create the initial test data. The copy method is the easier variant of the two. Changing or adjusting the initial test data can be done via the database user interface. If your test scenarios are only available as SQL scripts, you would have to run the script every time there is a change in order to determine whether the change is correct.

5.5 Quality Metrics

Like other software metrics, test metrics have gotten somewhat of a bad rap. There is hardly an article around in which details relating to lines of codes or function points are to be found.[2] However, if the figures collected in a project are not viewed as absolute values unto themselves but rather in relation to one's own experience, estimates and goals, they are sure to be of use in project management.

I have titled this section "Quality Metrics" because, in the context of integrated and product-oriented quality assurance, the figures given here do not provide information on how far along we are with testing (= process-oriented view), but rather where the project as a whole stands in relation to the quality attained.

Don't attempt to use these figures in assessing the productivity of testers and developers. Very soon, they will no longer tell you where the project stands, but rather how your people react to productivity measurements. If a team member makes finding as many bugs as possible his top priority, the task of ferreting out the most egregious errors is sure to get the short end of the stick.

5.5.1 Errors per Area

Errors per area is probably the most important metric. This figure can be directly correlated to the assumptions made in the risk assessment. Consequently, you should use the same breakdown for errors per area as

2 Or I haven't been reading the right articles.

you did for the risk analysis. In the example of risk assessment given in chapter 3, this was the functional breakdown into data collection, user administration, data backup, and reports. And also a technical breakdown into algorithm integration, input/output, and workflow.

If you are able to add up the errors detected according to this breakdown, you will know how prone to error individual modules or be able to gauge how critical technical conditions are. These findings can flow into the risk assessment for the test runs of the next program version.

By the way, the rule is that the number of errors detected is *directly* proportional to the number of errors not yet detected. If you have detected a particularly high number of errors in a module, this means that this module probably contains *more* undetected errors than the modules in which you have detected fewer errors.

5.5.2 Errors According to Error Type

Another breakdown classifies errors according to various error types. Here an attempt is made to give the *reason* for the error. The reasons for errors can lie in the analysis, design, programming, database, operating system, development environment, etc. Draw up a list of error reasons which are of interest to you, reasons which may be interesting because you see possibilities for remedying the source of the error. If the design is causing most of the errors, perhaps you need an experienced architect for your team. If it's the development environment, perhaps you should change vendors.

5.5.3 Errors per Unit of Time

The time can be indicated in your test evaluations via two particulars. First, via the date on which the error was detected, and secondly via the date on which the error was fixed. If you record the date on which an error occurred, you can perform an evaluation at any time of the number of errors detected per day or week. This is just one possible criterion for determining when testing can be concluded (see below). Discontinuing testing is a tricky matter as long as the number of errors detected per week increases or remains constant. When the number of errors detected is on the decline, you can decide whether there has been enough testing or whether the test method is to be changed in order to enhance testing efficiency again, or whether you should turn to testing other program components.

The date on which an error is fixed is needed in order to track the period between error detection and fixing. This period shows how quickly the developer team is able to respond to bug reports. If the periods between the detection and fixing of errors increase, this might be a sign that your developer team is overworked or it might point to shortcomings in the bug reports. Pursuing the causes is well worth the effort in any case.

5.6 Quality Control

5.6.1 Bug Tracking Database

The quality metrics described above are most easily derived from a database into which you enter all the errors detected. If the developers also have access to this database, it will soon become the most important communication tool between testers and developers.

Each error is entered in this database with a unique ID. The entry should contain the following information: project ID, name and/or e-mail address of the individual who located the error the date on which the error was detected, a description of the error, the steps for reproducing the error, and particulars pertaining to isolating the error, in addition to indicating the severity of the error and the priority given to resolving it. The severity of the error and the priority of fixing it are not entered by the individual reporting the error but rather by the team member who is in charge of incoming bug reports and reviewing and evaluating them. The idea of combining these two particulars into one is not so good because it can't be said whether a less serious error should also receive a lower priority when it comes to error fixing. Sometimes it is important to know who reported the error. In any event, old errors should have a higher priority as they increasingly become annoying to the user and the fact that they still haven't been fixed in the latest version does little to enhance the reputation of the developer team.

Look-up lists Developers can enter the date on which the error was fixed, the module allocation, and type of error in the same database. When making entries, it is advisable to use lookup lists with a module breakdown where the types of errors which may be entered are specified. In so doing, you facilitate data evaluation considerably, as variations in spellings, wordings, etc. are precluded.

An error table might be structured like this:

Field	Description	Data type
ID	Unique ID, e.g. consecutive number	integer
Project	Name of the project (or key)	string
Module	Name of the module, e.g. "data capturing", "user administration", etc.	string
Area	Technical area, e.g. "algorithm", "integration", "input/output", etc.	string
Who	Name or e-mail address of the individual reporting the error	string
When	Date on which the error was detected	date
What	Description of the error	text
Reproduction	Steps for reproducing the error (optional)	text
Isolation	Instructions for narrowing down the problem (optional)	text
Type	Type of error, e.g. "analysis", "design", "coding", etc.	string
Severity	Severity of the error, e.g. on a scale of 4 (see Chapter 1)	integer
Priority	Priority of fixing the error	integer
Done	Date on which error was fixed	date
By	Name or e-mail address of the individual who fixed the error, in the event of queries	string

Table 5.1 Fields of an error tracking record

Of course, lots of other particulars might also be conceivable. However, error capturing and tracking should remain as easy and effortless as possible. The name of the game is detecting errors and fixing them.

5.6.2 Bug Reporting

For an example of error reporting, see the debugging example given in chapter 4. When you use an error tracking database, the steps for reproducing the error and the isolation instructions are entered in the database at the same time. This eliminates the need to fill out another form.

Enumeration system

You should agree on a simple enumeration system if several people are manually capturing bug reports. An easy-to-decipher notation has been shown to be useful, for example the initials of the tester, date (YYMMDD) and time (HHmm). The log report number generated for a bug report from 5:30 PM on April 25, 2002 entered by the tester would be: MR020425-1730. Since there is little probability that the same tester will enter two bug reports in the space of one minute, this gives you a simple system for generating unique bug report numbers.

One last remark about the content of bug reports: State as concisely and precisely as you can what the error is and how it can be reproduced. Developers tend to have very little time.

5.6.3 Test Case Tracking

The status of the individual test cases should also be tracked. A spreadsheet suffices as long as the number of test cases remains manageable (< 50). The alternative would be to also use a database for test case tracking. The advantage of this is that the individual test cases can be more easily linked to the errors detected while running the test cases.

The following details should be logged for a test case: unique ID, brief designation, status (OK, failed, system error, not conducted), date, version number (build) of the (last) test run, entry of the test script used, name or initials of the tester, and a comment. Listing hardware and system equipment, driver versions, etc. is also useful but can be done in a comments field. Although making the proper data scenario available is one of the main tasks of the script, the data scenario needn't be explicitly listed in the table. It can be derived from the script. However, the data scenario should also be indicated in the comments field when no script has been allocated to a purely manual test case.

A test case table might be structured like this:

Field	Description	Data type
ID	Unique ID, e.g. consecutive number	integer
Description	Short designation of the test case, e.g. "test for multi-user capability"	string
Project	Name of the project (or key)	string
Module	Name of the module, e.g. "data capturing", "user administration", etc.	string
Area	Technical area, e.g. "algorithm", "integration", "input/output", etc.	string
Tester	Name or e-mail address of the individual who conducted the test	string
When run	Date and time of the test run	date
Status	OK, failed, system error, not conducted	string or integer
Plan	Test design	text
Script	Name of the associated test script	string
Comment	Remarks by the tester	text

Table 5.2 Fields of a test case record

As you can see, the test case table contains some particulars which are also contained in the table of errors reported. If you set up tables for the requirements analysis and change management in the same manner, the redundancy of these details will continue to increase. Consequently a suggestion is made in Figure 5.4 for integrated test case tracking.

In the UML class diagram in Figure 5.4, I have attempted to integrate the requirements analysis, change and error management with test case tracking. The main idea behind this diagram is that the original requirements along with the components or steps required to implement them have to be checked including the requisite actions. The result is test cases at all three levels which can also be designated as functional tests (for requirements), integration tests (for implementation steps), and unit tests (for actions).

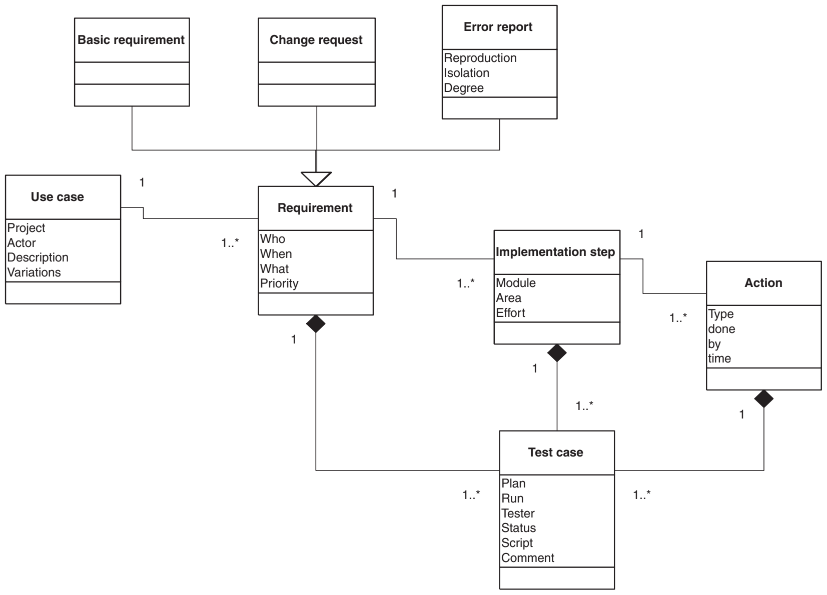


Figure 5.4 Integrated test case tracking

Implementation steps and individual actions

During the analysis phase, individual application scenarios are found which are designed to cover the program, thus resulting in the basic requirements. Over time, these requirements are supplemented by incoming change requests and error reports. These requests and reports can be understood as requirements to be satisfied by the program and incorporated in integrated test case tracking by way of this generalization step. Requirements are resolved into implementation steps which are performed in parallel or in sequence. In turn, implementation steps are subdivided into individual actions which can be allocated directly to a team member. Generally speaking, a workload estimate is made at the implementation step level. The actual times required are captured for the individual actions.

I purposely used the field names of the error and test case tables in the class diagram for the class attributes. This is designed to show where the information incorporated in the tables can be found in the class models. However, no 1-to-1 projection is possible between the tables and the class model. For example, the "done" field of the error table is resolved into a list of all "done" actions pertaining to the implementation steps allocated to the error report. There is no 1-to-1 projection unless the error report is processed in an implementation step and this step requires only one action.

By the same token, test cases allocated directly to a requirement don't feature any details on “module” and “area”. That makes sense as the requirement impacts several modules and areas for the most part. If you go in the other direction, however, and look for all the test cases that belong to a given requirement, additionally, you get the (integration) test cases and (unit) test cases of individual actions along with the directly allocated (functional) test cases.

5.6.4 Test Scripts

The various versions of test scripts are also an integral part of test documentation and tracking. A test script details the steps in which an automatic or semi-automatic test is conducted.

If a test script has to be modified because the new program version requires a different procedure, information on the test conducted thus far is lost. If you still need this information to document test runs, you should archive the test script in its previous form or print it out. If you continue to maintain the older program status, it is advisable to create a new test script. When modifying the older program status, you need the associated test scripts again to perform regression testing.

In order to keep administration effort within reasonable bounds I recommend that you also transfer the test scripts into the source code control system.

5.7 Criteria for Concluding Testing

There are no *generally applicable* criteria for concluding testing when quality assurance is integrated in the development process and linked to existing products (as described above in the section “Working Software” on page 219). This is because concluding testing is equivalent to concluding development. Up until then, everything which is produced is subjected to verification or testing. The team member in charge of quality decides when an *individual product* has undergoing “enough” testing.

Which criteria does this team member have in this case? The key aspect in making this decision is again the risk associated with the individual features of the product. The risk assessment conducted for the entire system also affects each and every resulting product. By the same token, every team member contributes to the ongoing risk assessment of the system as a whole through risk assessment of his own products. Here, too, there are interactions which should be utilized.

Frequent deliveries

The fear and loathing of a looming deadline will probably quickly be seen in perspective when a software update is supplied to the customer every one to two months. Show stoppers — or category 1 errors which bring everything to a screeching halt — detected right before delivery are minimized or remedied completely, because 1) all products being developed are tested immediately and not right before they are due to be delivered and 2) searching for the most severe bugs is done on the basis of a risk analysis which is constantly updated.

List of known bugs

So frequent deliveries means updating the list of known errors frequently, which should be included with every deliverable. A bug tracking database can be very helpful if not indispensable here. If you follow the advice given above for the integrated test case tracking model and enter and administer the basic requirements, change requests and bug reports as they are—i.e. as requirements to be satisfied by your program—you are not only able to supply a list of known bugs with a deliverable but also a list of the items that have been fixed.

6 Internationalization and Localization Testing

"Think like a wise man but communicate in the language of the people."
(William Butler Yeats, Irish Poet)

There are many software companies in the world who have produced software products for a long time. Some of these companies realized long ago that they could increase revenue by expanding their business outside the realm of their native language and country, so they began offering their products to the rest of the world. Unfortunately, creating software for many different languages isn't as simple as having your product translated by somebody familiar with the source and target languages. There are many other facets of developing and testing international software applications that need to be considered and addressed.

In this chapter I will attempt to illuminate the dark recesses of international software development and testing and help you avoid some of the more common pitfalls that companies run into when trying to create software for the global market.

In order to help you better test international products, I think it is important to understand some of the underlying issues that exist when planning, architecting and programming software for the international market. By understanding a little bit about the underlying structure and development of a program, I believe you can better test the program and increase the quality of your foreign language products.

6.1 Localization and Internationalization

Term definitions

Before we proceed, let me define some terms that will be used throughout this discussion on international software. I have worked at many software companies, and it seems that each of them used various definitions for these terms. Over the years, however, I have found the following definitions to be the easiest to work with and probably the most accurate.

- Localization

  The aspect of development and testing relating to the translation of the software and its presentation to the end user. This includes translating the program, choosing appropriate icons and graphics, and other cultural considerations. It also may include translating the program's help files and the documentation. You could think of localization as pertaining to the presentation of your program; the things the user sees.

- Internationalization

  The aspect of development and testing relating to handling foreign text and data within a program. This would include sorting, importing and exporting text and data, correct handling of currency and date and time formats, string parsing, upper and lower case handling, and so forth. It also includes the task of separating strings (or user interface text) from the source code, and making sure that the foreign language strings have enough space in your user interface to be displayed correctly. You could think of internationalization as pertaining to the underlying functionality and workings of your program.

- Localized

  During the course of this discussion, when I use this term, I am referring to programs, documentation, etc. that have been translated into a foreign language.

- Internationalized

  I use this term to refer to programs that have been prepared at the code level to properly handle international data. An internationalized program is one that will work everywhere, regardless of language and the myriad data formats.

- I18N and L10N

  These two abbreviations mean internationalization and localization respectively. You may already be familiar with these abbreviations, but I will explain them for those who aren't.

  Using the word "internationalization" as an example; here is how these abbreviations are derived. First, you take the first letter of the word you want to abbreviate; in this case the letter 'I'. Next, you take the last letter in the word; in this case the letter 'N'. These become the first and last letters in the abbreviation. Finally, you count the remaining letters in the word between the first and last letter. In this case, "nternationalizatio" has 18 characters in it, so we will plug the number 18 between the 'I' and the 'N'; thus I18N. This may not be the prettiest way to abbreviate a really long word, but these abbreviations are used throughout the industry and are much easier to type than the two words they are derived from.

If the above definitions are not extremely clear right now, don't worry. We will discuss them in detail through this chapter. I will take you through all the concepts you need to understand in order to effectively test global software products. Also, the things you will learn here are not only applicable to Windows desktop applications, but can be applied to applications on other platforms as well as, web sites, PDA applications, operating systems, and any other computer related testing you may do.

In the following pages I will discuss some of the issues that people encounter when planning and developing international software, and show you how to avoid them. Please note that some of the examples we will look at are worst case scenarios. I bring them up here since I have personally experienced several projects where companies were using these unproductive methods and wasting a lot of time and money, and I want to help you avoid these problems.

Many companies fall somewhere in the middle of the spectrum between these worst case scenarios and the best methods for creating international software. Some companies do better than others. Hopefully, after you finish this book, you will be able to help move your company into the best-practices section of the spectrum. You will help them make better products and save them money in the long run; and that is always a good thing to have on your resume.

6.2 International Planning and Architecture

As I said earlier, I think it is important to understand some of the issues that engineers and developers face when creating international software in order to better test international applications. As with any kind of development, global software development can be done in many different ways. Some of these methods will cause developers and testers large headaches and cost the company a lot of money. Other methods will be much easier to maintain and cost the company significantly less.

Create a project plan

The first step to creating any software is to create a project plan. You need to know what you are going to create, how you are going to create it, and how long it will take. Planning is a crucial first step to creating any project, so let's start by looking at some of the issues with planning an international software program.

6.2.1 Lack of International Focus in Project Plans

One of the biggest and most costly mistakes companies make is they plan and architect their products thoroughly, but they only take their native language into consideration during this critical phase of the product development cycle. These companies plan to develop their software natively and then later alter their software so it will run in foreign environments. Often times they don't even begin working on the international versions of their product until they are only a month or two away from releasing their native language version. This causes delays in their international product releases and usually results in multiple code bases, which are prone to error and costly to maintain.

Separate program functionality from user interface

With a little proper planning up front, these mistakes can easily be avoided. If companies will plan to code and test for international markets from the outset, it will make a huge difference in the quality of their product and the final cost will be significantly less. If companies separate the functionality of their program from the user interface and presentation the end user sees, they can eliminate most, if not all, of the mistakes that lead to costly international software that is difficult to maintain. If companies will look at their native language and all the foreign languages that they are planning to support as modules that will be inserted into their core product instead of trying to tweak a native language product to create a foreign language version, they would be much better off.

6.2.2 Why Native Language Centric Plans are an Issue in Development

As I mentioned previously, project plans often focus exclusively on the native language version of the software until about the time the code is deemed code complete. At this point, they start working on internationalizing their source code so it will work on various language platforms. Under this type of a project plan, developers often fail to consider international characters, data formats, and many other things relating to international software. For instance, they may hard code their time and date formats, or base their data handling of these time and date objects on a specific, usually native, format. When they do this, their code will be broken when the software is run on a foreign operating system. Fixing these issues takes time, and is one of the reasons that international software products usually ship two to three months after their native language counterparts.

Time and date formats

Above, I mentioned time and date formats, so I will use them here to illustrate why failing to consider internationalization from the beginning of a project will be a problem. First let me explain the date formats used in a few different countries so my example will make sense, then I will narrate a simple example of code that fails to take foreign date formats into consideration.

In the United States, we use the short date format "month/day/year". Therefore, the short date for Christmas in the year 2010 would be written 12/25/2010. In Germany, however, they use the format "day.month.year". Therefore, the short date for Christmas in Germany would be 25.12.2010. Finally, in Japan, they use the format "year/month/day", so our Christmas date is Japan would be written 2010/12/25.

Now, imagine that we have a program that keeps track of user's birthdays, and we are going to sell this program internationally. In our database, we are storing dates based on the format used in the United States. If a new customer from Germany installs our program and enters his birthday, February 10, 1969, in the short date format used in Germany (10.2.1969), our program will think he was born on October 2, 1969. It gets even worse. What if our customer was born on February 23, 1969 (23.2.1969)? Then our program will think he was born on the second day of the 23rd month of 1969. Of course this date is invalid and will be rejected by our program. Either way, our new German customers will want their money back; a practice which is not conducive to increased revenue and employee bonuses.

There are many other areas of development where a lack of proper international planning can cause issues. We will go over several of them in the next section.

6.2.3 Why Native Language Centric Plans are an Issue in Testing

A lack of proper international focus in a project plan also negatively affects testing. If the testing team has only planned to test the product in their native language until localized builds have been created, which is often times the case, they don't have enough time to properly ensure that the program works correctly in foreign languages. This is another reason why international versions of a product are usually delayed for up to 90 days after the native language product is released.

Even if testing does want to test for internationalization issues from the outset of the project, they can't do it unless an effective internationalization plan is created and they have the support of project managers and development. Without the support of all departments working on the project, testing will be doomed to doing internationalization testing towards the end of the product cycle; a time when they should only have to focus on localization issues.

Avoid multiple code bases

One negative side effect of this late-in-the-game testing practice for international software is multiple code bases. The English product usually ships well before the international product, and inevitably the testing department finds defects in the international builds once the native language product has shipped. To fix these defects, developers often times choose to branch the code. As I mentioned before, multiple code bases are costly and difficult to maintain. We will discuss these things in greater detail in the next section.

6.2.4 What the Plan Should Look Like

Below is a diagram that depicts the project plan that many companies tend to follow when creating software (Figure 6.1).

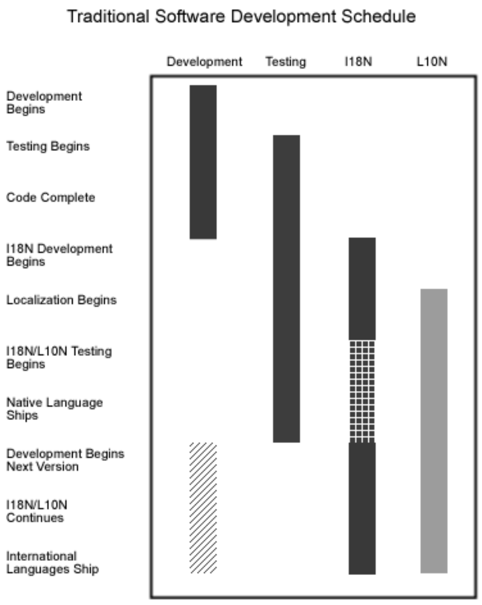


Figure 6.1 Traditional Software Development Schedule

Notice how development begins programming a little before testing. This is not related per se to internationalization, but when we talk about international testing in detail, I will discuss some testing practices that will allow the testers to begin work on the same day as development; if not earlier.

Now let's look at the internationalization aspects of this plan and discuss what is wrong with them.

First of all, notice how development switches into I18N mode after code complete (where all features in the program have been developed and no new features will be added to the program). It is this switch that can cause multiple code bases, and almost always causes international products to ship later than the native language products. Another thing to note regarding development, I have used a bar with hash lines that begins at the "Development Begins Next Version" step of the plan. This is meant to indicate that development will not be available full time to work on bug fixes for the international releases of your software. This is the part of the plan that causes features to be left out of international versions of your software.

In regards to testing, I used a bar with a square hashing pattern to indicate that testing would be working with development on internationalization, but not full time, since they still are working on the native language release. Testing must work part time on internationalization testing while still testing the native product until it ships. Once the native language version of the product ships, testing can begin testing the international versions full time.

Another thing of note is that testing does not begin testing international products until after localization has started and they have localized builds available. Testing should be done much earlier in the product cycle than this.

The biggest thing to note regarding this type of plan or schedule is that the international products ship later than the English ones. Wouldn't it be better if you could ship all of your products on the same day? Of course it would.

Now let's look at what a schedule might look like when proper consideration is given to internationalization and localization (Figure 6.2).

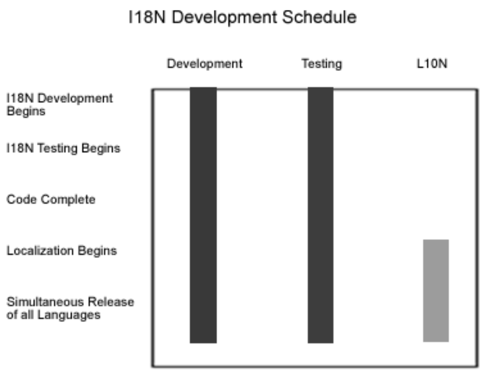


Figure 6.2 Ideal Software Development Schedule

This schedule looks a lot simpler, doesn't it? Of course these examples are both simplified, but the principles are the same. Your real plans will be smaller, too, with a little alteration to your software development and testing paradigms.

The first things you will notice in the diagram is that testing begins at the same time as development and internationalization is no longer a separate task, as it was in our previous example. Another good benefit is that testing for localization issues begins before the software has been localized. This is done using a pseudo build, which we will discuss later.

Regarding localization, notice how it is shorter in this graph than in the previous one. This is because testing and development will have flushed out most of the localization issues before the software is even translated. This makes localization much easier for you and the localization vendor.

Most importantly, notice that there isn't a separate native language release and international release. Under this plan, all languages are shipped at the same time. They use the same code and all versions have the exact same functionality. This should really please your international customers.

Planning is an integral part of software development and development can't effectively begin without a plan, however, the plan is not a magic spell for success. Proper planning alone cannot solve your international issues. There must be a change in the way you are developing and testing your software, and a good plan can facilitate this change.

Let's move on now and talk in detail about some of the software development aspects of international software that can be problematic and then let's look at some solutions. Hopefully, as we discuss these issues, you will see that you can plan for them and eliminate many of them in advance.

6.3 International Development Issues

6.3.1 Problems Working With Strings

Variables

For those who do not have any experience in programming, let me first mention variables. A variable is a place in the computer's memory that a developer creates to store information. A programmer can also retrieve that information at a later time, or manipulate it as he or she sees fit.

A variable is kind of like your bank account. You can go to the bank and create a space, or an account, for yourself that you can store money in. Once you have created that space, or account, you can deposit money into it whenever you want to. You can also go back to that account and get money out. You can manipulate the account by adding or subtracting funds from the account. Another thing to note is that you can only store one kind of thing in your bank account; money. If you try to store sandwiches in your account, the bank teller will tell you in no uncertain terms that you cannot do that.

Variables work the same way in many languages. You can insert data, extract data, manipulate data, and you can only store one kind of data in that variable. If you create a variable to store numbers, for instance, then you cannot store a sentence within that variable. If you try to store data of the wrong type into a variable, the compiler, much like our chimerical bank teller, will tell you in no uncertain terms that you cannot do that.

So how can variables be a problem when creating global software? Well, it isn't so much the variables as what the programmer does with them. For example, if I have a variable called PromptForName that is supposed to hold the string "Please Enter Your Name:", and I write the variable assignment like this in my code:

```
PromptForName = "Please Enter Your Name:"
```

Problems resulting from hard coded strings

Then every time I compile my code, the string becomes part of the executable. This is what is called a hard coded string.

Hard coded strings are the bane of global software for several reasons. First of all, if I have hard coded all of my program's strings, it is going to be much more difficult for a translator to translate my software into other languages, and the translator will be much more likely to miss something since they have to rummage around in my source code. I also run the risk of a translator accidentally translating portions of my code, which may cause it not to compile anymore.

An even bigger problem is that I will have one version of my code for each language that I want to produce. Let's say that I want to support English, the most common Western European languages, German, French, Spanish, Portuguese, and Italian, as well as the Asian languages

Chinese, Japanese and Korean. Since there are two different versions of Chinese (Traditional and Simplified), I now have to manage ten different code bases.

You may be asking why localizing my software in this manner is a problem. There are a few reasons. Let's go over them.

- ▶ Compile Time

  The first problem you will run into is compile time and the costs associated with it. I have worked on large programs that can take many hours to compile. If I only have one build machine to use, I may have to spend days compiling my program ten times for all the different markets. If I choose to buy a different machine for each language so I can build all the languages at the same time, then I have the cost of each machine plus the cost of maintaining build environments on ten different machines; which can be quite expensive.

- ▶ Defects

  Fixing defects can be quite costly if I have hard coded all my strings and have a different code base per language. Imagine this scenario. A tester has been testing and has found a severe bug in the English product. Development debugs the problem and fixes it in the English code base. Now, the developer also has to go into the remaining nine code bases for the foreign language builds and fix the same bug in each of those. Then, the build master must go and rebuild all ten languages again. This can be very costly.

  Imagine if the programmer makes a mistake and forgets to fix the bug in the German code base. When internationalization testers look at the program, they will log the same defect again; only this time against the German code base. If another developer is assigned to fix the defect, or the original developer forgets that he has already fixed the defect elsewhere, someone in development will debug the issue in the German code base, and have to go once again into the other code bases to make sure that the bug has been fixed everywhere.

  This is one of the most frustrating scenarios that developers must deal with when using multiple code bases.

- ▶ Debugging

  If you are maintaining ten different code bases for all of your language builds, you are more prone to make mistakes in one of the code bases.

Therefore, during the testing process, if a defect is found in one language you have to debug the defect in all the languages to ensure the bug doesn't exist in any of them. This also is very costly.

- Testing

  Testing is also greatly affected by hard coded strings and multiple code bases. The testing department now has to run full test suites on each and every language. The testing department must not only ensure proper localization, but also must ensure the program's core functionality in ten different language environments. Therefore, the work load of the test department has suddenly increased ten fold over what it should have been. This results in either longer work hours and weekend work, or hiring temporary contract testers to help during the localization test cycle. This extra work can be quite frustrating and costly.

As you can see, dealing with ten different code bases can become quite a costly task. It is unfortunate, but many companies create localized products using these methods. By hard coding all of their strings, they subject themselves to guaranteed delays in their releases and vastly increased development costs.

Separate strings from code

So, what can be done to make things easier and more cost effective? The most important thing is to separate the strings in your program from the rest of the code. This will be a huge benefit because now we only need one code base and we can still produce the ten different languages we mentioned earlier.

There are several different ways of separating strings from code. The basic idea is that you put all of your strings in one or more files that are separate from your code base. These are often called string tables, message files, properties files, etc. depending on which method of string separation you are using and which programming language you are using. Sometimes these files are compiled into libraries that can be linked into your code dynamically when you run the program, and other times these files are standard text files, which are parsed by your program at run time and loaded into the program dynamically. This method is a little less efficient, but it is still very usable.

Before we go on, let me illustrate one mistake that companies often make when they try to separate their strings from their code. Sometimes they will put the strings in a separate C or C++ header file and then compile the strings into the program's executable. This method is better than having your strings hard coded in your program code, and it does make localization easy because the translator doesn't need to rummage around in your source code, but it does not eliminate the need to recompile your program once for every language. Also, although you do not necessarily need to have multiple code bases if you use this method, for some reason it usually works out that you do. I would avoid using this method of separating strings from your source code. It does solve the translation issue, but usually doesn't solve any of the other issues that we have discussed so far.

Dynamic libaries and text files

Now, to get back to our discussion, it is best to either compile your strings into separate dynamic libraries, one for each language, or to have a text file for each language that can be parsed by your program during run time in order to present the correct user interface language to the user. Let's take a moment and look at the structure of these language files.

Key-value pairs or hash tables

Usually, the file with the strings in it consists of two values for each string entry. One value is the string itself, and the other value is a key to access the string. This combination is called a key-value pair or a hash table. A file containing these key-value pairs could look something like this:

```
MLoginMessage="Good Morning"
NLoginMessage="Good Afternoon"
ELoginMessage="Good Evening"
Prompt     =  "Please enter your name: "
```

Let's consider this file format example and the variable assignment example we saw a few pages back, when we demonstrated a hard coded string. Now that the strings are in a separate file, the developer no longer needs to hard code them in the program's code. Instead of typing the following line in the code, which is a hard coded string:

```
PromptForName = "Please Enter Your Name: "
```

The developer would instead access the string from the remote file or library using its key, which in this case is called "Prompt". The same line of code would now look like this:

```
PromptForName = Prompt
```

Load strings dynamically

The string will now be loaded dynamically from the correct language string file when the program runs, and the correct language version of the string will be displayed to the user. There will be one language file for every language that you want to support and the key to the string "Please Enter Your Name:" will be the same in each file; Prompt. Only the actual string value will be translated into each language, so all the program has to do is determine which file it needs to pull the string from.

In reality, it isn't as simple as creating these language files. The programmer must include logic in either the setup program or his program that will detect the locale (or language) of the operating system that the program is running on, and then load the appropriate language file or dynamic library to pull the string from. However, creating this logic isn't very difficult. In fact, programming environments like Java and Microsoft's VisualStudio .NET make it quite easy.

Let's compare the benefits of writing code in this manner as opposed to using hard coded strings in our programs.

▶ Compile Time is Reduced

  Our compile time is significantly reduced because we no longer have to recompile our program once for every language that we want to support.

  If we are using text-based message or properties files, we only need to compile our main code base and then tell the installer to put the language text files in the appropriate locations to achieve support for our ten different languages.

  If we are using compiled dynamic libraries to store our strings, then we need to compile one dynamic library for each language, but these libraries will be small and will compile in a matter of minutes, as opposed to possibly hours if we compiled ten different code bases.

▶ Testing Time is Reduced

We can test our code base on multiple language platforms a long time before localization has been completed to ensure that our software handles foreign text, currency, date and time formats, parsing, etc. correctly.

Another benefit is that if a defect is found during testing, development only has to fix that defect in one place, and testing only has to validate the fix in one place as opposed to testing ten different code bases to make sure the defect has been fixed in each one.

▶ Localization Testing is Easier

Under the hard coded string method, if a localization defect is found, meaning that testing has uncovered a string that wasn't translated or is incorrect in some way, the string must be fixed in the code base, another build must be produced, and testing must at least perform an acceptance test pass on the code to make sure nothing was broken during the simple fixing of a string.

Using the method of separating strings into different files, the string is either changed in a simple text file, or changed in the dynamic library's string table and then recompiled. Either way, the entire program does not need to be recompiled in order to test the fix; thus saving a lot of time. Also, the code base has not been touched, so an acceptance test is not required; although it is always a good idea if you have the time. You can never over test a product.

▶ Shipping Costs are Reduced

If you can get all your languages into small text files or small dynamic libraries, you can usually ship all of your language versions on one CD, or at least have one CD for English and European languages and one for Asian languages. This is more cost effective that creating different CDs for each language.

▶ Shipping Products Simultaneously

By separating your strings from the source code, you can begin testing for language issues much earlier in the development cycle. With proper planning, this can result in the ability to ship all of your language versions simultaneously, instead of shipping the localized versions of your software sixty to ninety days after your native version; as is done all too frequently. The benefit is that you can begin realizing the revenue of foreign markets at the same time as your native market, instead of two to three months later.

▶ Program Functionality is Equal across Language Products

When utilizing the error prone traditional software development method, what usually happens is some functionality is left out of at least some of the foreign language builds due do defects and time constraints.

The problem is that localization happens towards the end of a product's development cycle. Unfortunately, when there are multiple code bases, proper internationalization development and testing also happens towards the end of the product development cycle. Because of this, testers don't get to test the foreign language products until localization has taken place and internationalized foreign language builds have been created. Inevitably, about the time the test team finishes their first test pass on the foreign language builds, the native language product has been shipped and developers have been moved off of the project to work on the next release and are often times unwilling or unavailable to work on the foreign language products.

Since developers often do not have the time to fix defects as diligently as they did during the native language product cycle, the foreign products usually suffer. Functionality is often times sacrificed to meet deadlines and accommodate developers' schedules under the traditional software development method.

Under this multiple-code-base method of software development, foreign language versions are almost always created as an afterthought, which often times leads to inferior international products.

On the other hand, by separating strings and using only one code base, testers can begin testing for foreign language defects from the very outset of their test cycle. There is no longer any need to have a separate test cycle for the native language product and the localized products. They are all the same product now. They are the same code base.

Since there is only going to be one code base, then all language issues must be addressed in that code base and these issues should be identified as early in the development cycle as possible. At the end of the product cycle, when localization is usually done, testers have already flushed out all the internationalization issues and development has hopefully fixed them. This leaves only the need to check the translations; not the whole product.

- Pseudo Language Builds

Another benefit of separating strings from the rest of the code is that testers can create what is called a pseudo language build. What this means is that the native language string files are run through a parser that changes them in some way so they can easily be identified by the testing department. Next a build is created using these strings so they show up in the user interface instead of the English strings. This helps find strings that haven't been put into separate string files, problems with displaying foreign text, and problems with string expansion (which we will talk about later) where foreign strings will be truncated if an insufficient amount of space has been allocated for the strings.

Ideally, the altered strings are still readable to the native language speakers, but they account in some way for string expansion and also foreign text. For example, a pseudo language version of this string:

```
This is an example string.
```

Would look something like this:

```
Thîs îs än êxämplê strîng]]]]]]]]]]]]]]]]]]]]]*.
```

Notice how the string is still readable to English speakers, but it shows testing early on that the program can correctly display foreign text and it also shows testers that the space allocated to hold this string in the user interface is sufficient to hold the foreign versions of the string once translation has taken place. If the asterisk at the end of the string is not visible during testing, then testers will know that the space allocated to hold that string is too small and the string has been truncated. They can log defects against this and fix the problem early on so that when it comes time to translate the software, these sizing issues have already been taken care of. Also, if testing finds a string that is not in this format, they know that the string is hard coded and has not been separated into a different file.

Pseudo language builds are a key part of creating quality localized software. The help testing to identify defects early in the development cycle, and get them fixed. When it comes time to localize the product, these internationalization issues have already been taken care of. Usually, most, if not all of the defects that are found in the localized products are mistranslations and can be fixed by the localization vendor.

- Customer Service and Technical Support Benefits

  Customer Service and Technical Support departments will also benefit from the company writing international code correctly. They will no longer have to worry about issues that are language specific in your software. They also won't have to deal with complaints from international companies who buy your product and are upset because it doesn't work the same for their Japanese office as is does for their U.S. offices because some features had to be cut for the Asian language releases.

As you can see, there are a lot of benefits to architecting and writing code using separate language resource files instead of incorporating strings into your source code. Your code will be more stable, easier to maintain, and will be globally consistent. You will have faster times to market for your international products and be able to realize the revenue from your efforts much sooner. Operating costs will also be reduced significantly since you only have to focus on one code base.

Coding and architecting your software correctly for an international market is somewhat different from the standard paradigm of software development. Sometimes there is a little more work involved up front, especially when there is already some existing code, but believe me, it isn't that hard to do things right, and the benefits far outweigh the small amount of extra effort.

6.3.2 Problems Working With Dialogs – String Expansion

I briefly mentioned this earlier, but I would like to discuss in greater detail the problems of string expansion.

When words or sentences are translated into other languages, most of the time the resulting string will be either longer or shorter than the native language version of the string. To illustrate this, please look at the following two images. The first image (Figure 6.3) shows a dialog in English, which allows a user to select an Authorized User List from the drop down. This dialog looks fine in English.

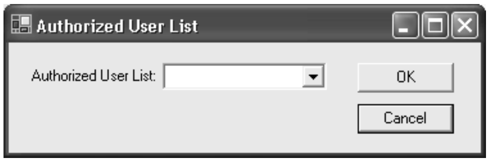


Figure 6.3 English example dialog

Let's see what happens, however, when we translate the string "Authorized User List:" into German (Figure 6.4). I have placed a lighter version of the German translation for this string under the combo box in order to show just how much of it has been cut off.

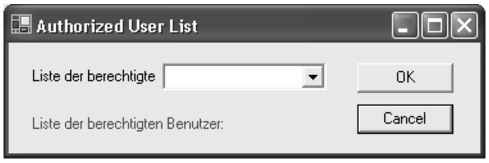


Figure 6.4 String expansion in German version

Notice that the last letter of the third word and the entire forth word have been truncated because I didn't leave enough room for the German version of the string. You will also run into the same or similar problems in other languages as well

Adjusting the layout vs. using separate resources

There are two solutions to this problem. You can either take into account the space needed for string expansion, adjusting the layout of your dialog accordingly, or you can separate your dialog resources into separate dynamic libraries in much the same way we talked about earlier regarding strings. In fact, you can even place the dialog sizing information in the same files as your string resources if you are using dynamic libraries. Let's talk about the plusses and minuses of each method.

Accounting for String Expansion via Layout

A long time ago, IBM came up with a very simple standard for estimating the space required for string expansion when creating user interfaces. Here is a simple table (Table 6.1), which is one of the many variations based upon IBM's standard and illustrates the string expansion guidelines you should follow when determining the space needed to accommodate string expansion. This table uses English as the base language and calculates the space requirements for other languages. There are other tables that are similar but slightly different, but these are the guidelines I usually use.

Number of Characters in the English String	Amount of Space Required to Accommodate String Expansion
1 to 6	15 Characters
7 to 25	2.2 times the number of characters
26 to 40	1.9 times the number of characters
41 to 70	1.7 times the number of characters
More than 70	1.5 times the number of characters

Table 6.1 String Expansion Guidelines

Using the information on this table, let's revisit the strings in Figure 6.1 and Figure 6.2. Remembering to count *all* the characters, including spaces and the colon, the original English string ("Authorized User List:") is 21 characters in length, and the German version of the string ("Liste der berechtigten Benutzer:") is 32 characters in length. If we calculate 21 * 2.2 and round the result to the nearest whole number, we get 46. As you can see, 46 characters are plenty to accommodate the translated German string. You may be thinking that 46 characters is overkill since the German string only needs 32; and you'd be right. However, you need to remember that this formula takes into account all languages. You may translate your product into a language that needs all 46 characters.

The idea behind using formulas to estimate the space necessary to accommodate string expansion in your user interface is that you would create your dialogs so that all languages will comfortably fit without you having to adjust the dialog size and recompile your program for each language. Some languages and environments don't support extracting dialog size information into separate resources, so the generic, one-size-fits-all layout method is all that is available to some programmers (this is not the case most of the time). This method of dealing with string expansion can be effective, but also frustrating if you don't create your dialogs correctly to begin with.

Let's look again at the German version of our example dialog (Figure 6.5). This time, however, we have taken into account the amount of space needed to accommodate the entire German string.

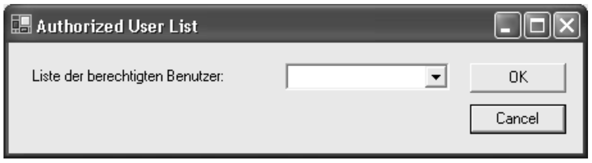


Figure 6.5 String expansion taken into account

As you can see, there is approximately 46 characters worth of space available to my German string, so there is plenty of room for it to be displayed. It is almost too much room, but not really that bad. However, if we look now at the English version of this dialog (Figure 6.6), we are going to want to start logging some bugs.

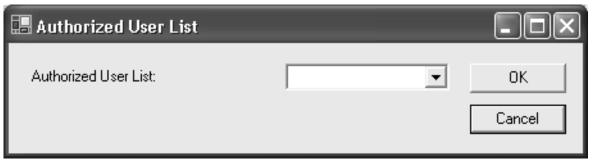
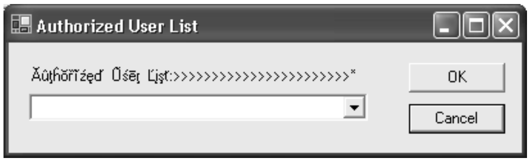


Figure 6.6 English dialog with room for string expansion

There is still 46 characters worth of space available to my English string, but my English string needs less than half of that space. Since there is only one stand alone string and one stand alone combo box on the page, I suppose it is easy to determine that they go together, but the dialog just looks stupid.

When using a single layout to accommodate all the different language versions of your program, you will want to come up with a layout that is not going to be affected as much by string sizes. One thing you don't want to do is place labels to the left of text boxes, combo boxes or other controls. Instead place them above.

Let's look at another example of our dialog (Figure 6.7) and see if this layout works a little better. In this example, I am going to use a pseudo language string to show what they would look like if you were testing a build created with them, and also to show the length of the English string and also the maximum length of the allocated space, which is 46 in this case.


Authorized User List

Ǻûţĥŏřĭźęď Ůśēŗ Ļįşţ:>>>>>>>>>>>>>>>>>>>>>>>>*

Figure 6.7 Pseudo language dialog

As you can see, the length of the string becomes a non-issue when the dialog is laid out in this manner. Any length of language string should fit quite nicely above the combo box, and the dialog will still look nice.

Design dialogs to accommodate expansion

This example is kind of a trivial one. Most dialogs and user interfaces that you test will have multiple user interface elements on them. It can be tricky sometimes to construct a dialog that will accommodate any length of string and still look nice. This is the drawback to creating international software using a single layout that takes string expansion into consideration; attractive user interfaces can be difficult to create. The plus side of this method is that you only have one dialog to worry about and you can test and fix sizing problems with the dialog very early in the development cycle.

If your software product is going to use this method for laying out your user interface, either out of necessity or choice, it is absolutely imperative that you create pseudo language builds. You must identify string expansion issues such as truncation or inelegant interfaces early in the development cycle so they can be fixed effectively. If you wait until the end, when you have actual localized builds to test, I guarantee these layout problems will cause your product to ship late.

Accounting for String Expansion via Separate Resources

Another method that can be used to accommodate string Expansion is separating your dialog resources into separate dynamic libraries. Microsoft's development tools make this easy to do, so if your company writes Windows applications they can easily use this method to create their user interfaces. Other languages, tools and environments also support creating interfaces this way.

Just as we talked about doing with the strings in our program, it is possible to put your dialog information in a separate dynamic library that is loaded into your program at run time. Also, just like with the program's strings, you need to create a separate library for each language. This means that each language's user interface can be sized differently.

Separate dynamic libraries allow custom dialogs for each language

The positive side of creating dialogs and user interfaces using this method is that you can customize each language's layout; making each language version of your software look as elegant as possible. The drawbacks to doing your user interface this way is that you have to resize one set of dialogs for each language that you want to create, and you can't really make the dialogs look their best until after the first drop from localization has been finished since you don't know exactly how long the strings are going to be for each language. This method takes a little bit more effort sometimes, but I think your dialogs end up looking better. If you test your program for internationalization issues from the outset, you should have plenty of time to deal with resizing these dialogs towards the end of the development cycle, when localization usually takes place.

6.3.3 Builds and Installers

Another important aspect of developing international software is having a build environment set up to support it. What this usually entails is creating an environment that supports a single version of your code, and multiple versions of the language files; whether they be dynamic libraries or standard text files. Every time a new build is created, the code base along with all the language files should be created.

Design of setup program

The setup program should also be designed to support these files, and should either automatically detect which language file should be installed based on the user's operating system's language settings, or the installer should install all the language files and the program itself should decide which resources to load when the program runs.

The language files can all be in your native language or pseudo code to begin with, but as a tester, you should test the product on all the language platforms you plan to support and make sure that the dynamic resources are loaded correctly.

If your build master or the maintainer of your setup scripts fails to create a build environment and installer that will handle multiple language resources, then your build process will be broken, and you should log a defect against the build environment.

A proper build environment and installer are things that should be planned for from the outset of the development cycle.

Before we go on, just for the sake of clarity, let's look at an example of a Windows directory structure (Figure 6.8) that we might find on an installation CD for a product that has been correctly built using the methods of string extraction that we have discussed so far. Also note that the build environment itself may have a similar directory structure.

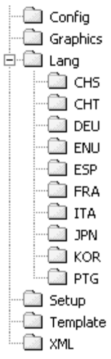


Figure 6.8 Directory Structures and Language Codes

Given this structure, here is what should happen during the installation process. The installation program would detect the user's operating system's language settings and then get the correct language files from the appropriate language directory (such as FRA for French). The setup program would then install these language files along with the rest of the program on the user's computer. This is all done automatically by the installer and the user only sees the localized version of your software in the same language as their operating system.

Another option that I sometimes see used, especially on programs that run from a server, is to install all the different language files onto the computer instead of just installing one language. Then, the language is either selected automatically by the program based on the locale of the client machine, or there may be an option screen built into the software that allows users to select which language they wish to use. In this case, the language selection logic is done by the program itself and not by the setup script.

Language codes

Before continuing, you may be wondering about the three letter codes I used in the example directory structure above. They are language codes that are commonly used by Microsoft. Other languages and environments may use different codes.

Below are two tables that illustrate both the Microsoft standard language codes (Table 6.2) and the Java standard language codes (Table 6.3). I am only including codes for the languages you most often will localize products into. There are many other language codes available to you as well. If you are planning to support a language that is not in the list, such as Arabic, Hebrew, or Russian, and are unfamiliar with the language codes, you can find them by visiting Microsoft's website, Sun's Java web site, or by searching on the internet.

CHS	Chinese Simplified
CHT	Chinese Traditional (Taiwan)
DEU	German (Germany)
ENU	English (United States)
ESM	Spanish (Mexico)

Table 6.2 Microsoft language codes

ESN	Spanish (Spain - International Sort)
ESP	Spanish (Spain - Traditional Sort)
FRA	French (France)
JPN	Japanese
ITA	Italian
KOR	Korean
PTB	Portuguese (Brazil)
PTG	Portuguese (Portugal)

Table 6.2 Microsoft language codes (cont.)

de or de_DE	German (Germany)
en or en_US	English (United States)
es_ES	Spanish (Spain)
es_MX	Spanish (Mexico)
fr or fr_FR	French (France)
it or it_IT	Italian (Italy)
ja or ja_JP	Japanese
ko or ko_KR	Korean
pt_PT	Portuguese (Portugal)
pt_BR	Portuguese (Brazil)
zh_CN	Chinese Simplified
zh_TW	Chinese Traditional (Taiwan)

Table 6.3 Java languages codes

Notice that Microsoft has built language and country codes into their three letter language code scheme and Java has separated the country from the language code by an underscore. In fact, in Java you can leave the country codes off all together and only use the two character language code if you would like to. For example, if you are only concerned with the Spanish and German languages and don't care about the country differences, you only have to use the first two letters "es" for Spanish, "de" for German, and so on.

Java also has one more level of lingual granularity called a region code. These are useful if you are supporting different dialects that exist in a single country. Personally, I have never seen programs written with this level of locale awareness built into them, so you will probably never see or use the region codes available in Java.

Region codes

Character Sets and Codepages

Character sets and codepages are another bothersome aspect of creating international software. If you have been testing long, I'm sure you have seen strings that look like blocks, ticks, and smiley faces. This happens when you try to view the characters from one language's character set when your machine is using a character set for another language.

Single-byte vs. double-byte

In the United States, we use a single byte codepage. Japan uses a double-byte codepage. Single-byte codepages can hold a maximum of 256 different characters. Asian languages, such as Japanese, have far more than 256 characters. To support these languages, the codepages must use two bytes to represent one character. By using this double-byte method, the Japanese codepage can support up to 65,536 different code points.

Because different countries and languages use different code pages, it is sometimes difficult to share data between different languages. If my Japanese friend writes me a letter in a codepage based program, even if I have the same program on my English machine, I most likely will not be able to read what my friend has written.

5C characters

Asian languages in particular can be problematic, especially if programmers are trying to write their own routines for handling the double-byte characters that are used in Asian languages. One problem that programmers run into sometimes is with what are called 5C characters. 5C is the hexadecimal value of a backslash character in English. Unfortunately, several Asian language characters end in the hexadecimal value 5C. What happens is that programmers will be parsing an Asian string, they will run into the hexadecimal value 5C, and the program will think it has hit a backslash and will destroy the rest of the string. This is not as big an issue if you are using a language library created by a third party. These issues have usually been taken care of for you. It is something that you, as a tester, will want to look out for though. If you see a string that looks fine until half way through, you will know what has most likely happened to it.

Another problem that can look the same from a testing point of view is where the programmer is deleting the last character in a string and forgets to check whether it is the first or last byte of a double-byte character, and only deletes the trailing byte. This will cause garbage to be displayed on your screen. Most libraries handle this automatically, so you will most likely only see it when programmers try to handle double-byte text in their own custom libraries.

Unicode standard

There is a method that gets around a lot of the issues with codepages and Asian languages. This standard is called Unicode. Unicode supports many different written languages in the world all in a single character encoding. In fact, it even supports some fake languages such as Klingon.

Depending on what language and programming environment you are using, writing a program so it supports Unicode instead of codepages is fairly easy. In Visual C++, for instance, it is simply a matter of setting a compiler flag and using certain string handling macros. These are well documented in the Microsoft Developer Network documentation, and are fairly easy to use.

Unicode is a very useful standard since it will probably support all the languages you want to translate your software into, however it can cause some problems in the Asian languages if it is not used correctly. I work a lot with Japanese (both the language and the people) and programmers in Japan hate Unicode because they find it hard to deal with. However, there are many excellent Unicode programs used in Japan that have not caused anybody major problems. An example of this would be Java. Java is quite popular in Japan, and it uses Unicode by default.

There are several reasons the Japanese, and probably other Asian programmers, have this acrimony towards Unicode. First of all, the number of characters that Unicode can support is limited and the Asian languages are quite vast. Since China, Japan and Korea all use what the Japanese call Kanji, the Unicode standard, to save space and accommodate many languages, has the characters from all three languages lumped into one section of the Unicode encoding. This is a problem because the characters in these three languages are sorted differently and sometimes the characters are written differently, therefore, a character can be displayed that doesn't look quite right. This unification of the languages causes other concerns in Asia as well, but these are beyond the scope of this book.

Another problem occurs if you are converting from the local codepage to Unicode and back. Sometimes this round trip conversion will change one character into a different one. I remember one time seeing the Japanese word for "view" change into the word "boil"; which didn't really convey the appropriate meaning in the program at all.

One of the reasons people convert between local codepage and Unicode is because of the way networking works. Networking packets are sent using single byte streams and Unicode doesn't fit too well into that mold. But as we can see, this conversion between codepage and Unicode has the potential to be a problem for Asian languages.

UTF8

There is a solution to this problem that you may have run across if you have used the internet to any degree. This solution is called *UTF8*. UTF8 is a variable length encoding of Unicode that can be easily sent through the network via single byte streams. If you are creating a network program that must pass data between clients and servers on a network, it is better to convert from Unicode to UTF8 than to convert from Unicode to codepage. This doesn't solve the problem of a few characters being written a little differently than people are used to, but it does solve the problem of characters magically changing into something else.

I know I have mentioned some of the foibles of Unicode here, but please don't misunderstand, it really is a great encoding to use if you want to create international software; especially international software that can easily share data between disparate languages.

6.3.4 Achieving Success through Proper Planning and Architecting

Okay, we have discussed in detail a few of the issues that companies can run into when creating international software from an architectural and development point of view. We have focused mainly on the separation of strings from the rest of the source code, dealing with string expansion in the user interface, and build and installation issues. I have also shared several solutions to these issues throughout the last several pages. Now I would like to put everything together and summarize several steps you can use when planning a project on your own or within your company that will help overcome many of the common obstacles of internationalizing and localizing your code.

Before listing all the areas that testers can help, let me mention that you are no longer just responsible for testing the software. You should test the project plan to ensure it has all the internationalization elements needed for a successful global release. Log defects against the project plan if you need to and have those responsible for the faulty plan make the appropriate adjustments. By becoming involved with the project prior to the first build, you can make internationalizing and localizing you product easier and cheaper.

Planning

I18N integral part of development plan

This part is crucial. No matter how willing and diligent a testing department is in following these internationalization practices, if the project and product managers, development team, and other stakeholders in the project don't cooperate, your project is destined to fail; or at least not go very smoothly. Everyone that works on the project must make the commitment to make internationalization and localization efforts a standard part of the development cycle. It can no longer be an afterthought. It needs to be discussed in core team meeting, test meetings, status reports, etc. and managers need to manage internationalization the same as they manage other aspects of the project.

My experience has been that the development managers and development teams are the hardest to convince. They are used to programming in a monoglot, or single language, environment. It may be hard to convince them to make changes to their process to support a polyglot development paradigm, but it is well worth the battle if they come around.

Build Environment

As I mentioned earlier, your build environment must support an international build. If the build environment doesn't support this in the first build of the product you receive, log a defect against it. An internationalized build environment should be a priority in the product development lifecycle.

Internationalized Installer

Remember, your installer needs to be internationalized. It needs to be able to either detect what the user's language is, and install the correct language and user interface resources, or it needs to install all language related files and let the program decide which resources get loaded.

Consider size of language resources

Sometimes the second approach is not possible. I have seen language resources get quite large. A user may not want to install 300 extra megabytes of language information that they may never use. I recommend considering the size of your language resources before dumping them all on a user's hard drive.

Development

The development team needs to commit to extract their strings from the core program from a very early stage; preferably from the first line of code they write. They also need to consider string expansion, codepages, Unicode, and all the other programming and architectural issues we have discussed so far.

Development should also look at their native language as being just another language module that will be plugged into the core product. They should never treat their native language as part of the core program.

Internationa-lization

Development should also be committed to fixing all internationalization defects from the outset. Internationalization is an integral part of coding if you are writing for a global market. It is as essential as functions, methods, classes, objects, variables, libraries, etc. Just as a native language program isn't much without these things, a global product isn't much without attention given to internationalization. Remember, no procrastinating!

Testing

Testing should test the software on localized environments from the moment they receive their first build. In fact, I would recommend that the majority of your testing takes place on European and Asian language environments. English is supported on every language platform available, so you can rest assured if your program runs in European and Asian language environments, it will run correctly in English. It is always good to do at least some testing in English though, just to be sure.

We will go over all the aspects of testing internationalized and localized programs in the next section.

Localization

Different types of localization vendors

Once the programs user interface has been frozen, it is time to send strings to a localization vendor for translation; unless your company has their own translators. There are many localization companies in the world. Some of them are content to receive strings from you, translate them, and then give them back; others want to partner with you and become an extension of your company. It is up to your company the level of help that they need. I like to be in complete control of internationalization and localization efforts at my company, so we use the former type of translation vendor. Your company may require a lot more help; especially if you are just starting to tread out into the global market. In this case you may want to work with a vendor who provides a deeper level of service.

No matter which type of vendor you choose, make sure that you use vendors who use native speakers to do translations. It is preferable too if the translator lives in their native country. Sometimes people's language becomes corrupt after living in a foreign country for a while; I know mine did. It is important to use native speakers, since that is really the only way to ensure quality translations.

I have worked at several large and well-known companies who have produced atrocious Japanese translations and products. I'm sure their other language translations were odd too, but Japanese is the only foreign language that I can understand. If you do a search on any book at Amazon.com that has some negative ratings, nine times out of ten, the low rating was given due to spelling or grammatical errors. I think this effectively illustrates how important a correct, quality translation is to the success of an international software product.

Quality assurance

Another thing I highly recommend is requiring your localization vendor to come in after the language builds have been completed and do a quality check of the translation in the context of the software. I also highly recommend that the person doing the review is not the same person who did the translation. You should have these localization quality assurance checks once after the initial translation and localize builds are complete, and then have them come in again after all the translation errors, if there are any, have been fixed. This will cost a little bit, but it will ensure quality and quality could bring you more customers.

6.4 Internationalization Testing

I think we have covered plenty of information to help you understand some of the issues that plague international software projects. This should help you better understand the rest of this chapter, where we will cover internationalization testing tasks in detail. You may also notice that in the realm of international software testing, in order to reduce costs and make the process go smoothly, testing is not just limited to running the compiled program and logging bugs. There are other aspects where testing should become involved, such as the build layout, installation file structure, product localizability, etc. We will talk about all of these things in the following pages.

6.4.1 Start Testing from Day One

If you will recall, I mentioned in the previous section that the traditional project schedule usually has testing start work after the first build of the product is created. I also said you should not wait that long to begin testing. There is more to a product cycle than just the software you are creating. Traditionally, it has been this myopic focus on the product itself that has caused some important aspects of international software development to be neglected.

At many places I have worked, testers are often treated in much the same way one might treat a peanut butter and salmon sandwich. Nobody wants to deal with them. However, testers can be very effective at a much earlier stage in the development cycle if they are allowed to become involved.

Involve testers in planning stage

In order for this to work, testers must become an integral part of the planning stage of the software. Frequently, testers are left out of this phase of the product cycle and only become involved once there is a tangible build for them to work with. However, there is a lot to do when you are making international software, so testers might as well jump in and get started. Here are a few things that testing can work on prior to receiving a build:

Planning

During the planning phase of the product cycle, testing can test the plan itself. The plan is a very important aspect of developing international software since all of the teams involved must support internationalization completely for it to work. If the plan does not account for internationalization properly, then testing should log a defect against the plan, and the product should not continue until the plan has been corrected and ratified.

This is why I think it is so important for testers to understand the underlying issues of international software development. By understanding the issues we have talked about, and will talk about, you can help your company plan their international products correctly in advance. A well thought out and supported international plan up front will save you a lot of time and effort during the product cycle.

Build Environments

Testing should be aware of the languages your company plans to support. Once you know the languages, you can work with the build master to ensure the build is able to create all languages you need to support. If the build environment isn't adequate, then you should log a defect against it and make sure it gets fixed.

Architecture

Testing can be involved at the architecture stage of the product cycle and log defects against parts of the planned architecture that are not going to work correctly in an international environment.

For example, if your company is planning to support Unicode in their products, and in a design document somebody has suggested converting from Unicode to codepage when transferring data across the network, and then converting back to Unicode once the data has arrived at its destination, you could bring up the issues that such a conversion causes in the Asian languages, and suggest they convert to UTF8 instead. Again, by planning correctly up front, you will save time later on because developers won't have to rewrite this portion of their code and you wont have to run a regression test on it.

Once all the plans and architecture issues are worked out, and a build has been created, it's time to do what you do best. Test.

6.4.2 Testing Your Program's Installation

Of course, in order to test your program in any environment, you must install it. There are some things you need to watch out for, however, when testing the installation in foreign languages.

Check default install directory

You will want to check the default directory you are installing to. Using Windows 95 and up as an example, in some countries, like English and Japanese, the directory structure contains a "Program Files" directory (which is where most Windows programs install to by default), however, the same directory is called "Archivos de programa" in Spanish. You want to make sure the developers are using the Windows alias for the Program Files directory instead of trying to hard code "Program Files" into their install scripts.

This next item is becoming less and less of an issue since the Japanese NEC PC-98 machines are finally being phased out. However, if you have one to test on, you need to make sure your program will even install on the PC-98. Unlike every other PC in the world, the PC-98's first hard drive is A: instead of C: (there are other architectural differences as well). If your software is going to support the PC-98, you need to make sure to test the installer on it since most programs aren't accustomed to running on what looks to them like a floppy disk.

Check uninstaller

This should be a part of your standard testing, but to be thorough, make sure you check the uninstaller for your program too. I have on occasion run into cases where the uninstall program failed on foreign machines.

6.4.3 Testing for Localizable Strings

Localizable strings are strings that are no longer hard coded and compiled directly into the programs executable files. As I mentioned earlier, these strings should be pulled out of the code and placed into either dynamic libraries or language text files.

There are a few ways you can test for this. Some methods focus on the source code and other ways focus on the resource files.

First of all, you can obtain the source code for your project and manually go through looking for strings. The downside to this method is that you have to be somewhat familiar with programming in order to do it, and it is sometimes hard to determine if something is a localizable string or not. There are several tools on the market that will help you do this type of testing, but they are usually not very effective. I used one of these programs on some code I was working on a few years ago. I received over a thousand warnings regarding hard coded strings. Only two of them were valid.

Create a pseudo build

An easier method for testers is to create a pseudo build as described in the previous section. This method focuses only on the resource files, not the code. The most difficult part about it is that you have to run a full test suite against your code to make sure you test all the strings, but if you schedule this task simultaneously with a scheduled top-down test, it should be very easy. Also, please remember that you must check all error message dialogs for hard coded strings as well. Testers often forget to perform this step.

You can create this pseudo build manually or automatically using a small tool, which your company will probably have to create. To create this build manually, make a copy of your string table and edit it so that all of the strings contain at least a few foreign letters inside of them. This can be very time consuming. A better option is to have a developer write a simple utility to do this for you. A developer shouldn't have too much trouble writing a utility that will extract strings from a string table or language text file and convert them into foreign characters that can still be read and understood by a tester. The developer should also add functionality to account for string expansion as outlined in Table 6.1, "String Expansion Guidelines," on page 258.

Once you have a string table or file that has been modified with these pseudo language strings, have the build master create a new build for you with these strings in it. When this build is available, perform a complete test pass on the code using your test suites or test cases. Log a defect against any string that does not show up in this pseudo language. If a string is not in the pseudo language, then you know it is not contained in the resource file and is therefore hard coded into the program.

By periodically creating this pseudo language build and testing against it, you will ensure that all of your program's strings are separated out into resource files instead of being hard coded in an executable. This will make localization a lot simpler since you know where all the strings are, and you have also accounted for strings expansion by using a pseudo build and resizing your dialogs and user interface where necessary.

Sometimes developers will need to keep strings inside of the executable. For example, if I had a string in my program that warned the user of a file I/O error on his hard drive, I wouldn't want to have to read that message from a separate dynamic library file. It wouldn't work. If a file I/O error is occurring on my hard drive, how am I going to access a dynamic library file to extract the error message?

There are a couple of ways to have these critical message strings compiled into the executable and still maintain the separation of strings and code that we want (although to a lesser extent). We mentioned this earlier when we talked about placing strings in a header file and compiling them into the executable. Developers should only do this when absolutely necessary. From the testing aspect, however, the program should look the same either way. You will just need to make sure to run these strings through a pseudo language tool so they will show up correctly during your tests.

6.4.4 Testing With Foreign Characters

We talked a little bit about the way character sets work before, and you may be asking yourself how you test them. It's really quite easy.

The best way to test various character sets is to test your program on localized platforms for each locale you plan to support. On these platforms, make sure you enter foreign characters into every part of your program that accepts textual data. Test the data handling capabilities of your program using these characters. For instance, if you have a program that requires a username and password, enter foreign text for both and make sure that functionally everything works.

Entering European or Latin characters is quite easy on Windows. You can either do it by searching for these characters in Windows' Character Map tool, or you can enter them via escape sequences.

The first method, using the Character map, simply involves opening the tool, which is located either in the Accessories menu or the System Tools menu inside the Accessories menu, and searching for foreign characters that you want to insert in your program. Once you find a character you wish to use, you must click on the Select button to grab it, and then click on the Copy button to copy it to the clipboard. Now you can paste it into the program you are testing. This can become tedious since there is a lot of work involved to get each individual character.

The second way, which I find easier to use once you get used to it, is to use escape sequences to input these foreign characters. You do this by holding down the ALT key and typing in certain decimal values using the number pad. Here are two tables containing sequences you can use to input upper ASCII characters.

ALT + Number	Result	ALT + Number	Result
ALT + 128	Ç	ALT + 148	ö
ALT + 129	ü	ALT + 149	ò
ALT + 130	é	ALT + 150	û
ALT + 131	â	ALT + 151	ù

Table 6.4 DOS Codepage Values

ALT + 132	ä	ALT + 152	ÿ
ALT + 133	à	ALT + 153	Ö
ALT + 134	å	ALT + 154	Ü
ALT + 135	ç	ALT + 155	¢
ALT + 136	ê	ALT + 156	£
ALT + 137	ë	ALT + 157	¥
ALT + 138	è	ALT + 158	_
ALT + 139	ï	ALT + 159	ƒ
ALT + 140	î	ALT + 160	á
ALT + 141	ì	ALT + 161	í
ALT + 142	Ä	ALT + 162	ó
ALT + 143	Å	ALT + 163	ú
ALT + 144	É	ALT + 164	ñ
ALT + 145	æ	ALT + 165	Ñ
ALT + 146	Æ	ALT + 166	ª
ALT + 147	ô	ALT + 167	º

Table 6.4 DOS Codepage Values (cont.)

ALT + Number	Result	ALT + Number	Result
ALT + 0128	€	ALT + 0210	Ò
ALT + 0191	¿	ALT + 0211	Ó
ALT + 0192	À	ALT + 0212	Ô
ALT + 0193	Á	ALT + 0213	Õ
ALT + 0194	Â	ALT + 0214	Ö
ALT + 0195	Ã	ALT + 0215	×
ALT + 0196	Ä	ALT + 0216	Ø
ALT + 0197	Å	ALT + 0217	Ù
ALT + 0198	Æ	ALT + 0218	Ú
ALT + 0199	Ç	ALT + 0219	Û
ALT + 0200	È	ALT + 0220	Ü

Table 6.5 Windows Codepage Values

ALT + 0201	É	ALT + 0221	Ý
ALT + 0202	Ê	ALT + 0222	Þ
ALT + 0203	Ë	ALT + 0223	ß
ALT + 0204	Ì	ALT + 0224	à
ALT + 0205	Í	ALT + 0225	á
ALT + 0206	Î	ALT + 0226	â
ALT + 0207	Ï	ALT + 0227	ã
ALT + 0208	Ð	ALT + 0228	ä
ALT + 0209	Ñ	ALT + 0229	å

Table 6.5 Windows Codepage Values (cont.)

I haven't provided every possible ALT + Number Combination possible in these codepages, but this should be enough to get you started. Also, notice that the only difference between the ALT + Number combinations for the DOS codepage and the Windows codepage is that the numbers used to input Windows codepage characters have a zero at the beginning of the number. This may seem hard to you at first, but I guarantee, after you enter a few characters, you will remember the ALT + Number combinations and will find it easier to input characters this way than to use the Character Map tool.

If you are testing a program on AIX, then you can input accented characters in the same way you do on Windows. On Solaris, you must use the Compose key instead of the ALT key. On Linux platforms, you must set up your system to support Dead Keys. This is fairly easy to do with distributions such as Red Hat and SuSE. Other Linux distributions require you manually set up Dead Keys functionality. Please consult the documentation for your flavor of Linux for information on setting up Dead Keys.

Before we continue, please note that simply displaying foreign text in your program's input fields is not enough. For data entry fields, you will need to make sure that the data you entered is not only displayed on the screen correctly, but also that the data has been transported correctly to the database or other storage mechanism. You can do this by looking at the database directly, or by viewing portions of your program that will pull data from the database and display it on the screen. A good place to look to verify that your foreign data has successfully made the round trip to and from your database is in reports, if your program supports them, since they nearly always pull data from a database and display it to the user.

NOTE: Sometimes You Don't Want Certain Characters to Work

The example of the login dialog I mentioned a while ago brings up a very interesting point. There is at least one case where you absolutely do not want certain foreign text to be accepted by your program. This is when you are using masked fields, such as the password section of a login prompt, with Asian languages. The reason is due to the way Asian languages input their characters.

IME and FEP

Asian languages use what is usually called an *IME* (Input Method Editor), or sometimes a *FEP* (Front End Processor). An IME accepts roman text as input, and then uses a dictionary to create the characters used in Asian languages. I will use Japanese to demonstrate how IMEs work, and then explain why you do not want to support them in the instance of passwords and other masked fields.

Let's say I wanted to enter the name Miko as a password in Japanese. With the IME set to input Japanese, I would type the roman characters "mi", which would give me the character み, and then I would type the roman characters "ko", which would give me the character こ. These two Japanese Hiragana characters will be displayed either in the password text field, or in an IME text area somewhere on the screen. Once I have the Hiragana displayed, I need hit the space bar to bring up a Kanji combination. Since there are usually several combinations of Kanji available, I will need to select the appropriate writing or spelling if you will, of the name I am trying to enter from a list in the IME. Using the IME that comes with Windows 2000, if I enter the name Miko, I will receive the following character combinations to choose from:
巫女, 御子, 皇子, 皇女, and 神子.

Finally, I select the correct writing for Miko from the list and press the enter key to input it into my password field. However, as you can see, the characters I would be trying to enter into my masked field are displayed plainly on my screen in order for me to determine the correct characters to input into the password field. Since the whole idea behind a masked field is that people can't read your password over your shoulder, you don't want to allow masked fields to accept Asian characters that must be entered via an IME or similar mechanism.

If you have masked text fields in your program, you want to make sure the IME is disabled when the cursor is inside the field. If it is not, then you should log a defect against your program. Also, remember that English, European languages and other single byte languages don't use IMEs so you will want to test password fields using these characters.

6.4.5 Double-Byte Overlapping Characters

Double-byte languages tend to be more challenging for developers than single-byte languages are, so there are some tests you will need to perform on double-byte languages that you don't need to worry about in single-byte environments. One of the things that you need to test when using double-byte languages is overlapping characters. In order to explain how to test them, I first need to explain what they are.

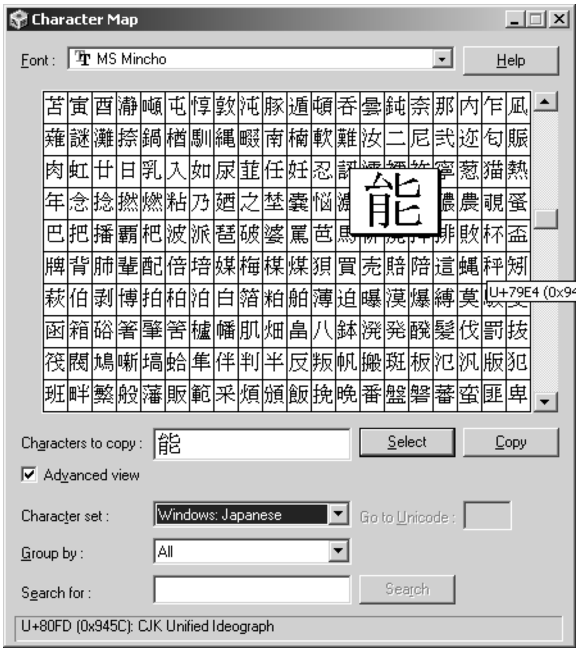
Previously, I mentioned that the ASCII value for a backslash character is 0x5C. There are several Japanese characters that use this hexadecimal value in the trailing byte of a two-byte character. This is what I am talking about when I say overlapping characters. They are values that can be mapped to more than one character depending on the context in which they are used (single-byte or double-byte). 0x5C is mapped to the backslash when it is not part of a double-byte value, but it can be used to display any number of characters that use the 0x5C value as part of a double-byte character.

> **NOTE:** The Japanese representation of a backslash is a YEN sign (¥) instead of the backslash character (\ ) that you are probably used to. Therefore, do not be alarmed if you type a backslash and get a YEN symbol when using a Japanese machine. It is supposed to work that way.

This can cause problems in programs if the program recognizes the 0x5C value as a backslash when it really is part of a different character. For example, let's assume that the program you are testing is a Windows program with a custom dialog that lets users save files to the hard drive. We will also assume this program has not been properly internationalized and does not support overlapping characters correctly.

If a Japanese user were to open this program's custom file dialog, and enter a string containing a 0x5C character, the file would fail to save since the dialog would interpret the last byte of the character as a backslash and Windows doesn't support the use of the backslash character in a file name.

Although you don't run into problems with these characters as much as you used to, I still recommend checking for them. The best way to enter these characters into your program on Windows is to open the Character Map tool (Figure 6.9), which is located either in the Accessories menu or the System Tools menu that resides in the Accessories menu.



Font : MS Mincho

Characters to copy : 能

☑ Advanced view

Character set : Windows: Japanese

Go to Unicode :

Group by : All

Search for :

U+80FD (0x945C): CJK Unified Ideograph

Figure 6.9 Character Map tool

Open the Advanced View by checking the "Advanced view" checkbox, and make sure to set your Character set to "Windows: Japanese" as is shown in Figure 6.9. This will use the Japanese codepage values instead of the default Unicode values, which are different.

The character that is shown bigger than the rest is displayed that way because I clicked it with my mouse. If you look at the status bar area of the dialog, you will see the text "U+80FD (0x945C): CJK Unified Ideograph". The number you want to check is the one in parenthesis. Notice how the last two digits are 5C?

Finding a 5C number

You may be wondering how to find a 5C number in this sea of characters. It is actually quite easy since the characters are in numerical order. All you have to do is scroll to a place where the Kanji characters begin, hold the primary button down on your mouse, and move it through the characters until you hit a character where the second to the last digit of the hexadecimal number is a 5. Now you just need to move your mouse horizontally to the right (or down a row if you are already on the right column) until the last digit is a C.

Once you have the character you want to use in your tests, press the Select button to place that character in the "Characters to copy" field, and then press the Copy button to copy that character to the clipboard. Once you have done all this, simply paste the character into your program and run your tests to see if the program will properly handle the character.

0x5C is not the only overlapping value; however, it probably causes the most problems on Windows systems because when they do get misinterpreted as a backslash they cause not only display problems, but functionality problems as well. The "#" character (0x23) character can cause problems on platforms such as Linux, *BSD, and UNIX because the "#" character is used to indicate comments.

If you are testing Japanese, one of the best places on the internet to get Japanese strings for use in your testing is Jim Breen's web site at Monash University. The URL is: http://www.csse.monash.edu.au/~jwb/wwwjdic.html. If you click on the "Search for Words in the Dictionary" link, you can enter English sentences into the text field and the web site will provide you with Japanese translations of the string, which you can copy into the program you are testing. For the other languages, I recommend using Babelfish. It isn't as good as Jim Breen's site, but works well enough. I am not providing a link for Babelfish, since there are many different locations that offer Babelfish services. Just do a search for Babelfish using your favorite internet search engine and select one of the myriad Babelfish sites available.

For those of you who don't speak an Asian language, or are not familiar with the IME, you will find that cut, copy and paste can be three of your best friends.

6.4.6 Keyboards

If you are going to support international platforms with your software, you should also test using international keyboards. Some international keyboards have functionality that is not found on English keyboards. The Japanese keyboard has several buttons that provide functionality exclusive to their language; such as allowing the user to switch input modes between the four different writing systems commonly used in Japan.

Since many foreign keyboards have functionality that may not be available on your native language keyboard, I recommend getting at least one keyboard from each locale you plan to support and testing your product using them.

I have seen a program in the past where foreign data was able to be entered correctly using an English keyboard on a Portuguese system, so the product was shipped. However, when the program was installed by people in Brazil, who were using a Portuguese keyboard, they were not able to enter the C Cedilla character (Ç).

I have only worked for one company that was willing to provide the budget necessary to buy foreign keyboards. Interestingly enough, it was the same company that shipped the product mentioned above, and the budget came after this defect was discovered. I suppose they found buying a few keyboards cheaper than developing and distributing a patch to their Portuguese customers.

Another reason to get a few foreign keyboards is convenience. Foreign language keyboards often times have different layouts than those used in English speaking areas. One point of frustration I have seen with many testers is when they try to type a password on a German language OS using an English language keyboard, where the password contains either a 'Y' or a 'Z'. On German keyboards, the 'Y' and 'Z' are in reversed positions compared to an English keyboard. Also, to add to the problem, password fields are masked so you cannot see what you are typing. Therefore, instead of typing the password "B-e-l-L-y-2-4", which is what they are typing according to the layout on the English keyboard, they are actually entering "B-e-l-L-z-2-4" on the German machine, which of course won't work.

Foreign language keyboards have the correct layout printed on their keys, so you can avoid this kind of frustration. You can also avoid it by changing the keyboard layout used by the German OS from German to English; however, this makes entering some German characters a little more difficult (See the section titled "Testing With Foreign Characters" on page 276 for information on entering accented characters using an English keyboard).

6.4.7 Printing and Paper Sizes

Different countries use different paper sizes. The most common used paper size in the United States is "Letter", which refers to 8½" X 11" sheets of paper. In many other countries the most common size of paper is the ISO size A4, which has slightly different dimensions. If your program contains the ability to print things like reports, you should make sure you test the reporting functionality by printing to commonly used paper sizes in the locales you plan to support.

One problem with printing that sometimes occurs is programmers will create reports with beautiful borders and layouts, but they will only take into consideration the paper size commonly used in their country. When you print your program's reports out on other paper sizes, they suddenly stop looking pretty and professional.

6.4.8 Sorting

Foreign languages are collated using different sorting rules than those employed in English. In German, for example, the letter ö is sorted so that the letters ö and o would appear next to each other. In Sweden, however, ö is sorted at the very end of the alphabet; a couple of letters after the letter z.

Working with disparate collation rules in different languages can be interesting to say the least. Sometimes, however, you will encounter multiple collation rules within the same language. Spanish and German are examples of these.

Spanish has four more letters than English, for a total of 30 (although they only use 29 of them in Spanish. The W is only used for foreign words). These extra letters are 'CH', 'LL', 'RR', and Ñ. 'CH', for example, looks like the English letters 'C' and 'H', but in Spanish 'CH' is considered a single letter; not two individual letters.

It is with three of these four extra letters that the two different sorting rules are concerned. The first rule, which is commonly referred to as Traditional Sort, sorts the letters 'CH', 'LL', 'RR', and 'Ñ' as though they were individual letters. This is probably the sorting order that you were taught in Spanish class when you attended high school. The newer collation standard, which is commonly referred to as International Sort or Modern Sort, treats the letters 'CH', 'LL', and 'RR' as two separate letters instead of a single letter; the same way we do in English.

To give an example of the differences between the traditional and international sorting rules used in Spanish, let's use the 'CH' character and the names Cecil, Charles, and Cynthia. If we were to use the traditional sorting rules, the names would appear in this order:

Cecil
Cynthia
Charles

Using the newer sorting rules, initiated by an organization called "la Asociación de Academias de la Lengua Española", the names would appear in this order:

Cecil
Charles
Cynthia

Most of the time, companies will only offer the International, or Modern Sort collation. However, some choose to extend Traditional Sort functionality to their customers living in Spain; since Spain still uses the Traditional Sort standard of collation. If your company decides to support the Traditional Sort standard, you will need to test the sorting functionality as described above.

Here are the sort orders for both Traditional and International, or Modern, collation methods.

A	E	J	N	R	V
B	F	K	Ñ	RR	W
C	G	L	O	S	X
CH	H	LL	P	T	Y
D	I	M	Q	U	Z

Table 6.6 Spanish Sort Order (Traditional)

A	F	K	O	T	Y
B	G	L	P	U	Z
C	H	M	Q	V	
D	I	N	R	W	
E	J	Ñ	S	X	

Table 6.7 Spanish Sort Order (International or Modern – *'CH', 'LL', and 'RR' are ignored*)

German, like Spanish, also has multiple collation rules. There are three of them, but you will usually only see the first one used; unless you are sorting peoples names, as in a phonebook program. I will touch on each of these rules briefly.

In the first rule, called *DIN-1*, the umlauted characters are sorted the same as their unaccented equivalents. Therefore, Ä = A, Ö = O, and so on. DIN-1 is the sort order used in dictionaries and other word lists. It is the sort order you will work with nearly always.

In the second rule, called *DIN-2*, the umlauted characters are sorted the same as their unaccented equivalents plus the letter E. Therefore, Ä = AE, Ö = OE, and so on. DIN-2 is the sort order used for lists of names. It is the sort order used in phonebooks in Germany.

The last sort order, called *Austrian*, was used in Austrian phonebooks, but I believe they have switched over to DIN-2. You will never use this sort order since most software libraries and databases don't support it.

Here is the sort order that you should use when testing German applications. Remember, usually the umlauted characters are sorted with the same weight as their unaccented counterparts. If you are planning to support the DIN-2 collation, just replace the umlauted characters in the table with their unaccented counterparts plus an E as described above.

A	E	J	O	S	V
Ä	F	K	Ö	ß	W
B	G	L	P	T	X
C	H	M	Q	U	Y
D	I	N	R	Ü	Z

Table 6.8 German Sort Order

Spanish and German look complicated perhaps, but they really aren't that hard to test. French makes it nice by sorting the same way we do in English. The most difficult languages to work with are the Asian ones due to the sheer number of characters involved. In order to give you an idea of how Asian language sorting works, I will use Japanese as an example.

Japan uses the following four "alphabets":

Kanji	These are Chinese characters and constitute the largest of the four writing systems. Example: 漢字
Hiragana	This is a phonetic alphabet that is used for native words and grammar. Example: ひらがな

Table 6.9 Japanese Writing Systems

Katakana	This is a phonetic alphabet similar to Hiragana, only this alphabet is used mostly for foreign words. Example: カタカナ
Romaji	These are roman characters and are often used when referring to foreign proper nouns; with the exception of people's names, which are usually translated into Katakana. When testing software in Japanese, it is acceptable to leave your company name, trademarked names, and product names in English. I have seen the name Microsoft and Windows translated into Katakana, but usually this is not done.

Table 6.9 Japanese Writing Systems (cont.)

In the case of Japanese, the sort order is done by phonetics regardless of which writing system is being used. Here is a table showing the Romanization of the Japanese phonetics, and their sort order.

A	KA	SA	TA	NA	HA
I	KI	SHI	CHI	NI	HI
U	KU	SU	TSU	NU	FU
E	KE	SE	TE	NE	HE
O	KO	SO	TO	NO	HO
MA	YA	RA	WA	N	
MI		RI			
MU	YU	RU			
ME		RE			
MO	YO	RO	WO		

Table 6.10 Japanese Phonetic Sort Order

Therefore, if I had the words:

黒澤明 (Kurosawa Akira)

くちぐるまにのる (Kuchiguruma ni noru)

クレヨンしんちゃん (Kureyon Shinchan)

Clint Eastwood (which is pronounced Kurinto Iisutouddo in Japan)

They would be sorted in this order based on the phonetic table listed above:

くちぐるまにのる (Kuchiguruma ni noru)

Clint Eastwood (which is pronounced Kurinto Iisutouddo in Japan)

クレヨンしんちゃん (Kureyon Shinchan)

黒澤明 (Kurosawa Akira)

Japan has another sorting method that is used only in Kanji dictionaries. This is based on the concept of radicals (common segments of Kanji characters), and the number of lines it takes to draw both the radical and the entire character. Since this is not a book on Japanese, and since you probably are not writing a Japanese Kanji dictionary program, I will refrain from delving into these concepts since they would require me teaching you Kanji. You will most likely never have to test this sorting method.

Most people in America cannot read Asian text, so usually companies will not test sort orders in Asian languages. Without years of language study, it would be difficult to do this particular test, so it's best to find a work around. For example, on my projects I usually ask the Asian language translators we hire to quickly check the sorting capabilities for us. While this is not as thorough a test as I would like, it is better than nothing.

Asian languages are difficult to check even if you can speak the language because there are so many characters. It is virtually impossible to check the sort order of tens of thousands of characters during a product test cycle, so just do a reasonable sample and move on.

In this section, I have provided you with detailed sorting information for three of the most popular target languages, and also mentioned French. This should give you an idea of what you need to look for when testing sorting on international platforms.

Because different countries and languages sort their alphabets differently, you will need to ensure that databases and other data storage mechanisms in your program present sorted data to your international customers according to the rules of collocation used in each locale.

6.4.9 Filtering and Searching functionality

Programs that are used to collect and manipulate data usually provide the user with a mechanism for searching and filtering that data. As a global software tester, you need to make sure that the filtering and searching capabilities of your program work correctly with foreign text.

The problem that I see most often with filtering and sorting capabilities in a program is they will ignore the accent marks used in foreign text. Therefore, if a user performs a search on the database for the word "Wörd", the search feature will return not only the word "Wörd," but also the words "Word", "Wórd", and "Wõrd", which is probably not what the user had in mind.

Filtering works in much the same way as a search does, only it usually is a more permanent aspect of data manipulation. Searches usually have to be performed manually each time. In counterpoint to searches, filters are usually saved within the program so that by clicking a button or performing some other non-trivial task, you can apply a saved filter on your data, which will disregard any data that doesn't mean the criteria defined by the filter.

Most programs that support filters have a few predefined ones built into the program itself. While it is, of course, important to test custom filters that you build and save manually, it is very important to check the filters that may be built into your program. Quite often, developers forget to include support for international characters in these predefined filters, so they must be checked.

6.4.10 Shortcut Keys and Mnemonics

Shortcut keys are function keys or key combinations that perform certain tasks within a program without having to use the mouse to click on menu items. An example of a shortcut key is the F7 key in Microsoft Word, which brings up the spelling and grammar checker. Another example in Word is SHIFT + F7, which brings up the Thesaurus.

Shortcut keys are usually noted to the right of the menu item to which they are bound. For example, in Microsoft Word if you open the file menu, you will see shortcut keys listed for the New, Open and Save menu items (Figure 6.10). These shortcuts are listed as Ctrl + N, Ctrl + O, and Ctrl + S respectively.

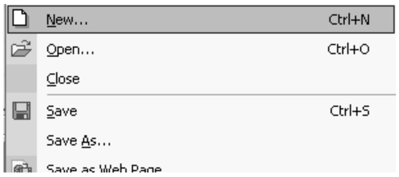


Figure 6.10 Menu item shortcuts

Notice how the key that is combined with the CTRL key is the first letter of the menu item to which it is bound? When testing international software, you will want to make sure that these letters are updated so they match the localized word. It wouldn't make much sense in English if the shortcut key for the "New" menu item was CTRL+J, so you will want to make sure that foreign users don't see a shortcut that doesn't make sense either.

Mnemonics are kind of like shortcuts, but they differ a little bit. Mnemonics are the underlined letter of a menu item (Figure 6.10), button, or other window control. For example, in the Microsoft Word File menu example listed above, the 'N' in "New" is the mnemonic, as is the 'C' in "Close". To access a mnemonic, you press the ALT key together with the underlined letter in the menu command, button, etc. you wish to activate.

Mnemonics differ slightly from shortcuts not only in appearance, as we just discussed, but also in functionality. Shortcuts can be activated from anywhere in the program simply by pressing the right key combination. The key combinations are usually listed in the menu system as shown above, but this is only to help you if you forgot what the shortcut is. The menu does not have to be open in order to execute the shortcut. Menu mnemonics, on the other hand, cannot be activated unless the menu containing them is open. Mnemonics can also appear on buttons, list boxes, combo boxes, and almost any other window control you can imagine. A simple way to think about them is Shortcuts are tied to a specific function in the program and Mnemonics are tied to the user interface.

If you think about it, both mnemonics and shortcuts are strings, and as such are contained in your resource file (or at least they should be). Because of their inclusion into localizable resource files, translators can change the shortcuts and mnemonics in your program to match foreign strings. This can sometimes cause an issue in your program that you will need to watch for.

On occasion, translators have been known to assign the same mnemonic to two different menu items in the same menu. This causes a problem. When you execute the mnemonic, which one of the menu items will be called? If you find this has occurred, log a defect against it so the localization vendor can fix it.

There is one more distinction that needs to be made regarding mnemonics and shortcuts. Localization vendors can change a mnemonic by simply changing which character in the menu string is underlined. The same is not true of shortcuts. The reason is that mnemonics are tied to a specific menu item and the operating system will recognize them regardless of which letter you choose to make your mnemonic. Shortcut key strings, on the other hand, can be changed by the localization vendor, but then a developer also needs to make a change to the ID associated with that shortcut key. Because of this, it is possible to have a shortcut key and its ID out of sync. This is a problem that cannot occur with mnemonics.

Since localization can cause problems with mnemonics and shortcut keys, and usually does, it is always a good idea to meticulously test your programs menu system and interface for these mnemonic and shortcut related issues.

6.4.11 Date and Time

Date and time formats were discussed previously in the section where we talked about internationalization development issues. However, let's discuss them again from a testing centric aspect.

As we discussed earlier, different countries use different date and time formats. Here is a table showing the different formats for several countries.

Country	Short Date	Before Noon	After Noon
United States	Month/Day/Year	11:45 AM	1:30 PM
France	Day/Month/Year	11:45	13:30
Germany	Day.Month.Year	11:45 Uhr	13:30 Uhr
Japan	Year/Month/Day	11:45	13:30
Sweden	Year/Month/Day	11.45	13.30

Table 6.11 Different Date and Time Formats

You need to test all time and date fields in your international programs and make sure when a German user enters the date 13.05.03, that your program doesn't interpret that to mean the fifth day of the thirteenth month of the year 2003, but rather May 13, 2003.

Another thing that you need to test is the format of calendars if your program contains them. In the United States, they format their calendars with Sunday being the first day of the week. Sunday therefore appears in the leftmost column in the calendar. Other countries consider Monday to be the first day of the week. In these countries, Monday should be the leftmost column and Sunday should be in the rightmost position.

Time format is usually not a big issue. Some countries may prefer the 12 hour clock to the 24 hour clock, and visa versa, but people everywhere can work with either clock (although it may take some counting on their fingers) and the computer really isn't going to care which format is used. The time format is more a cultural convenience than a computer stability issue. Time formatting won't crash your program the way that incorrect date formatting will.

Having said that, notice how the time format for Sweden uses a period instead of a colon to distinguish hours from minutes? It is possible that this delimiting token between hours and minutes could cause a problem within your program. If you are planning to sell your product in Sweden, you will want to make sure your program accepts alternate delimiters rather than only recognizing the colon. Most modern operating systems handle these delimiters for you, but it is always a good thing to check.

6.4.12 Currency

As you are probably aware, most countries and currencies have their own monetary symbol. Here is a table showing the currency symbols used in several countries.

Country	Currency
United States	$
Germany	DM
France	FR
Euro	€
Japan	¥
England	£

Table 6.12 Currency Symbols

Most of these monetary symbols are fairly easy to deal with. The Euro (€) can be the exception. The Euro symbol is a fairly recent addition to the financial monikers of the world. As such, it is a new addition to the myriad codepages and encodings used throughout the world. Some platforms and programs support the Euro fine, but others fail miserably.

It is always a good idea to test you program for Euro support. You should not limit these tests to places in your program that accept monetary input either. It is a good idea to use the Euro character as part of your passwords, and anywhere else you can input data. Since somebody in Europe is likely to use the Euro symbol in passwords, descriptions, etc. you need to make sure your program supports it everywhere.

One more thing regarding the Euro; it is entirely possible for your program to support it, but still not display it properly. You need to test both aspects when testing for Euro support. I remember working on a console based CIFS product a couple of years ago which allowed us to share files between Netware and Windows platforms easily.

6.4.13 Numbers

There is another aspect to testing currency beyond which symbol is used to specify a country's monetary system. This aspect of testing also applies to numbers in general. This aspect is the symbols used to delineate thousands and decimal values. In the United States, the number one million would be written like this: 1,000,000.00. However, in Germany and France, the same number would be written like this: 1.000.000,00. Notice how the meaning of the periods and commas is reversed?

During your testing, you need to make sure that any numerical or currency value is written correctly according to which language you are validating. You also need to make sure your programs work correctly with numbers formatted in different ways.

6.4.14 Addresses, Postal Codes and Phone Numbers

Addresses and postal codes are another fun aspect of creating international software. In the United States, the address format is usually:

Name

Street Number

Extra line for apartment numbers, Suites, Buildings, etc.

City, State Zip Code (Zip Codes are either five or nine digits long)

Other countries have different ways of formatting their addresses. Japan, for example, formats their addresses like this:

Postal Code (postal codes in Japan used to be three digits, but now they are seven)

Prefecture

Town

Street Number

Name

As you are testing software, you need to make sure foreign addresses can be entered into your software and retrieved from the database if your program includes this functionality.

There are several ways a program can support foreign address data. For example, just use a single text field for address information and allow the user to enter address strings in any format they choose. This approach will not work very well, however, if you need to retrieve individual portions of the addresses to run database queries; for example, listing all of your customers who live in Florida.

One good way to overcome the limitations imposed by a single text area input field is to have a different address dialog for each language. You would then pull that dialog from the appropriate dynamic resource library along with the foreign strings. There are other ways to solve this problem as well.

Phone numbers are another thing that can different from locale to locale. In the United States, we use a three digit area code, followed by a seven digit phone number (i.e. 1 (555) 555-5555). In parts of India, they use the format (55) 55 555 55555. Japan uses either (55) 55-5555-5555 or (55) 55-55-5555 depending on the size of the town you live in (although I have heard they may standardize on the first format).

Often times, programmers place masks on their input fields to limit a phone number's length, and to automatically provide the hyphen and parenthesis characters so the user doesn't need to type them. This is great functionality, but doesn't work well internationally. Therefore, you need to test you program with various phone number formats to ensure international functionality and quality.

6.4.15 Spelling, Grammar and Other Language Considerations

Usually you don't have to worry about spelling for two reasons. First of all, the likelihood that you speak a foreign language well enough to be well versed in spelling and grammar constructs is quite low. Secondly, you usually hire or contract with linguists who will test the spelling and grammar of the translations used in your program.

What if you are shipping your product to English speaking countries who spell words differently than you do in your country? For example, people living in England tend to beautify and flower words like Color and

Behavior with extraneous 'u's; such as colour and behaviour. On the other hand, people living in the United States tend to like their words clinical and to the point, so we leave out the 'u's in color and behavior. If I were writing this book in England, I would spell the word "internationalization" "internationalisation" instead; with an 's' instead of a 'z'.

The truth of the matter is that nobody localizes software into variations of their own language unless the variations are quite extreme; such as the difference between Chinese Simplified and Chinese Traditional. While there are locale identifiers available so you could localize your product into US English, Australian English, Canadian English, and UK English, I have never seen a program that actually did that. The costs are too significant and the benefits too minute.

Cultural differences and idiomatic phrase

Just because companies don't localize their products into various dialects doesn't mean that there isn't something for you to test. Let me use British Comedies as an example. Have you ever watched an episode of Red Dwarf, The Black Adder, A Bit of Fry and Laurie, etc. and noticed that the laugh track is laughing but you are not? This is either because you don't find British humor funny, or because you don't understand the British culture enough to understand the joke.

This can happen in software as well. If your program makes heavy use of idioms or colloquial phrases that are specific to your culture, people in other countries who speak the same language you do still may not understand. As you test your software, look for colloquialisms and idioms, especially in help files, that might be difficult for others to understand.

The problem of idiomatic phrases is exacerbated when you try to translate your software into other languages. Phrases like "shoot the breeze", "for all of me" and "putting the cart before the horse" will not translate very well into other languages. At least with other English speaking countries, you could explain the colloquialism or idiom to them and they would most likely understand. These are difficult to translate into other languages though. For example, there is an old Japanese idiom "where have you been selling oil". It basically means "where have you been wasting time", but I have no idea how it was derived. It is best to avoid slang, idioms, puns, and other culturally specific terminology.

Use of abbreviations and acronyms

Another thing you need to watch out for is abbreviations and acronyms. Since you are testing software, I recommend you particularly watch out for acronyms. I cannot imagine another group on Earth that has made such heavy use of acronyms as the computer industry. It's almost to the point that technical conversations are nothing but acronyms. If your software does use abbreviations and acronyms, make sure that they are explained well so others will know what you are talking about.

Acronyms are derived from the first letter of each word in multi-word phrases. "Domain Name Server", for instance, is shortened using the acronym DNS. When testing international software, remember that acronyms are derived from your language, not somebody else's. This may make it difficult for foreign users to decipher the meaning of your acronyms. As you test, try to look at abbreviations and acronyms through the eyes of a non-English speaker, and then log defects against the product if you believe it will be confusing.

6.4.16 Brand Names and Terminology

The computer industry, being fairly new in comparison to other industries, probably hasn't been around long enough to develop a wide vocabulary of its own. Therefore, most companies hijack existing words, or piece together odd phrases, to describe their program's innovation or technology.

In English, these words and phrases make sense to some degree, but when translated literally they can be confusing and sometimes nonsensical. For this reason, it is usually best to leave these specialty words in English and then explain what they mean in your documentation.

The made-up words and phrases that we trademark and pepper our products with can easily be compared to humor in foreign languages. Let me use a simple Japanese joke as an example (by simple I mean it is a joke of the same caliber as *Why did the man throw his clock out the window? – He wanted to see time fly.*) Here's the joke: *There is a tall building. A man* *walks out of the front door. What is his name?* The puzzling punch line is *Devilman*.

Now you are probably not laughing, mainly because it is a dumb joke, but unlike the clock joke, you likely cannot fathom how the Japanese joke could be considered a joke at any level; dumb or otherwise. The same is often true of proprietary technical terms and phrases. People from other countries will understand each of the words in your technical term, but they may not be in any order or combination that makes sense.

As you test, be mindful of this. It is a good idea to write a defect against proprietary words that have been translated. This is also something that should be discussed during the planning stages of development.

Ideally, your company should create a document outlining these technical and proprietary terms, and you should make this glossary available to your localization vendor before they start translating your software. The vendor will be very pleased with you if you provide them with this information.

6.4.17 Asian Text in Programs

We have already discussed Asian text a little bit when we talked about testing with foreign characters. However, there are a few more points regarding these topics that I feel are important to discuss.

Remember in the beginning portion of this chapter where we talked about variables and how you can usually only store one kind of data in a variable? This restriction to a certain data type can cause problems when working with Asian characters. To explain the issue, let me illustrate using the C programming language.

Unlike some languages, C does not have a "string" data type. Instead string variables in C are stored inside of character arrays. So, if I want to store the ubiquitous programming phrase "Hello World" in a C variable, I cannot declare a single string variable and put "Hello World" into it as illustrated below.

String Variable
Hello World

Instead, I must declare an array of characters and store each individual character in the phrase "Hello World" in a separate component of the array as shown here (note the '\0' character in the last column. This is the null terminator, which indicates the end of the string in C).

Character Array											
H	e	l	l	o		W	o	r	l	d	\0

The problem lies not in the fact that C doesn't have a string variable type, but in that C's character data type (char), and therefore array elements created using the char variable type, are only a single byte in size. This means that each element, or cell, of this array can only contain one byte.

As we have discussed several times in this chapter, Asian characters require two bytes per character instead of just one. If we were to try and force an Asian string in our "Hello World" array, it would destroy our string. The array treats a double-byte string in the same way our faux bank teller at the beginning of the chapter would treat a tuna fish sandwich being proffered for deposit.

Many developers are aware of this issue, and many programming tools provide good mechanisms to avoid the problems introduced by double-byte characters. However, if you are testing your product on an Asian language and the text you are working with is not displayed correctly, but rather looks like garbage characters, the problem may be that your program is using char arrays to store strings.

Always test Asian strings wherever you can in your program and make sure they are displayed correctly. Nothing makes a customer more upset than seeing their data turn into squares, blocks and other meaningless characters.

6.4.18 Databases

In the previous section, we talked about variables and data types in programming languages. Databases have a similar concept in regards to data fields as well. You can set a field so that it will only accept one kind of data.

Occasionally, programmers will either not pass data to the database correctly, or the database field type itself will not correctly handle foreign data. If you have access to the database, meaning it is not stored on a remote server that is inaccessible to you, you can open the database and test the validity of your foreign data directly. Of course, this approach requires that you are familiar with SQL or some other querying mechanism.

You can also perform tests on your data from within your program using the data retrieval mechanisms built within. Whichever method you choose to use, make sure that foreign date formats, strings, addresses, etc. are all supported by your database and that they are being transported to and from the program correctly.

I have worked on projects where the data was being handled correctly by the program, but the database was not configured correctly to handle certain foreign data. Once the data entered the database, it became corrupt.

6.4.19 Seasons

I have come across many excellent testers who are surprised when I bring up seasons as an international software issue. The thought of seasons being related to software never occurred to them. It never really occurred to me until I made my first trip to India.

I traveled to Bangalore, India from Japan in the heat of a wet Tokyo summer a few years ago. Nobody told me what to expect, so I packed my luggage in preparation for a hot two weeks in India. To my complete befuddlement, it was actually cool in Bangalore. When I talked to the taxi driver, who hardly left my side during my stay, he told me it was actually wintertime in India.

When I returned, I spoke to a friend from Brazil to explain this new found nugget of trivia I had found. My friend just looked at me as if I were as dumb as a bag of particularly un-insightful rocks. It was at that moment that I realized seasons occurred at different times in different parts of the world.

Once I made this brilliant discovery, I realized that I had worked on software in the past that represented different months in the calendar using seasonal icons such as kids playing on a sunny day to represent July, or Snowmen and scarves to represent December. From that moment on, I've been conscious of the icons and graphics which are specific to the seasons in my part of the world.

Most software does not include graphics and icons that are chosen based on the weather, but if the software you are testing does, you will want to work out these issues before you ship your product. It doesn't snow in December in many parts of the world.

6.4.20 Measurements

When I first went to live in Japan, I had a really hard time figuring out my height in centimeters. This was slightly discouraging since I was a good head taller than everybody else, and was constantly being asked how tall I was. I would try to explain my height using feet and inches, as I was accustomed to doing, but was usually met with a polite change of subject.

When you ship software, you don't want customers to change the subject since that means a change in product. During your testing, make sure that measurements are displayed in the correct standards used in foreign markets. For example, if you are displaying a temperature, make sure it is either displayed in both Celsius and Fahrenheit, or displayed correctly based on the machine locale.

6.4.21 Signs, Symbols and Colors

Sometimes companies are tempted to use signs and symbols in their software as icons for toolbar buttons, images for wizards, and graphics to depict certain functionality. One educational software product I worked on a few years ago used a speed limit sign to indicate that you were really starting to learn quickly and a stop sign at the end of each lesson.

The first thing I did was removed the traffic sign based graphics since they don't mean anything in Japan. Japan's stop sign is an inversed triangle and their speed limit sign is a circle. When you are testing software, look for graphics in your program that are specific to your country or culture.

To give another example, there was a sever product I worked on several years ago that used a red circle to indicate that an error had occurred and a green 'X' mark to indicate that everything had worked correctly. This makes sense in the United States since the colors are based on traffic lights. Red meaning that something stopped or failed to work, and green indicating that everything was a go.

This color scheme based visual representation of success and failure was a big problem for Japan since red and green are not associated with success or failure. The circle and 'X' shape, however, are. In Japan, an 'X' shape signifies a failure. In fact, you will often see Japanese people make an 'X' mark by crossing their arms when an answer is incorrect or a suggestion distasteful to them. They call this mark a *batsu*. The circle mark, on the other hand, is called a *maru* and is used to signify success, or a correct answer or suggestion. You will often see these two shapes used on Japanese game shows, for instance, to signify a correct or incorrect answer.

Because of the cultural use of the 'X' mark and circle in Japan, the server product I worked on was, at least to the Japanese, reporting all the successes as failures and all the failures as successes.

Another funny graphic I saw before was included in a recipe program. It was of a bowl of rice with two chop sticks sticking up out of it. This would probably be a nice graphic for an oriental food section of a recipe program; however, this is a very rude thing to do in Japan since it is part of their funeral ceremony. No one would ever leave their chopsticks sticking up out of their food in Japan.

It is a good idea to understand signs, symbols and colors and the various meaning they have in different cultures. However, it would require a lot of study on any individual's part to know and understand all the implications of signs, symbols and colors in a wide range of cultures. For this reason, I would recommend discussing these concerns with your localization vendor and requesting that they look over your graphics and suggest changes where the graphics carry no meaning in a foreign market.

If they find any problems, then you can log a defect against the product and have the graphic changed.

Above all else, you do not want to confuse or insult foreign customers through the use of inappropriate graphics. The entire purpose of graphics in a program is to convey meaning and help the customer easily work with your product. If you confuse or insult the customer, your product will not be very successful internationally.

6.5 Conclusion

I hope this chapter has given you an idea of the many issues you need to test for as you work with international software. We have discussed many topics during this chapter. Here is a summary of the things we have discussed:

- We defined internationalization and localization and discussed some of the benefits of producing international software.
- We discussed the importance of planning your software products to include a focus on international issues.
- We discussed some of the problems that occur when a good international plan is not in effect.
- We discussed the problems of using the traditional software approach, which is to create a native language version of your software and then try and tweak it at a later time to work internationally. We also discussed the negative effects such a plan would have on development, testing, and the overall cost of the project.
- We discussed what an internationalization-centric plan should look like.
- We talked about testing getting involved at the beginning of the project by testing the project plan, the build environment, and so on.
- We discussed the issues development must deal with when working with foreign text, especially double-byte Asian text.
- We illustrated what hard coded strings were and why they have a negative impact on international software.
- We learned why multiple code bases are costly and prone to errors. We also learned that maintaining multiple code bases usually leads to features being left out of international versions of the software.

- We discussed the benefits to our company's budget and time to market if we follow a good international plan and focus on internationalization from the very beginning of each project.
- We discussed pseudo language builds and how to use them. We also mentioned that by using a pseudo language build and always testing on foreign platforms, we would be able to eliminate internationalization and localization defects at an early stage.
- We discussed string expansion and learned some methods to eliminate string expansion issues in our dialogs using a pseudo language build. We also learned some strategies development can use to provide room for foreign strings on their dialogs.
- We discussed separating our strings into separate resources, and making all languages, including our native language, modules that plug into our core product.
- We talked about builds and installer programs and how they should handle multiple languages.
- We discussed character sets, codepages and encodings and some of the issues surrounding them.
- We learned how double-byte character sets work and discussed many of the problems that they cause in software.
- We talked about testing with foreign characters and how to input them into your program.
- Finally, we discussed the international issues you need to watch for when testing products. This included printing, dates, times, seasons, currency, numbers, spelling and grammar, measurements, vernacular, sorting, searching, filtering, etc.

As you learn to use the concepts outlined in this chapter, testing for international issues will become second nature to you. I think you will also find that by planning projects better and testing in a slightly different paradigm than you are used to, the international product will not be the only products that benefit from your efforts. I think you will also find that the quality of your native language products will increase as well.

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