Marco Cantù
Essential Pascal

2nd Edition, March 2003

(version 2.01)

Apollo, the God Worshiped at Delphi,
in an Italian 17th Century Fresco.

Introduction

The first few editions of Mastering Delphi, the best selling Delphi book I've written, provided an introduction to the Pascal language in Delphi. Due to space constraints and because many Delphi programmers look for more advanced information, in the latest edition this material was completely omitted. To overcome the absence of this information, I've started putting together this ebook, titled ***Essential Pascal***.

This is a detailed book on Pascal, which for the moment will be available for free on my web site (I really don't know what will happen next, I might even find a publisher). This is a work in progress, and any feedback is welcome. The first complete version of this book, dated July '99, has been published on the Delphi 5 Companion CD.

Note to the Second Edition

After a few years (in the early 2003), the book had a complete revision, trying to refocus it even more on the core features of the Pascal language. Alongside, the book covers the language from the perspective of the Delphi for Windows programmer, but also of the Kylix and Delphi for .NET programmer. Differences among these different versions of the language will be mentioned.

This change in focus (not only Delphi with the VCL library) was another reason to change most of the examples from visual ones to console based ones – something I plan doing but that I still haven't done. Beside the theoretical advantage that the reader con focus even more on the language, ignoring event handlers, methods, component, and other more advance topics, only using a console application the code will be easily portable among the different compilers Borland has made available for Delphi in the recent years.

Another change is that I've gone from an HTML-based format to a PDF based one. With the increased bandwidth people generally have over a few years back this is really an advantage, and distribution of a single file helps a lot. By the way, the book is now being written with *OpenOffice.org*.

Copyright

Donations

Although the book is available for free to everyone, if you benefit from reading it from a business perspective (that is, if Pascal programming is part of your job) and if you can afford it (because you live in a wealthy country) I ask yo to donate a small sum to me, as I live on writing and training on programming languages and tool. Donation information is available on my web site. The currently suggested price is 5 Euros (which at the time I'm writing this is just a little over 5 US Dollars).

An alternative way of supporting me is to buy one of my books, but in that case I'll get only a limited fraction of the money you spend (which is the beauty of publishing an ebook). Coming to a seminar of mine or offering me consulting work is another interesting payback.

Notice that the money earned will allow me to pay for a professional editor, the web site itself, and (of course) the time devoted to update the book.

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Source Code

The source code of all the examples mentioned in the book is available. The code has the same copyright as the book: Feel free to use it at will but don't publish it on other documents or site. Links back to the Essential Pascal site (`www.marcocantu.com/epascal`) are welcomed.

If you go to the site you can download the source code in a single zip file, `EPasCode.zip` (about 30 KB in size), and check out the list of the examples in Appendix B.

Feedback

Please let me know of any errors you find, but also of topics not clear enough for a beginner. I'll be able to devote time to the project depending also on the feedback I receive. Let me know also which other topics you'd like to see here.

The preferred way of sending feedback is on my public newsgroup (see my web site for login information) in the area devoted to books. If you have troubles using the newsgroups send an email at the address to `marco@marcocantu.com` (putting *Essential Pascal* in the subject, and your request or comment in the text).

Acknowledgments

If I'm publishing a book on the web for free, I think this is mainly due to Bruce Eckel's experience with *Thinking in Java*. I'm a friend of Bruce and think he really did a great job with that book and few others.

As I mentioned the project to people at Borland I got a lot of positive feedback as well. And of course I must thank the company for making first the Turbo Pascal series of compilers and now the Delphi series of visual IDEs.

I'm starting to get some precious feedback. The first readers who helped improving this material quite a lot are Charles Wood and Wyatt Wong. Mark Greenhaw helped with some editing of the text. Rafael Barranco-Droege offered a lot of technical corrections and language editing. Thanks.

About the Author

Marco Cantù lives in Piacenza, Italy. After teaching the C++ language and writing C++ and Object Windows Library books and articles, in 1995 he delved into Delphi programming. He is the author of the *Mastering Delphi* book series, published by Sybex, as well as the advanced *Delphi Developers Handbook* (which is hardly available any more). Marco writes articles for many magazines, including *The Delphi Magazine*, speaks at Delphi and Borland conferences around the world, and teaches Delphi classes at basic and advanced levels.

Lately he's getting more and more involved in XML-related technologies, although mostly from the Delphi perspective. You can find more details about Marco and his work on his web site, `www.marcocantu.com`.

Chapter 1:
A Short History of the Pascal Language

The Object Pascal programming language we use in Delphi wasn't invented in 1995 along with the Borland visual development environment. It was simply extended from the Object Pascal language already in use in the Borland Pascal products. But Borland didn't invent Pascal, it only helped make it very popular and extended it a little...

Wirth's Pascal

The Pascal language was originally designed in 1971 by Niklaus Wirth, professor at the Polytechnic of Zurich, Switzerland. Pascal was designed as a simplified version for educational purposes of the language Algol, which dates from 1960.

When Pascal was designed, many programming languages existed, but few were in widespread use: FORTRAN, C, Assembler, COBOL. The key idea of the new language was order, managed through a strong concept of data type, and requiring declarations and structured program controls. The language was also designed to be a teaching tool for students of programming classes.

Turbo Pascal

Borland's world-famous Pascal compiler, called Turbo Pascal, was introduced in 1983, implementing "Pascal User Manual and Report" by Jensen and Wirth. The Turbo Pascal compiler has been one of the best-selling series of compilers of all time, and made the language particularly popular on the PC platform, thanks to its balance of simplicity and power.

Turbo Pascal introduced an Integrated Development Environment (IDE) where you could edit the code (in a WordStar compatible editor), run the compiler, see the errors, and jump back to the lines containing those errors. It sounds trivial now, but previously you had to quit the editor, return to DOS; run the command-line compiler, write down the error lines, open the editor and jump there.

Moreover Borland sold Turbo Pascal for 49 dollars, where Microsoft's Pascal compiler was sold for a few hundred. Turbo Pascal's many years of success contributed to Microsoft's eventual cancellation of its Pascal compiler product.

You can actually download a copy of the original version of Borland's Turbo Pascal from the Borland Developer's Network web site (http://bdn.borland.com) in the *Museum* section.

Delphi's Pascal

After 9 versions of Turbo and Borland Pascal compilers, which gradually extended the language into the OOP realm, Borland released Delphi in 1995, turning Pascal into a visual programming language. Delphi extends the Pascal language in a number of ways, including many

object-oriented extensions which are different from other flavors of Object Pascal, including those in the *Borland Pascal with Objects* compiler (the last incarnations of Turbo Pascal).

With Delphi 2, Borland brought the Pascal compiler to the 32-bit world, actually re-engineering it to provide a code generator common with the C++ compiler. This brought to the Pascal language many optimizations previously found only in C/C++ compilers.

With Kylix, Borland made a further step and opened to Pascal/Delphi programmers the Linux operating system (even if only in its Intel-based incarnation). Most of the examples of this book can be executed almost unchanged on Linux.

With the release of version 7 of Delphi (and version 3 of Kylix) Borland has formally started to names the Pascal (or Object Pascal) language as the Delphi language. So Delphi 7 uses the Delphi language, Kylix 3 supports both the Delphi and the C++ languages, and Borland ships a Delphi language compiler for the Microsoft's .NET architecture. This is mainly a cosmetic and marketing change, probably due to the fact that the Pascal language was never popular in the US as it used to be (and still is) in Europe and other areas of the world.

Chapter 2:
Coding in Pascal

Before we move on to the subject of writing Pascal language statements, it is important to highlight a couple of elements of Pascal coding style. The question I'm addressing here is this: Besides the syntax rules, how should you write code? There isn't a single answer to this question, since personal taste can dictate different styles. However, there are some principles you need to know regarding comments, uppercase, spaces, and the so-called pretty-printing. In general, the goal of any coding style is clarity. The style and formatting decisions you make are a form of shorthand, indicating the purpose of a given piece of code. An essential tool for clarity is consistency-whatever style you choose, be sure to follow it throughout a project.

Comments

In Pascal, comments are enclosed in either braces or parentheses followed by a star. Delphi also accepts the C++ style comments, which can span to the end of the line:

```
{this is a comment}
(* this is another comment *)
// this is a comment up to the end of the line
```

The first form is shorter and more commonly used. The second form was often preferred in Europe because many European keyboards lacked the brace symbol. The third form of comments has been borrowed from C++ and was added in Delphi 2. Comments up to the end of the line are very helpful for short comments and for commenting out a line of code.

> In the listings of the book I'll try to mark comments as italic and keywords in bold, to be consistent with the default Delphi syntax highlighting (and that of most other editors).

Having three different forms of comments can be helpful for making nested comments. If you want to comment out several lines of source code to disable them, and these lines contain some real comments, you cannot use the same comment identifier:

```
{  ... code
{comment, creating problems}
... code }
```

With a second comment identifier, you can write the following code, which is correct:

```
{  ... code
//this comment is OK
... code }
```

Note that if the open brace or parenthesis-star is followed by the dollar sign ($), it becomes a compiler directive, as in `{$X+}`.

> Actually, compiler directives are still comments. For example, `{$X+ This is a comment}` is legal. It's both a valid directive and a comment, although sane programmers will probably tend to separate directives and comments.

Use of Uppercase

The Pascal compiler (unlike those in other languages) ignores the case (capitalization) of characters. Therefore, the identifiers `Myname`, `MyName`, `myname`, `myName`, and `MYNAME` are all exactly equivalent. On the whole, this is definitely a positive, since in case-sensitive languages, many syntax errors are caused by incorrect capitalization.

> There is only one exception to the case-insensitive rule of Pascal: the *Register* procedure of a components' package must start with the uppercase *R*, because of a C++Builder compatibility issue.

There are a couple of subtle drawbacks, however. First, you must be aware that these identifiers really are the same, so you must avoid using them as different elements. Second, you should try to be consistent in the use of uppercase letters, to improve the readability of the code.

A consistent use of case isn't enforced by the compiler, but it is a good habit to get into. A common approach is to capitalize only the first letter of each identifier. When an identifier is made up of several consecutive words (you cannot insert a space in an identifier), every first letter of a word should be capitalized:

```
MyLongIdentifier
MyVeryLongAndAlmostStupidIdentifier
```

Other elements completely ignored by the compiler are the spaces, new lines, and tabs you add to the source code. All these elements are collectively known as white space. White space is used only to improve code readability; it does not affect the compilation.

Unlike BASIC, Pascal allows you to write a statement on several lines of code, splitting a long instruction on two or more lines. The drawback (at least for many BASIC programmers) of allowing statements on more than one line is that you have to remember to add a semicolon to indicate the end of a statement, or more precisely, to separate a statement from the next one. Notice that the only restriction in splitting programming statements on different lines is that a string literal may not span several lines.

Again, there are no fixed rules on the use of spaces and multiple-line statements, just some rules of thumb:

- The Delphi editor has a vertical line you can place after 60 or 70 characters. If you use this line and try to avoid surpassing this limit, your source code will look better when you print it on paper. Otherwise long lines may get broken at any position, even in the middle of a word, when you print them.
- When a function or procedure has several parameters, it is common practice to place the parameters on different lines.
- You can leave a line completely white (blank) before a comment or to divide a long piece of code in smaller portions. Even this simple idea can improve the readability of the code, both on screen and when you print it.
- Use spaces to separate the parameters of a function call, and maybe even a space before the initial open parenthesis. Also keep operands of an expression separated. I know that some programmers will disagree with these ideas, but I insist: Spaces are free; you don't pay for them. (OK, I know that they use up disk space and modem connection time when you upload or download a file, but this is less and less relevant, nowadays.)

Pretty-Printing

The last suggestion on the use of white spaces relates to the typical Pascal language-formatting style, known as pretty-printing. This rule is simple: Each time you need to write a compound statement, indent it two spaces to the right of the rest of the current statement. A compound statement inside another compound statement is indented four spaces, and so on:

```
if ... then
  statement;

if ... then
begin
  statement1;
  statement2;
end;

if ... then
begin
  if ... then
    statement1;
  statement2;
end;
```

The above formatting is based on pretty-printing, but programmers have different interpretations of this general rule. Some programmers indent the begin and end statements to the level of the inner code, some of them indent begin and end and then indent the internal code once more, other programmers put the begin in the line of the if condition. This is mostly a matter of personal taste. There are Delphi add-in programs you can use to convert an existing source code to the indentation format you prefer.

A similar indented format is often used for lists of variables or data types, and to continue a statement from the previous line:

```
type
  Letters = set of Char;
var
  Name: string;
begin
  { long comment and long statement, going on in the
    following line and indented two spaces }
  MessageDlg ('This is a message',
    mtInformation, [mbOk], 0);
```

Of course, any such convention is just a suggestion to make the code more readable to other programmers, and it is completely ignored by the compiler. I've tried to use this rule consistently in all of the samples and code fragments in this book. Delphi source code, manuals, and Help examples use a similar formatting style.

Syntax Highlighting

To make it easier to read and write Pascal code, the Delphi editor has a feature called color syntax highlighting. Depending on the meaning in Pascal of the words you type in the editor, they are displayed using different colors. By default, keywords are in bold, strings and comments are in color (and often in italic), and so on.

Reserved words, comments, and strings are probably the three elements that benefit most from this feature. You can see at a glance a misspelled keyword, a string not properly terminated, and the length of a multiple-line comment.

You can easily customize the syntax highlight settings using the Editor Colors page of the Environment Options dialog box (see Figure 2.1). If you work by yourself, choose the colors you like. If you work closely with other programmers, you should all agree on a standard color scheme. I find that working on a computer with a different syntax coloring than the one I am used to is really difficult.

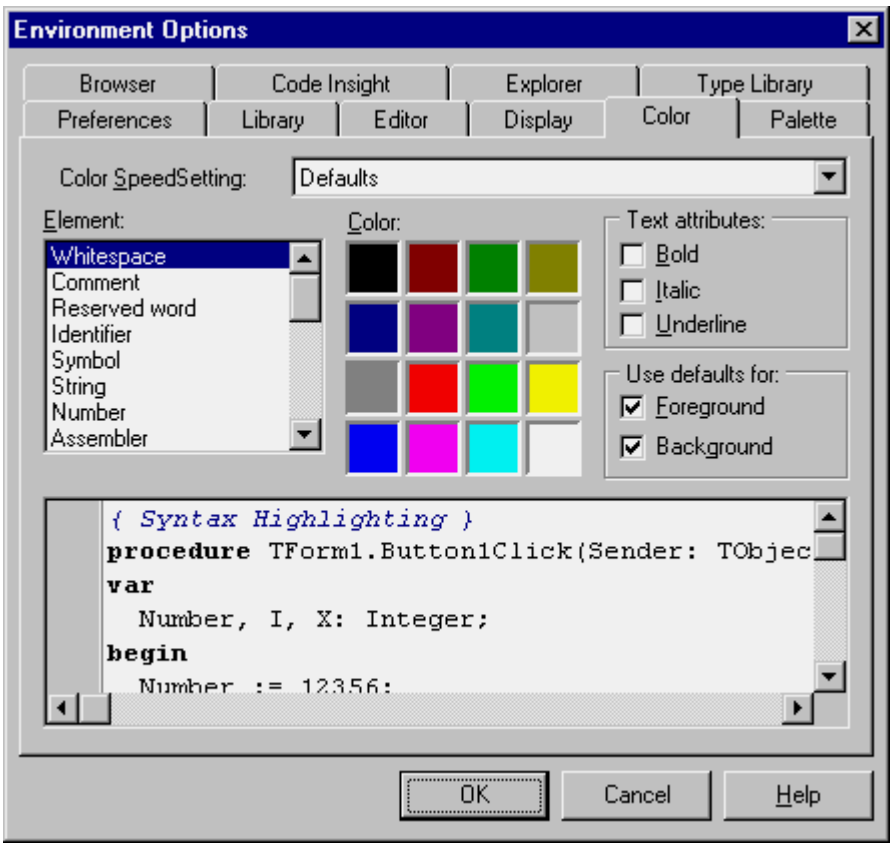


FIGURE 2.1: THE DIALOG BOX USED TO SET THE COLOR SYNTAX HIGHLIGHTING.

In this book I've tried to apply a sort of syntax highlighting to the source code listings. I hope this actually makes them more readable.

Using Code Templates

When writing Pascal language statements you often repeat the same sequence of keywords. For this reason, Borland has provided a new feature called Code Templates. A code template is simply a piece of code related with a shorthand. You type the shorthand, then press Ctrl+J, and the full piece of code appears. For example, if you type `arrayd`, and then press Ctrl+J, the Delphi editor will expand your text into:

```
array [0..] of ;
```

Since the predefined code templates usually include several versions of the same construct, the shortcut generally terminates with a letter indicating which of the versions you are interested in. However, you can also type only the initial part of the shortcut. For example, if you

type `ar` and then press Ctrl+J, the editor will display a local menu with a list of the available choices with a short description, as you can see in Figure 2.2.

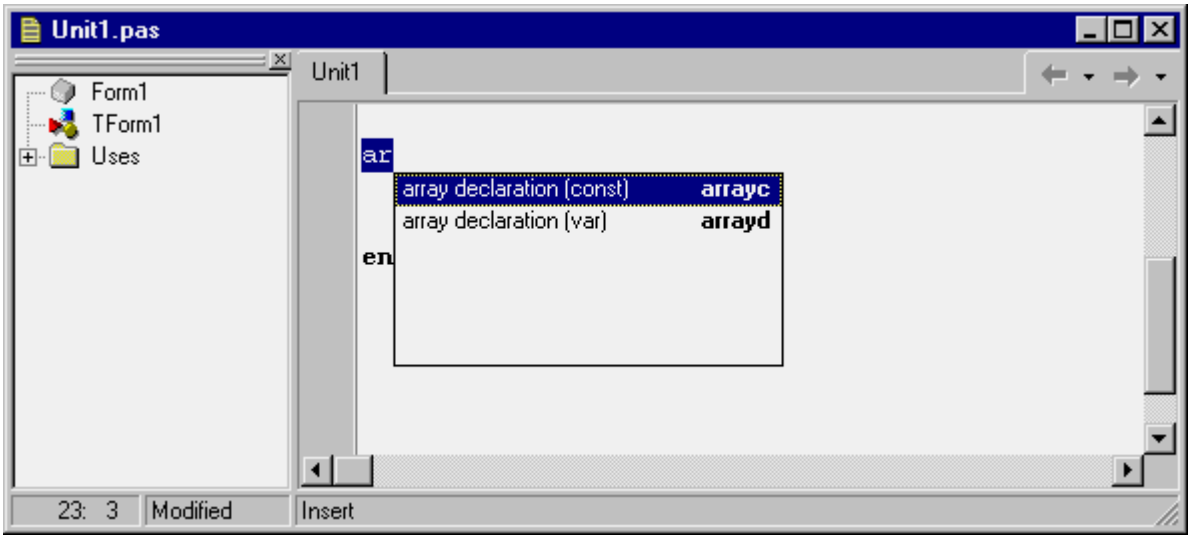


FIGURE 2.2: CODE TEMPLATES SELECTION

You can fully customize the code templates by modifying the existing ones or adding your own common code pieces. If you do this, keep in mind that the text of a code template generally includes the '|' character to indicate where the cursor should jump to after the operation, that is, where you start typing to complete the template with custom code.

Language Statements

Once you have defined some identifiers, you can use them in statements and in the expressions that are part of some statements. Pascal offers several statements and expressions. Let's look at keywords, expressions, and operators first.

Keywords

Keywords are all the Object Pascal reserved identifiers, which have a role in the language. Delphi's help distinguishes between reserved words and directives: Reserved words cannot be used as identifiers, while directives should not be used as such, even if the compiler will accept them. In practice, you should not use any keywords as an identifier.

In Table 2.1 you can see a complete list of the identifiers having a specific role in the Object Pascal language (in Delphi 4), including keywords and other reserved words.

TABLE 2.1: KEYWORDS AND OTHER RESERVED WORDS IN THE OBJECT PASCAL LANGUAGE

Keyword	Role
absolute	directive (variables)
abstract	directive (method)
and	operator (boolean)
array	type
as	operator (RTTI)
asm	statement

assembler	backward compatibility (asm)
at	statement (exceptions)
automated	access specifier (class)
begin	block marker
case	statement
cdecl	function calling convention
class	type
const	declaration or directive (parameters)
constructor	special method
contains	operator (set)
default	directive (property)
destructor	special method
dispid	dispinterface specifier
dispinterface	type
div	operator
do	statement
downto	statement (for)
dynamic	directive (method)
else	statement (if or case)
end	block marker
except	statement (exceptions)
export	backward compatibility (class)
exports	declaration
external	directive (functions)
far	backward compatibility (class)
file	type
finalization	unit structure
finally	statement (exceptions)
for	statement
forward	function directive
function	declaration
goto	statement
if	statement
implementation	unit structure
implements	directive (property)
in	operator (set) - project structure
index	directive (dipinterface)
inherited	statement
initialization	unit structure
inline	backward compatibility (see asm)
interface	type
is	operator (RTTI)
label	declaration
library	program structure
message	directive (method)
mod	operator (math)

name	directive (function)
near	backward compatibility (class)
nil	value
nodefault	directive (property)
not	operator (boolean)
object	backward compatibility (class)
of	statement (case)
on	statement (exceptions)
or	operator (boolean)
out	directive (parameters)
overload	function directive
override	function directive
package	program structure (package)
packed	directive (record)
pascal	function calling convention
private	access specifier (class)
procedure	declaration
program	program structure
property	declaration
protected	access specifier (class)
public	access specifier (class)
published	access specifier (class)
raise	statement (exceptions)
read	property specifier
readonly	dispatch interface specifier
record	type
register	function calling convention
reintroduce	function directive
repeat	statement
requires	program structure (package)
resident	directive (functions)
resourcestring	type
safecall	function calling convention
set	type
shl	operator (math)
shr	operator (math)
stdcall	function calling convention
stored	directive (property)
string	type
then	statement (if)
threadvar	declaration
to	statement (for)
try	statement (exceptions)
type	declaration
unit	unit structure
until	statement

uses	unit structure
var	declaration
virtual	directive (method)
while	statement
with	statement
write	property specifier
writeonly	dispatch interface specifier
xor	operator (boolean)

Expressions and Operators

There isn't a general rule for building expressions, since they mainly depend on the operators being used, and Pascal has a number of operators. There are logical, arithmetic, Boolean, relational, and set operators, plus some others. Expressions can be used to determine the value to assign to a variable, to compute the parameter of a function or procedure, or to test for a condition. Expressions can include function calls, too. Every time you are performing an operation on the value of an identifier, rather than using an identifier by itself, that is an expression.

Expressions are common to most programming languages. An expression is any valid combination of constants, variables, literal values, operators, and function results. Expressions can also be passed to value parameters of procedures and functions, but not always to reference parameters (which require a value you can assign to).

Operators and Precedence

If you have ever written a program in your life, you already know what an expression is. Here, I'll highlight specific elements of Pascal operators. You can see a list of the operators of the language, grouped by precedence, in Table 2.2.

> Contrary to most other programming languages, the and and or operators have precedence compared to the relational one. So if you write `a < b and c < d`, the compiler will try to do the and operation first, resulting in a compiler error. For this reason you should enclose each of the < expression in parentheses: `(a < b) and (c < d)`.

Some of the common operators have different meanings with different data types. For example, the + operator can be used to add two numbers, concatenate two strings, make the union of two sets, and even add an offset to a `PChar` pointer. However, you cannot add two characters, as is possible in C.

Another strange operator is div. In Pascal, you can divide any two numbers (real or integers) with the / operator, and you'll invariably get a real-number result. If you need to divide two integers and want an integer result, use the div operator instead.

TABLE 2.2: PASCAL LANGUAGE OPERATORS, GROUPED BY PRECEDENCE

Unary Operators (Highest Precedence)	
@	Address of the variable or function (returns a pointer)
not	Boolean or bitwise not

Multiplicative and Bitwise Operators	
*	Arithmetic multiplication or set intersection
/	Floating-point division
div	Integer division
mod	Modulus (the remainder of integer division)
as	Allows a type-checked type conversion among at runtime (part of the RTTI support)
and	Boolean or bitwise and
shl	Bitwise left shift
shr	Bitwise right shift
Additive Operators	
+	Arithmetic addition, set union, string concatenation, pointer offset addition
-	Arithmetic subtraction, set difference, pointer offset subtraction
or	Boolean or bitwise or
xor	Boolean or bitwise exclusive or
Relational and Comparison Operators (Lowest Precedence)	
=	Test whether equal
<>	Test whether not equal
<	Test whether less than
>	Test whether greater than
<=	Test whether less than or equal to, or a subset of a set
>=	Test whether greater than or equal to, or a superset of a set
in	Test whether the item is a member of the set
is	Test whether object is type-compatible (another RTTI operator)

Set Operators

The set operators include union (+), difference (-), intersection (*),membership test (in), plus some relational operators. To add an element to a set, you can make the union of the set with another one that has only the element you need. Here's a Delphi example related to font styles:

```
Style := Style + [fsBold];
Style := Style + [fsBold, fsItalic] - [fsUnderline];
```

As an alternative, you can use the standard Include and Exclude procedures, which are much more efficient (but cannot be used with component properties of the set type, because they require an l-value parameter):

```
Include (Style, fsBold);
```

Conclusion

Now that we know the basic layout of a Pascal program we are ready to start understanding its meaning in detail. We'll start by exploring the definition of predefined and user defined data types, then we'll move along to the use of the keywords to form programming statements.

Chapter 3
Types, Variables, and Constants

The original Pascal language was based on some simple notions, which have now become quite common in programming languages. The first is the notion of *data type*. The type determines the values a variable can have, and the operations that can be performed on it. The concept of type is stronger in Pascal than in C, where the arithmetic data types are almost interchangeable, and much stronger than in the original versions of BASIC, which had no similar concept.

Variables

Pascal requires all variables to be declared before they are used. Every time you declare a variable, you must specify a data type. Here are some sample variable declarations:

```
var
  Value: Integer;
  IsCorrect: Boolean;
  A, B: Char;
```

The *var* keyword can be used in several places in the code, such as at the beginning of the code of a function or procedure, to declare variables local to the routine, or inside a unit to declare global variables. After the *var* keyword comes a list of variable names, followed by a colon and the name of the data type. You can write more than one variable name on a single line, as in the last statement above.

Once you have defined a variable of a given type, you can perform on it only the operations supported by its data type. For example, you can use the Boolean value in a test and the integer value in a numerical expression. You cannot mix Booleans and integers (as you can with the C language).

Using simple assignments, we can write the following code:

```
Value := 10;
IsCorrect := True;
```

But the next statement is not correct, as the two variables have different data types:

```
Value := IsCorrect; // error
```

If you try to compile this code, Delphi issues a compiler error with this description: *Incompatible types: 'Integer' and 'Boolean'*. Usually, errors like this are programming errors, because it does not make sense to assign a True or False value to a variable of the Integer data type. You should not blame Delphi for these errors. It only warns you that there is something wrong in the code.

Of course, it is often possible to convert the value of a variable from one type into a different type. In some cases, this conversion is automatic, but usually you need to call a specific system function that changes the internal representation of the data.

In Delphi you can assign an initial value to a global variable while you declare it. For example, you can write:

```
var
  Value: Integer = 10;
  Correct: Boolean = True;
```

This initialization technique works only for global variables, not for variables declared inside the scope of a procedure or method.

Constants

Pascal also allows the declaration of constants to name values that do not change during program execution. To declare a constant you don't need to specify a data type, but only assign an initial value. The compiler will look at the value and automatically use its proper data type. Here are some sample declarations:

```
const
  Thousand = 1000;
  Pi = 3.14;
  AuthorName = 'Marco Cantù';
```

Delphi determines the constant data type based on its value. In the example above, the Thousand constant is assumed to be of type `SmallInt`, the smallest integral type which can hold it. If you want to tell Delphi to use a specific type you can simply add the type name in the declaration, as in:

```
const
  Thousand: Integer = 1000;
```

When you declare a constant, the compiler can choose whether to assign a memory location to the constant, and save its value there, or to duplicate the actual value each time the constant is used. This second approach makes sense particularly for simple constants.

The 16-bit version of Delphi allows you to change the value of a typed constant at run-time, as if it was a variable. The 32-bit version still permits this behavior for backward compatibility when you enable the *$J* compiler directive, or use the corresponding *Assignable typed constants* check box of the Compiler page of the Project Options dialog box. This was the default until Delphi 6, but in any case you are strongly advised not to use this trick as a general programming technique. Assigning a new value to a constant disables all the compiler optimizations on constants. In such a case, simply declare a variable, instead.

Resource String Constants

When you define a string constant, instead of writing:

```
const
  AuthorName = 'Marco Cantù';
```

starting with Delphi 3 you can write the following:

```
resourcestring
  AuthorName = 'Marco Cantù';
```

In both cases you are defining a constant; that is, a value you don't change during program execution. The difference is only in the implementation. A string constant defined with the *resourcestring* directive is stored in the resources of the program, in a string table.

To see this capability in action, you can look at the ResStr example, which has a button with the following code:

```
resourcestring
  AuthorName = 'Marco Cantù';
  BookName = 'Essential Pascal';
procedure TForm1.Button1Click(Sender: TObject);
begin
  ShowMessage (BookName + #13 + AuthorName);
end;
```

The output of the two strings appears on separate lines because the strings are separated by the *newline* character (indicated by its numerical value in the *#13* character-type constant).

Starting with Delphi 6, you can use the `sLineBreak` predefined string for Windows/Linux compatibility.

The interesting aspect of this program is that if you examine it with a resource explorer (there is one available among the examples that ship with Delphi) you'll see the new strings in the resources. This means that the strings are not part of the compiled code but stored in a separate area of the executable file (the EXE file). Finally notice that although this might sound odd, resource strings are available also on Kylix.

> In short, the advantage of resources is in an efficient memory handling performed by Windows and in the possibility of localizing a program (translating the strings to a different language) without having to modify its source code.

Data Types

In Pascal there are several predefined data types, which can be divided into three groups: *ordinal types*, *real types*, and *strings*. We'll discuss ordinal and real types in the following sections, while strings are covered later in this chapter. In this section I'll also introduce some types defined by the Delphi libraries (not predefined by the compiler), which can be considered predefined types.

Delphi also includes a *non-typed* data type, called *variant*, and discussed in Chapter 10 of this book. Strangely enough a variant is a type without proper type-checking. It was introduced in Delphi 2 to handle OLE Automation.

Ordinal Types

Ordinal types are based on the concept of order or sequence. Not only can you compare two values to see which is higher, but you can also ask for the value following or preceding a given value or compute the lowest or highest possible value.

The three most important predefined ordinal types are Integer, Boolean, and Char (character). However, there are a number of other related types that have the same meaning but a different internal representation and range of values. The following Table 3.1 lists the ordinal data types used for representing numbers.

TABLE 3.1: ORDINAL DATA TYPES FOR NUMBERS

Size	Signed: Range	Unsigned: Range
8 bits	ShortInt: -128 to 127	Byte: 0 to 255
16 bits	SmallInt: -32768 to 32767	Word: 0 to 65,535
32 bits	LongInt: -2,147,483,648 to 2,147,483,647	LongWord (since Delphi 4): 0 to 4,294,967,295
64 bits	Int64	
16/32 bits	Integer	Cardinal

As you can see, these types correspond to different representations of numbers, depending on the number of bits used to express the value, and the presence or absence of a sign bit. Signed values can be positive or negative, but have a smaller range of values, because

one less bit is available for the value itself. You can refer to the Range example, discussed in the next section, for the actual range of values of each type.

The last group (marked as 16/32) indicates values having a different representation in the 16-bit and 32-bit versions of Delphi. Integer and Cardinal are frequently used, because they correspond to the native representation of numbers in the CPU.

Integral Types

In Delphi 2 and 3, the 32-bit unsigned numbers indicated by the Cardinal type were actually 31-bit values, with a range up to 2 gigabytes. Delphi 4 introduced a new unsigned numeric type, *LongWord*, which uses a truly 32-bit value up to 4 gigabytes. The Cardinal type is now an alias of the *LongWord* type. *LongWord* permits 2GB more data to be addressed by an unsigned number, as mentioned above. Moreover, it corresponds to the native representation of numbers in the CPU.

Another new type introduced in Delphi 4 is the Int64 type, which represents integer numbers with up to 18 digits. This new type is fully supported by some of the ordinal type routines (such as `High` and `Low`), numeric routines (such as Inc and Dec), and string-conversion routines (such as `IntToStr`). For the opposite conversion, from a string to a number, there are two new specific functions: `StrToInt64` and `StrToInt64Def`.

Boolean

Boolean values other than the Boolean type are seldom used. Some Boolean values with specific representations are required by Windows API functions. The types are ByteBool, WordBool, and LongBool.

In Delphi 3 for compatibility with Visual Basic and OLE automation, the data types *ByteBool*, *WordBool*, and *LongBool* were modified to represent the value *True* with -1, while the value *False* is still 0. The *Boolean* data type remains unchanged (*True* is 1, *False* is 0).

Characters

Finally there are two different representation for characters: *ANSIChar* and *WideChar*. The first type represents 8-bit characters, corresponding to the ANSI character set traditionally used by Windows; the second represents 16-bit characters, corresponding to the new Unicode characters supported by Windows NT, and only partially by Windows 95 and 98. Most of the time you'll simply use the *Char* type, which in Delphi 3 corresponds to *ANSIChar*. Keep in mind, anyway, that the first 256 Unicode characters correspond exactly to the ANSI characters.

Constant characters can be represented with their symbolic notation, as in *'k'*, or with a numeric notation, as in *#78*. The latter can also be expressed using the *Chr* function, as in *Chr (78)*. The opposite conversion can be done with the *Ord* function.

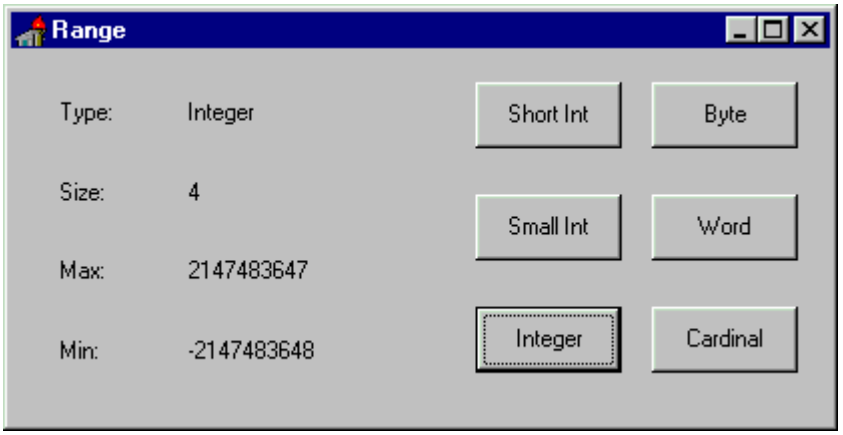
It is generally better to use the symbolic notation when indicating letters, digits, or symbols. When referring to special characters, instead, you'll generally use the numeric notation. The following list includes some of the most commonly used special characters:

#9	tabulator
#10	newline
#13	carriage return (enter key)

The Range Example

To give you an idea of the different ranges of some of the ordinal types, I've written a simple Delphi program named Range. The Range program is based on a simple form, which has six buttons (each named after an ordinal data type) and some labels for categories of information, as you can see in Figure 3.1. Some of the labels are used to hold static text, others to show the information about the type each time one of the buttons is pressed.

FIGURE 3.1: THE RANGE EXAMPLE DISPLAYS SOME INFORMATION ABOUT ORDINAL DATA TYPES (INTEGERS IN THIS CASE).

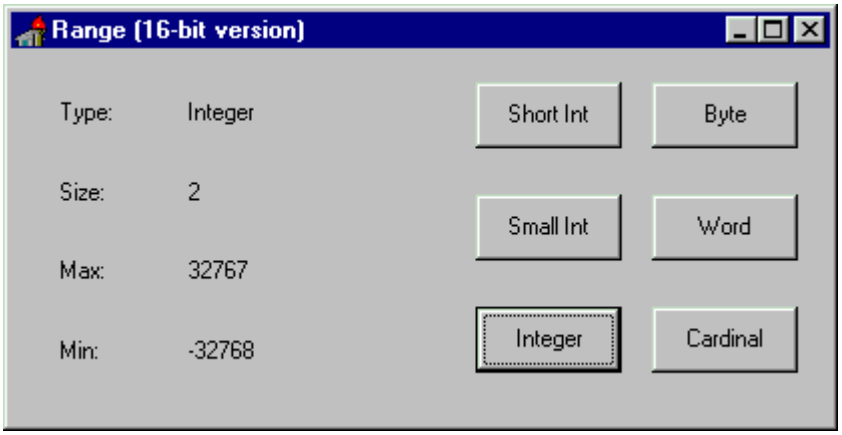


Every time you press one of the buttons on the right, the program updates the labels with the output. Different labels show the data type, number of bytes used, and the maximum and minimum values the data type can store. Each button has its own *OnClick* event-response method because the code used to compute the three values is slightly different from button to button. For example, here is the source code of the *OnClick* event for the Integer button (*BtnInteger*):

```
procedure TFormRange.BtnIntegerClick(Sender: TObject);
begin
  LabelType.Caption := 'Integer';
  LabelSize.Caption := IntToStr (SizeOf (Integer));
  LabelMax.Caption := IntToStr (High (Integer));
  LabelMin.Caption := IntToStr (Low (Integer));
end;
```

If you have some experience with Delphi programming, you can examine the source code of the program to understand how it works. For beginners, it's enough to note the use of three functions: *SizeOf*, *High*, and *Low*. The results of the last two functions are ordinals of the same type (in this case, integers), and the result of the *SizeOf* function is always an integer. The return value of each of these functions is first translated into strings using the *IntToStr* function, then copied to the captions of the three labels. The methods associated with the other buttons are very similar to the one above. The only real difference is in the data type passed as a parameter to the various functions. Figure 3.2 shows the result of executing this same program under Windows 95 after it has been recompiled with the 16-bit version of Delphi. Comparing Figure 3.1 with Figure 3.2, you can see the difference between the 16-bit and 32-bit Integer data types.

FIGURE 3.2: THE OUTPUT OF THE 16-BIT VERSION OF THE RANGE EXAMPLE, AGAIN SHOWING INFORMATION ABOUT INTEGERS.



The size of the *Integer* type varies depending on the CPU and operating system you are using. In 16-bit Windows, an Integer variable is two bytes wide. In 32-bit Windows, an Integer is four bytes wide. For this reason, when you recompile the Range example, you get a different output. The two different representations of the *Integer* type are not a problem, as long as your program doesn't make any assumptions about the size of integers. If you happen to save an Integer to a file using one version and retrieve it with another, though, you're going to have some trouble. In this situation, you should choose a platform-independent data type (such as *LongInt* or *SmallInt*). For mathematical computation or generic code, your best bet is to stick with the standard integral representation for the specific platform--that is, use the Integer type--because this is what the CPU likes best. The *Integer* type should be your first choice when handling integer numbers. Use a different representation only when there is a compelling reason to do so.

Ordinal Types Routines

There are some system routines (routines defined in the Pascal language and in the Delphi system unit) that work on ordinal types. They are shown in Table 3.2. C++ programmers should notice that the two versions of the *Inc* procedure, with one or two parameters, correspond to the ++ and += operators (the same holds for the Dec procedure).

TABLE 3.2: SYSTEM ROUTINES FOR ORDINAL TYPES

Routine	Purpose
Dec	Decrements the variable passed as parameter, by one or by the value of the optional second parameter.
Inc	Increments the variable passed as parameter, by one or by the specified value.
Odd	Returns True if the argument is an odd number.
Pred	Returns the value before the argument in the order determined by the data type, the predecessor.
Succ	Returns the value after the argument, the successor.
Ord	Returns a number indicating the order of the argument within the set of values of the data type.
Low	Returns the lowest value in the range of the ordinal type passed as its parameter.
High	Returns the highest value in the range of the ordinal data type.

Notice that some of these routines, when applied to constants, are automatically evaluated by the compiler and replaced by their value. For example if you call *High(X)* where *X* is defined as an Integer, the compiler can simply replace the expression with the highest possible value of the Integer data type.

Real Types

Real types represent floating-point numbers in various formats. The smallest storage size is given by *Single* numbers, which are implemented with a 4-byte value. Then there are *Double* floating-point numbers, implemented with 8 bytes, and *Extended* numbers, implemented with 10 bytes. These are all floating-point data types with different precision, which correspond to the IEEE standard floating-point representations, and are directly supported by the CPU numeric coprocessor, for maximum speed.

In Delphi 2 and Delphi 3 the *Real* type had the same definition as in the 16-bit version; it was a 48-bit type. But its usage was deprecated by Borland, which suggested that you use the Single, Double, and Extended types instead. The reason for their suggestion is that the old 6-byte format is neither supported by the Intel CPU nor listed among the official IEEE real types. To completely overcome the problem, Delphi 4 modifies the definition of the Real type to represent a standard 8-byte (64-bit) floating-point number.

In addition to the advantage of using a standard definition, this change allows components to publish properties based on the Real type, something Delphi 3 did not allow. Among the disadvantages there might be compatibility problems. If necessary, you can overcome the possibility of incompatibility by sticking to the Delphi 2 and 3 definition of the type; do this by using the following compiler option:

```
{$REALCOMPATIBILITY ON}
```

There are also two strange data types: *Comp* describes very big integers using 8 bytes (which can hold numbers with 18 decimal digits); and *Currency* (not available in 16-bit Delphi) indicates a fixed-point decimal value with four decimal digits, and the same 64-bit representation as the *Comp* type. As the name implies, the *Currency* data type has been added to handle very precise monetary values, with four decimal places.

We cannot build a program similar to the Range example with real data types, because we cannot use the *High* and *Low* functions or the *Ord* function on real-type variables. Real types represent (in theory) an infinite set of numbers; ordinal types represent a fixed set of values.

> Let me explain this better. when you have the integer 23 you can determine which is the following value. Integers are finite (they have a determined range and they have an order). Floating point numbers are infinite even within a small range, and have no order: in fact, how many values are there between 23 and 24? And which number follows 23.46? It is 23.47, 23.461, or 23.4601? That's really hard to know!

For this reason, it makes sense to ask for the ordinal position of the character *w* in the range of the Char data type, but it makes no sense at all to ask the same question about 7143.1562 in the range of a floating-point data type. Although you can indeed know whether one real number has a higher value than another, it makes no sense to ask how many real numbers exist before a given number (this is the meaning of the *Ord* function).

Real types have a limited role in the user interface portion of the code (the Windows side), but they are fully supported by Delphi, including the database side. The support of IEEE standard floating-point types makes the Object Pascal language completely appropriate for the wide range of programs that require numerical computations. If you are interested in this aspect, you can look at the arithmetic functions provided by Delphi in the system unit (see the Delphi Help for more details).

Delphi also has a *Math* unit that defines advanced mathematical routines, covering trigonometric functions (such as the *ArcCosh* function), finance (such as the *InterestPayment* function), and statistics (such as the *MeanAndStdDev* procedure). There are a number of these routines, some of which sound quite strange to me, such as the *MomentSkewKurtosis* procedure (I'll let you find out what this is).

Date and Time

Delphi uses real types also to handle date and time information. To be more precise Delphi defines a specific *TDateTime* data type. This is a floating-point type, because the type must be wide enough to store years, months, days, hours, minutes, and seconds, down to millisecond resolution in a single variable. Dates are stored as the number of days since 1899-12-30 (with negative values indicating dates before 1899) in the integer part of the *TDateTime* value. Times are stored as fractions of a day in the decimal part of the value.

TDateTime is not a predefined type the compiler understands, but it is defined in the system unit as:

```
type
  TDateTime = type Double;
```

Using the *TDateTime* type is quite easy, because Delphi includes a number of functions that operate on this type. You can find a list of these functions in Table 3.3.

TABLE 3.3: SYSTEM ROUTINES FOR THE TDATETIME TYPE

Routine	Description
Now	Returns the current date and time into a single TDateTime value.
Date	Returns only the current date.
Time	Returns only the current time.
DateTimeToStr	Converts a date and time value into a string, using default formatting; to have more control on the conversion use the FormatDateTime function instead.
DateTimeToString	Copies the date and time values into a string buffer, with default formatting.
DateToStr	Converts the date portion of a TDateTime value into a string.
TimeToStr	Converts the time portion of a TDateTime value into a string.
FormatDateTime	Formats a date and time using the specified format; you can specify which values you want to see and which format to use, providing a complex format string.
StrToDateTime	Converts a string with date and time information to a TDateTime value, raising an exception in case of an error in the format of the string.
StrToDate	Converts a string with a date value into the TDateTime format.
StrToTime	Converts a string with a time value into the TDateTime format.
DayOfWeek	Returns the number corresponding to the day of the week of the TDateTime value passed as parameter.
DecodeDate	Retrieves the year, month, and day values from a date value.
DecodeTime	Retrieves out of a time value.
EncodeDate	Turns year, month, and day values into a TDateTime value.
EncodeTime	Turns hour, minute, second, and millisecond values into a TDateTime value.

To show you how to use this data type and some of its related routines, I've built a simple example, named TimeNow. The main form of this example has a Button and a ListBox

component. When the program starts it automatically computes and displays the current time and date. Every time the button is pressed, the program shows the time elapsed since the program started.

Here is the code related to the *OnCreate* event of the form:

```
procedure TFormTimeNow.FormCreate(Sender: TObject);
begin
  StartTime := Now;
  ListBox1.Items.Add (TimeToStr (StartTime));
  ListBox1.Items.Add (DateToStr (StartTime));
  ListBox1.Items.Add ('Press button for elapsed time');
end;
```

The first statement is a call to the *Now* function, which returns the current date and time. This value is stored in the *StartTime* variable, declared as a global variable as follows:

```
var
  FormTimeNow: TFormTimeNow;
  StartTime: TDateTime;
```

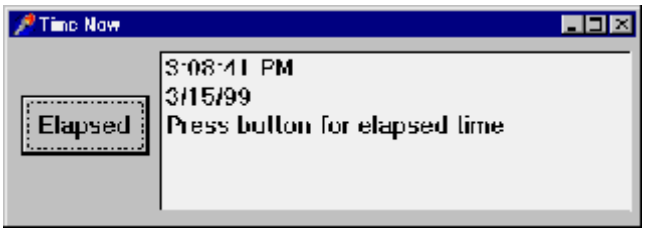
I've added only the second declaration, since the first is provided by Delphi. By default, it is the following:

```
var
  Form1: TForm1;
```

Changing the name of the form, this declaration is automatically updated. Using global variables is actually not the best approach: It should be better to use a private field of the form class, a topic related to object-oriented programming and discussed in Mastering Delphi 4.

The next three statements add three items to the ListBox component on the left of the form, with the result you can see in Figure 3.3. The first line contains the time portion of the *TDateTime* value converted into a string, the second the date portion of the same value. At the end the code adds a simple reminder.

FIGURE 3.3: THE OUTPUT OF THE TIMENOW EXAMPLE AT STARTUP.



This third string is replaced by the program when the user clicks on the Elapsed button:

```
procedure TFormTimeNow.ButtonElapsedClick(Sender: TObject);
var
  StopTime: TDateTime;
begin
  StopTime := Now;
  ListBox1.Items [2] :=  FormatDateTime ('hh:nn:ss',
    StopTime - StartTime);
end;
```

This code retrieves the new time and computes the difference from the time value stored when the program started. Because we need to use a value that we computed in a different event handler, we had to store it in a global variable. There are actually better alternatives, based on classes.

The code that replaces the current value of the third string uses the index 2. The reason is that the items of a list box are zero-based: the first item is number 0, the second number 1, and the third number 2. More on this as we cover arrays.

Besides calling *TimeToStr* and *DateToStr* you can use the more powerful *FormatDateTime* function, as I've done in the last method above (see the Delphi Help file for details on the formatting parameters). Notice also that time and date values are transformed into strings depending on Windows international settings. Delphi reads these values from the system, and copies them to a number of global constants declared in the SysUtils unit. Some of them are:

```
DateSeparator: Char;
ShortDateFormat: string;
LongDateFormat: string;
TimeSeparator: Char;
TimeAMString: string;
TimePMString: string;
ShortTimeFormat: string;
LongTimeFormat: string;
ShortMonthNames: array [1..12] of string;
LongMonthNames: array [1..12] of string;
ShortDayNames: array [1..7] of string;
LongDayNames: array [1..7] of string;
```

More global constants relate to currency and floating-point number formatting. You can find the complete list in the Delphi Help file under the topic *Currency and date/time formatting variables*.

Delphi includes a DateTimePicker component, which provides a sophisticated way to input a date, selecting it from a calendar.

Specific Windows Types

The predefined data types we have seen so far are part of the Pascal language. Delphi also includes other data types defined by Windows. These data types are not an integral part of the language, but they are part of the Windows libraries. Windows types include new default types (such as *DWORD* or *UINT*), many records (or structures), several pointer types, and so on.

Among Windows data types, the most important type is represented by handles, discussed in Chapter 9.

Typecasting and Type Conversions

As we have seen, you cannot assign a variable to another one of a different type. In case you need to do this, there are two choices. The first choice is *typecasting*, which uses a simple functional notation, with the name of the destination data type:

```
var
  N: Integer;
  C: Char;
  B: Boolean;
begin
  N := Integer ('X');
  C := Char (N);
  B := Boolean (0);
```

You can typecast between data types having the same size. It is usually safe to typecast between ordinal types, or between real types, but you can also typecast between pointer types (and also objects) as long as you know what you are doing. Casting, however, is generally a dangerous programming practice, because it allows you to access a value as if it represented something else. Since the internal representations of data types generally do not match, you risk hard-to-track errors. For this reason, you should generally avoid typecasting.

The second choice is to use a type-conversion routine. The routines for the various types of conversions are summarized in Table 3.4. Some of these routines work on the data types that we'll discuss in the following sections. Notice that the table doesn't include routines for special types (such as *TDateTime* or variant) or routines specifically intended for formatting, like the powerful *Format* and *FormatFloat* routines.

TABLE 3.4: SYSTEM ROUTINES FOR TYPE CONVERSION

Routine	Description
Chr	Converts an ordinal number into an ANSI character.
Ord	Converts an ordinal-type value into the number indicating its order.
Round	Converts a real-type value into an Integer-type value, rounding its value.
Trunc	Converts a real-type value into an Integer-type value, truncating its value.
Int	Returns the Integer part of the floating-point value argument.
IntToStr	Converts a number into a string.
IntToHex	Converts a number into a string with its hexadecimal representation.
StrToInt	Converts a string into a number, raising an exception if the string does not represent a valid integer.
StrToIntDef	Converts a string into a number, using a default value if the string is not correct.
Val	Converts a string into a number (traditional Turbo Pascal routine, available for compatibility).
Str	Converts a number into a string, using formatting parameters (traditional Turbo Pascal routine, available for compatibility).
StrPas	Converts a null-terminated string into a Pascal-style string. This conversion is automatically done for AnsiStrings in 32-bit Delphi. (See the section on strings later in this chapter.)
StrPCopy	Copies a Pascal-style string into a null-terminated string. This conversion is done with a simple PChar cast in 32-bit Delphi. (See the section on strings later in this chapter.)
StrPLCopy	Copies a portion of a Pascal-style string into a null-terminated string.
FloatToDecimal	Converts a floating-point value to record including its decimal representation (exponent, digits, sign).
FloatToStr	Converts the floating-point value to its string representation using default formatting.
FloatToStrF	Converts the floating-point value to its string representation using the specified formatting.
FloatToText	Copies the floating-point value to a string buffer, using the specified formatting.
FloatToTextFmt	As the previous routine, copies the floating-point value to a string buffer, using the specified formatting.
StrToFloat	Converts the given Pascal string to a floating-point value.
TextToFloat	Converts the given null-terminated string to a floating-point value.

In recent versions of Delphi's Pascal compiler, the *Round* function is based on the FPU processor of the CPU. This processor adopts the so-called "Banker's Rounding", which rounds middle values (as 5.5 or 6.5) up and down depending whether they follow an odd or an even number.

Conclusion

In this chapter we've explored the basic notion of type in Pascal. But the language has another very important feature: It allows programmers to define new custom data types, called user-defined data types. This is the topic of the next chapter.

Chapter 4
User-Defined Data Types

Along with the notion of type, one of the great ideas introduced by the Pascal language is the ability to define new data types in a program. Programmers can define their own data types by means of *type constructors*, such as subrange types, array types, record types, enumerated types, pointer types, and set types. The most important user-defined data type is the class, which is part of the object-oriented extensions of Object Pascal, not covered in this book.

If you think that type constructors are common in many programming languages, you are right, but Pascal was the first language to introduce the idea in a formal and very precise way. There are still few languages with so many mechanisms to define new types.

Named and Unnamed Types

These types can be given a name for later use or applied to a variable directly. When you give a name to a type, you must provide a specific section in the code, such as the following:

```
type
  // subrange definition
  Uppercase = 'A'..'Z';

  // array definition
  Temperatures = array [1..24] of Integer;

  // record definition
  Date = record
    Month: Byte;
    Day: Byte;
    Year: Integer;
  end;

  // enumerated type definition
  Colors = (Red, Yellow, Green, Cyan, Blue, Violet);

  // set definition
  Letters = set of Char;
```

Similar type-definition constructs can be used directly to define a variable without an explicit type name, as in the following code:

```
var
  DecemberTemperature: array [1..31] of Byte;
  ColorCode: array [Red..Violet] of Word;
  Palette: set of Colors;
```

In general, you should avoid using *unnamed* types as in the code above, because you cannot pass them as parameters to routines or declare other variables of the same type. The type compatibility rules of Pascal, in fact, are based on type names, not on the actual definition of the types. Two variables of two identical types are still not compatible, unless their types have exactly the same name, and unnamed types are given internal names by the compiler. Get used to defining a data type each time you need a variable with a complicated structure, and you won't regret the time you've spent in it.

But what do these type definitions mean? I'll provide some descriptions for those who are not familiar with Pascal type constructs. I'll also try to underline the differences from the same constructs in other programming languages, so you might be interested in reading the following sections even if you are familiar with kind of type definitions exemplified above. Finally, I'll show some Delphi examples and introduce some tools that will allow you to access type information dynamically.

Subrange Types

A subrange type defines a range of values within the range of another type (hence the name *subrange)*. You can define a subrange of the Integer type, from 1 to 10 or from 100 to 1000, or you can define a subrange of the *Char* type, as in:

```
type
  Ten = 1..10;
  OverHundred = 100..1000;
  Uppercase = 'A'..'Z';
```

In the definition of a subrange, you don't need to specify the name of the base type. You just need to supply two constants of that type. The original type must be an ordinal type, and the resulting type will be another ordinal type. When you have defined a subrange, you can legally assign it a value within that range. This code is valid:

```
var
  UppLetter: UpperCase;
begin
  UppLetter := 'F';
```

But this one is not:

```
var
  UppLetter: UpperCase;
begin
  UppLetter := 'e'; // compile-time error
```

Writing the code above results in a compile-time error, *"Constant expression violates subrange bounds."* If you write the following code instead:

```
var
  UppLetter: Uppercase;
  Letter: Char;
begin
  Letter :='e';
  UppLetter := Letter;
```

Delphi will compile it. At run-time, if you have enabled the Range Checking compiler option (in the Compiler page of the Project Options dialog box), you'll get a *Range check error* message.

I suggest that you turn on this compiler option while you are developing a program, so it'll be more robust and easier to debug, as in case of errors you'll get an explicit message and not an undetermined behavior. You can eventually disable the option for the final build of the program, to make it a little faster. However, the difference is really small, and for this reason I suggest you to leave all these run-time checks turned on, even in a shipping program. The same holds true for other run-time checking options, such as overflow and stack checking.

Enumerated Types

Enumerated types constitute another user-defined ordinal type. Instead of indicating a range of an existing type, in an enumeration you list all of the possible values for the type. In other words, an enumeration is a list of values. Here are some examples:

```
type
  Colors = (Red, Yellow, Green, Cyan, Blue, Violet);
  Suit = (Club, Diamond, Heart, Spade);
```

Each value in the list has an associated *ordinality*, starting with zero. When you apply the *Ord* function to a value of an enumerated type, you get this zero-based value. For example, *Ord (Diamond)* returns 1.

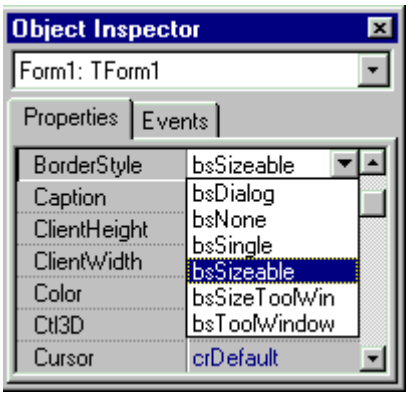
> Enumerated types can have different internal representations. By default, Delphi uses an 8-bit representation, unless there are more than 256 different values, in which case it uses the 16-bit representation. There is also a 32-bit representation, which might be useful for compatibility with C or C++ libraries. You can actually change the default behavior, asking for a larger representation, by using the *$Z* compiler directive.

The Delphi VCL (Visual Component Library) uses enumerated types in many places. For example, the style of the border of a form is defined as follows:

```
type
  TFormBorderStyle = (bsNone, bsSingle, bsSizeable,
    bsDialog, bsSizeToolWin, bsToolWindow);
```

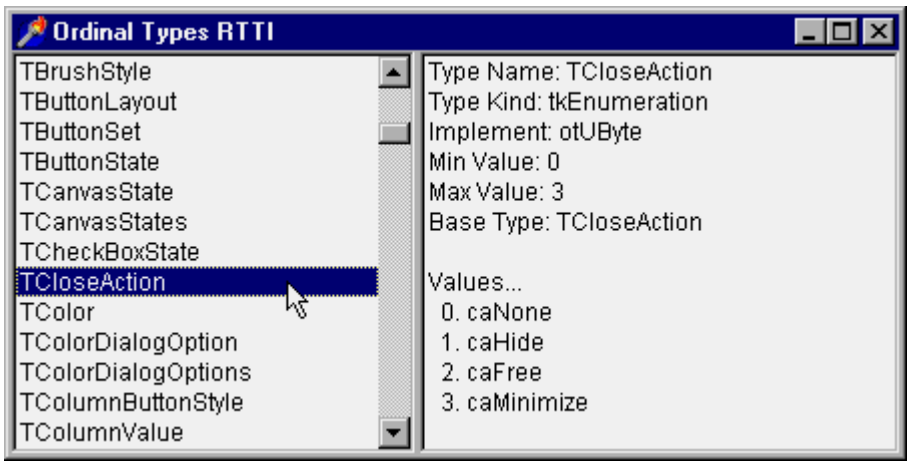
When the value of a property is an enumeration, you usually can choose from the list of values displayed in the Object Inspector, as shown in Figure 4.1.

FIGURE 4.1: AN ENUMERATED TYPE PROPERTY IN THE OBJECT INSPECTOR



The Delphi Help file generally lists the possible values of an enumeration. As an alternative you can use the *OrdType* program, available on www.marcocantu.com, to see the list of the values of each Delphi enumeration, set, subrange, and any other ordinal type. You can see an example of the output of this program in Figure 4.2.

FIGURE 4.2: DETAILED INFORMATION ABOUT AN ENUMERATED TYPE, AS DISPLAYED BY THE ORDTYPE PROGRAM (AVAILABLE ON MY WEB SITE).



Set Types

Set types indicate a group of values, where the list of available values is indicated by the ordinal type the set is based onto. These ordinal types are usually limited, and quite often represented by an enumeration or a subrange. If we take the subrange 1..3, the possible values of the set based on it include only 1, only 2, only 3, both 1 and 2, both 1 and 3, both 2 and 3, all the three values, or none of them.

A variable usually holds one of the possible values of the range of its type. A set-type variable, instead, can contain none, one, two, three, or more values of the range. It can even include all of the values. Here is an example of a set:

```
type
  Letters = set of Uppercase;
```

Now I can define a variable of this type and assign to it some values of the original type. To indicate some values in a set, you write a comma-separated list, enclosed within square brackets. The following code shows the assignment to a variable of several values, a single value, and an empty value:

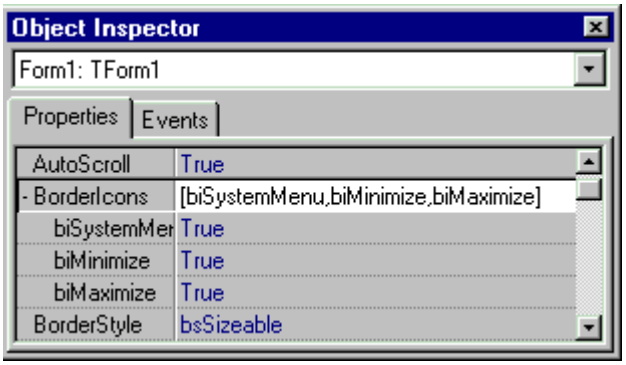
```
var
  Letters1, Letters2, Letters3: Letters;
begin
  Letters1 := ['A', 'B', 'C'];
  Letters2 := ['K'];
  Letters3 := [];
```

In Delphi, a set is generally used to indicate nonexclusive flags. For example, the following two lines of code (which are part of the Delphi library) declare an enumeration of possible icons for the border of a window and the corresponding set type:

```
type
  TBorderIcon = (biSystemMenu, biMinimize, biMaximize, biHelp);
  TBorderIcons = set of TBorderIcon;
```

In fact, a given window might have none of these icons, one of them, or more than one. When working with the Object Inspector (see Figure 4.3), you can provide the values of a set by expanding the selection (double-click on the property name or click on the plus sign on its left) and toggling on and off the presence of each value.

FIGURE 4.3: A SET-TYPE PROPERTY IN THE OBJECT INSPECTOR



Another property based on a set type is the style of a font. Possible values indicate a bold, italic, underline, and strikethrough font. Of course the same font can be both italic and bold, have no attributes, or have them all. For this reason it is declared as a set. You can assign values to this set in the code of a program as follows:

```
Font.Style := []; // no style
Font.Style := [fsBold]; // bold style only
Font.Style := [fsBold, fsItalic]; // two styles
```

You can also operate on a set in many different ways, including adding two variables of the same set type (or, to be more precise, computing the union of the two set variables):

```
Font.Style := OldStyle + [fsUnderline]; // two sets
```

Again, you can use the OrdType examples included in the TOOLS directory of the book source code to see the list of possible values of many sets defined by the Delphi component library.

Array Types

Array types define lists of a fixed number of elements of a specific type. You generally use an *index* within square brackets to access to one of the elements of the array. The square brackets are used also to specify the possible values of the index when the array is defined. For example, you can define a group of 24 integers with this code:

```
type
  DayTemperatures = array [1..24] of Integer;
```

In the array definition, you need to pass a subrange type within square brackets, or define a new specific subrange type using two constants of an ordinal type. This subrange specifies the valid indexes of the array. Since you specify both the upper and the lower index of the array, the indexes don't need to be zero-based, as is necessary in C, C++, Java, and other programming languages.

Since the array indexes are based on subranges, Delphi can check for their range as we've already seen. An invalid constant subrange results in a compile-time error; and an out-of-range index used at run-time results in a run-time error if the corresponding compiler option is enabled.

Using the array definition above, you can set the value of a *DayTemp1* variable of the *DayTemperatures* type as follows:

```
type
  DayTemperatures = array [1..24] of Integer;

var
  DayTemp1: DayTemperatures;

procedure AssignTemp;
```

```
begin
  DayTemp1 [1] := 54;
  DayTemp1 [2] := 52;
  ...
  DayTemp1 [24] := 66;
  DayTemp1 [25] := 67; // compile-time error
```

An array can have more than one dimension, as in the following examples:

```
type
  MonthTemps = array [1..24, 1..31] of Integer;
  YearTemps = array [1..24, 1..31, Jan..Dec] of Integer;
```

These two array types are built on the same core types. So you can declare them using the preceding data types, as in the following code:

```
type
  MonthTemps = array [1..31] of DayTemperatures;
  YearTemps = array [Jan..Dec] of MonthTemps;
```

This declaration inverts the order of the indexes as presented above, but it also allows assignment of whole blocks between variables. For example, the following statement copies January's temperatures to February:

```
var
  ThisYear: YearTemps;
begin
  ThisYear[Feb] := ThisYear[Jan];
```

You can also define a *zero-based* array, an array type with the lower bound set to zero. Generally, the use of more logical bounds is an advantage, since you don't need to use the index 2 to access the third item, and so on. Windows, however, uses invariably zero-based arrays (because it is based on the C language), and the Delphi component library tends to do the same.

If you need to work on an array, you can always test its bounds by using the standard *Low* and *High* functions, which return the lower and upper bounds. Using *Low* and *High* when operating on an array is highly recommended, especially in loops, since it makes the code independent of the range of the array. Later, you can change the declared range of the array indices, and the code that uses *Low* and *High* will still work. If you write a loop hard-coding the range of an array you'll have to update the code of the loop when the array size changes. *Low* and *High* make your code easier to maintain and more reliable.

> Incidentally, there is no run-time overhead for using *Low* and *High* with arrays. They are resolved at compile-time into constant expressions, not actual function calls. This compile-time resolution of expressions and function calls happens also for many other simple system functions.

Delphi uses arrays mainly in the form of array properties. We have already seen an example of such a property in the TimeNow example, to access the *Items* property of a ListBox component. I'll show you some more examples of array properties in the next chapter, when discussing Delphi loops.

> Delphi 4 introduced dynamic arrays into Object Pascal , that is arrays that can be resized at runtime allocating the proper amount of memory. Using dynamic arrays is easy, but in this discussion of Pascal I felt they were not an proper topic to cover. You can find a description of Delphi's dynamic arrays in Chapter 8.

Record Types

Record types define fixed collections of items of different types. Each element, or *field*, has its own type. The definition of a record type lists all these fields, giving each a name you'll use later to access it.

Here is a small listing with the definition of a record type, the declaration of a variable of that type, and few statements using this variable:

```
type
  Date = record
    Year: Integer;
    Month: Byte;
    Day: Byte;
  end;

var
  BirthDay: Date;

begin
  BirthDay.Year := 1997;
  BirthDay.Month := 2;
  BirthDay.Day := 14;
```

Classes and objects can be considered an extension of the record type. Delphi libraries tend to use class types instead of record types, but there are many record types defined by the Windows API.

Record types can also have a variant part; that is, multiple fields can be mapped to the same memory area, even if they have a different data type. (This corresponds to a union in the C language.) Alternatively, you can use these variant fields or groups of fields to access the same memory location within a record, but considering those values from different perspectives. The main uses of this type were to store similar but different data and to obtain an effect similar to that of typecasting (something less useful now that typecasting has been introduced also in Pascal). The use of variant record types has been largely replaced by object-oriented and other modern techniques, although Delphi uses them in some peculiar cases.

The use of a variant record type is not type-safe and is not a recommended programming practice, particularly for beginners. Expert programmers can indeed use variant record types, and the core of the Delphi libraries makes use of them. You won't need to tackle them until you are really a Delphi expert, anyway.

Pointers

A pointer type defines a variable that holds the memory address of another variable of a given data type (or an undefined type). So a pointer variable indirectly refers to a value. The definition of a pointer type is not based on a specific keyword, but uses a special character instead. This special symbol is the caret (^):

```
type
  PointerToInt = ^Integer;
```

Once you have defined a pointer variable, you can assign to it the address of another variable of the same type, using the @ operator:

```
var
  P: ^Integer;
  X: Integer;
```

```
begin
  P := @X;
  // change the value in two different ways
  X := 10;
  P^ := 20;
```

When you have a pointer *P*, with the expression *P* you refer to the address of the memory location the pointer is referring to, and with the expression *P^* you refer to the actual content of that memory location. For this reason in the code fragment above *^P* corresponds to *X*.

Instead of referring to an existing memory location, a pointer can refer to a new memory block dynamically allocated (on the heap memory area) with the *New* procedure. In this case, when you don't need the pointer any more, you'll also have to to get rid of the memory you've dynamically allocated, by calling the *Dispose* procedure.

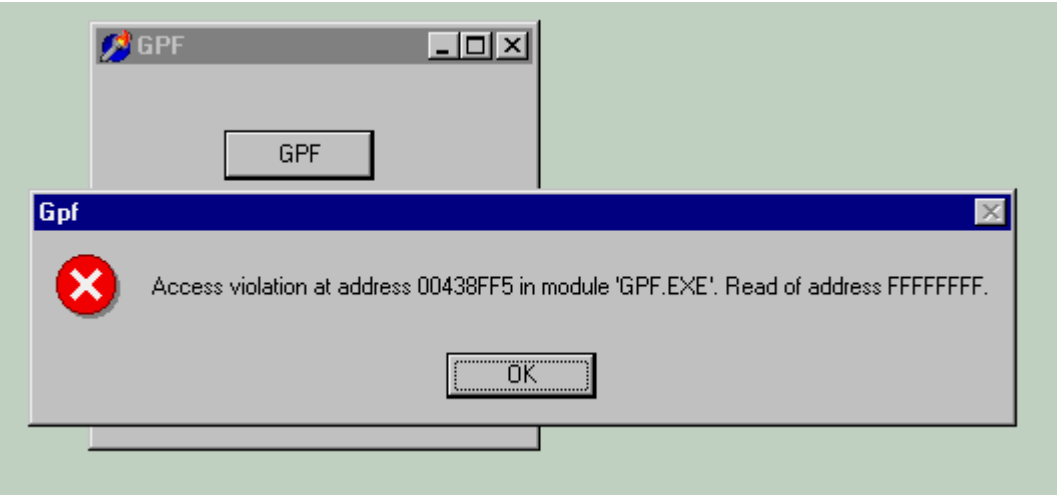
```
var
  P: ^Integer;
begin
  // initialization
  New (P);
  // operations
  P^ := 20;
  ShowMessage (IntToStr (P^));
  // termination
  Dispose (P);
end;
```

If a pointer has no value, you can assign the *nil* value to it. Then you can test whether a pointer is *nil* to see if it currently refers to a value. This is often used, because dereferencing an invalid pointer causes an access violation (also known as a general protection fault, GPF):

```
procedure TFormGPF.BtnGpfClick(Sender: TObject);
var
  P: ^Integer;
begin
  P := nil;
  ShowMessage (IntToStr (P^));
end;
```

You can see an example of the effect of this code by running the GPF example (or looking at the corresponding Figure 4.4). The example contains also the code fragments shown above.

FIGURE 4.4: THE SYSTEM ERROR RESULTING FROM THE ACCESS TO A NIL POINTER, FROM THE GPF EXAMPLE.



In the same program you can find an example of safe data access. In this second case the pointer is assigned to an existing local variable, and can be safely used, but I've added a safe-check anyway:

```
procedure TFormGPF.BtnSafeClick(Sender: TObject);
var
  P: ^Integer;
  X: Integer;
begin
  P := @X;
  X := 100;
  if P <> nil then
    ShowMessage (IntToStr (P^));
end;
```

Delphi also defines a *Pointer* data type, which indicates untyped pointers (such as *void** in the C language). If you use an untyped pointer you should use *GetMem* instead of *New*. The *GetMem* procedure is required each time the size of the memory variable to allocate is not defined.

The fact that pointers are seldom necessary in Delphi is an interesting advantage of this environment. Nonetheless, understanding pointers is important for advanced programming and for a full understanding of the Delphi object model, which uses pointers "behind the scenes."

Although you don't use pointers often in Delphi, you do frequently use a very similar construct—namely, references. Every object instance is really an implicit pointer or reference to its actual data. However, this is completely transparent to the programmer, who uses object variables just like any other data type. Notice also that pointers support will be severely limited (if not abolished) in the .NET version of the Delphi compiler, due to the restrictions imposed by the platform to the so-called "safe" code.

File Types

Another Pascal-specific type constructor is the *file* type. File types represent physical disk files, certainly a peculiarity of the Pascal language. You can define a new file data type as follows:

```
type
  IntFile = file of Integer;
```

Then you can open a physical file associated with this structure and write integer values to it or read the current values from the file.

Files-based examples are covered in a specific chapter.

The use of files in Pascal is quite straightforward, but in Delphi there are also some components that are capable of storing or loading their contents to or from a file. There is some serialization support, in the form of streams, and there is also database support.

Conclusion

This chapter discussing user-defined data types complete our coverage of Pascal type system. Now we are ready to look into the statements the language provides to operate on the variables we've defined.

Chapter 5
Statements

If the data types are one of the foundations of Pascal programming the other are statements. Statements of the programming language are based on keywords and other elements which allow you to indicate to a program a sequence of operations to perform. Statements are often enclosed in procedures or functions, as we'll see in the next chapter. Now we'll just focus on the basic types of commands you can use to create a program.

Simple and Compound Statements

A Pascal statement is simple when it doesn't contain any other statements. Examples of simple statements are assignment statements and procedure calls. Simple statements are separated by a semicolon:

```
X := Y + Z;  // assignment
Randomize;   // procedure call
```

Usually, statements are part of a compound statement, marked by begin and end brackets. A compound statement can appear in place of a generic Pascal statement. Here is an example:

```
begin
  A := B;
  C := A * 2;
end;
```

The semicolon after the last statement before the end isn't required, as in the following:

```
begin
  A := B;
  C := A * 2
end;
```

Both versions are correct. The first version has a useless (but harmless) semicolon. This semicolon is, in fact, a null statement; that is, a statement with no code. Notice that, at times, null statements can be used inside loops or in other particular cases.

> Although these final semicolons serve no purpose, I tend to use them and suggest you do the same. Sometimes after you've written a couple of lines you might want to add one more statement. If the last semicolon is missing you should remember to add it, so it might be better to add it in the first place.

Assignment Statements

Assignments in Pascal use the colon-equal operator, an odd notation for programmers who are used to other languages. The = operator, which is used for assignments in some other languages, in Pascal is used to test for equality.

> By using different symbols for an assignment and an equality test, the Pascal compiler (like the C compiler) can translate source code faster, because it doesn't need to examine the context in which the operator is used to determine its meaning. The use of different operators also makes the code easier for people to read.

Conditional Statements

A conditional statement is used to execute either one of the statements it contains or none of them, depending on some test. There are two basic flavors of conditional statements: if statements and case statements.

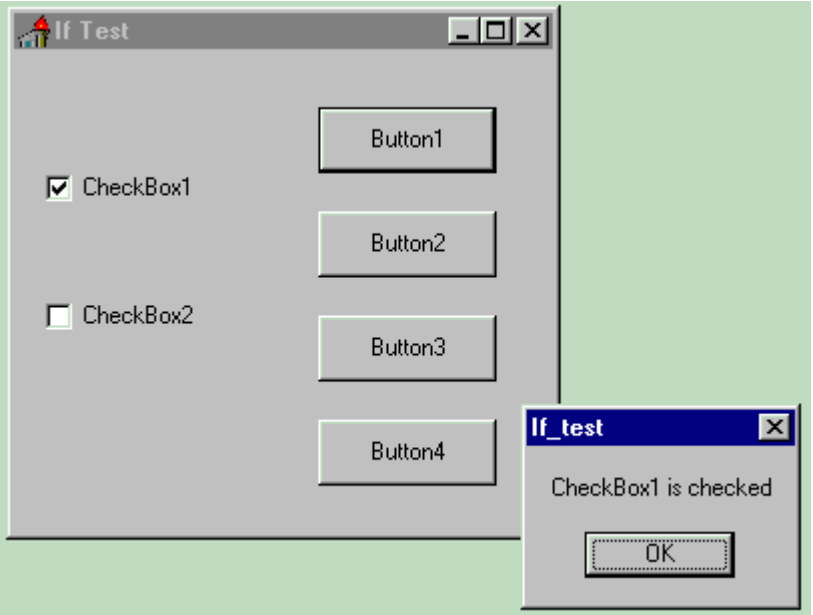
If Statements

The if statement can be used to execute a statement only if a certain condition is met (if-then), or to choose between two different alternatives (if-then-else). The condition is described with a Boolean expression. A simple Delphi example will demonstrate how to write conditional statements. First create a new application, and put two check boxes and four buttons in the form. Do not change the names of buttons or check boxes, but double-click on each button to add a handler for its *OnClick* event. Here is a simple *if* statement for the first button:

```
procedure TForm1.Button1Click(Sender: TObject);
begin
  if CheckBox1.Checked then
    ShowMessage ('CheckBox1 is checked')
end;
```

When you click on the button, if the first check box has a check mark in it, the program will show a simple message (see Figure 5.1). I've used the `ShowMessage` function because it is the simplest Delphi function you can use to display a short message to the user.

FIGURE 5.1: THE MESSAGE DISPLAYED BY THE IFTEST EXAMPLE WHEN YOU PRESS THE FIRST BUTTON AND THE FIRST CHECK BOX IS CHECKED.



If you click the button and nothing happens, it means the check box was not checked. In a case like this, it would probably be better to make this more explicit, as with the code for the second button, which uses an if-then-else statement:

```
procedure TForm1.Button2Click(Sender: TObject);
begin
  // if-then-else statement
  if CheckBox2.Checked then
```

```
    ShowMessage ('CheckBox2 is checked')
  else
    ShowMessage ('CheckBox2 is NOT checked');
end;
```

Notice that you cannot have a semicolon after the first statement and before the *else* keyword, or the compiler will issue a syntax error. The *if-then-else* statement, in fact, is a single statement, so you cannot place a semicolon in the middle of it.

An *if* statement can be quite complex. The condition can be turned into a series of conditions (using the *and*, *or* and *not* Boolean operators), or the *if* statement can nest a second *if* statement. The last two buttons of the IfTest example demonstrate these cases:

```
procedure TForm1.Button3Click(Sender: TObject);
begin
  // statement with a double condition
  if CheckBox1.Checked and CheckBox2.Checked then
    ShowMessage ('Both check boxes are checked')
end;

procedure TForm1.Button4Click(Sender: TObject);
begin
  // compound if statement
  if CheckBox1.Checked then
    if CheckBox2.Checked then
      ShowMessage ('CheckBox1 and 2 are checked')
    else
      ShowMessage ('Only CheckBox1 is checked')
  else
    ShowMessage ('Checkbox1 is not checked, who cares for Checkbox2?')
end;
```

Look at the code carefully and run the program to see if you understand everything. When you have doubts about a programming construct, writing a very simple program such as this can help you learn a lot. You can add more check boxes and increase the complexity of this small example, making any test you like.

Case Statements

If your *if* statements become very complex, at times you can replace them with *case* statements. A *case* statement consists in an expression used to select a value, a list of possible values, or a range of values. These values are constants, and they must be unique and of an ordinal type. Eventually, there can be an *else* statement that is executed if none of the labels correspond to the value of the selector. Here are two simple examples:

```
case Number of
  1: Text := 'One';
  2: Text := 'Two';
  3: Text := 'Three';
end;

case MyChar of
  '+' : Text := 'Plus sign';
  '-' : Text := 'Minus sign';
  '*', '/': Text := 'Multiplication or division';
  '0'..'9': Text := 'Number';
  'a'..'z': Text := 'Lowercase character';
  'A'..'Z': Text := 'Uppercase character';
```

```
else
  Text := 'Unknown character';
end;
```

Loops in Pascal

The Pascal language has the typical repetitive statements of most programming languages, including *for*, *while*, and *repeat* statements. Most of what these loops do will be familiar if you've used other programming languages, so I'll cover them only briefly.

The For Loop

The for loop in Pascal is strictly based on a counter, which can be either increased or decreased each time the loop is executed. Here is a simple example of a for loop used to add the first ten numbers.

```
var
  K, I: Integer;
begin
  K := 0;
  for I := 1 to 10 do
    K := K + I;
```

This same for statement could have been written using a reverse counter:

```
var
  K, I: Integer;
begin
  K := 0;
  for I := 10 downto 1 do
    K := K + I;
```

The for loop in Pascal is less flexible than in other languages (it is not possible to specify an increment different than one), but it is simple and easy to understand. If you want to test for a more complex condition, or to provide a customized counter, you need to use a while or repeat statement, instead of a for loop.

> The counter of a for loop doesn't need to be a number. It can be a value of any ordinal type, such as a character or an enumerated type.

While and Repeat Statements

The difference between the *while-do* loop and the *repeat-until* loop is that the code of the *repeat* statement is always executed at least once. You can easily understand why by looking at a simple example:

```
while (I <= 100) and (J <= 100) do
begin
  // use I and J to compute something...
  I := I + 1;
  J := J + 1;
end;

repeat
  // use I and J to compute something...
  I := I + 1;
```

```
  J := J + 1;
until (I > 100) or (J > 100);
```

If the initial value of *I* or *J* is greater than 100, the statements inside the repeat-until loop are executed once anyway.

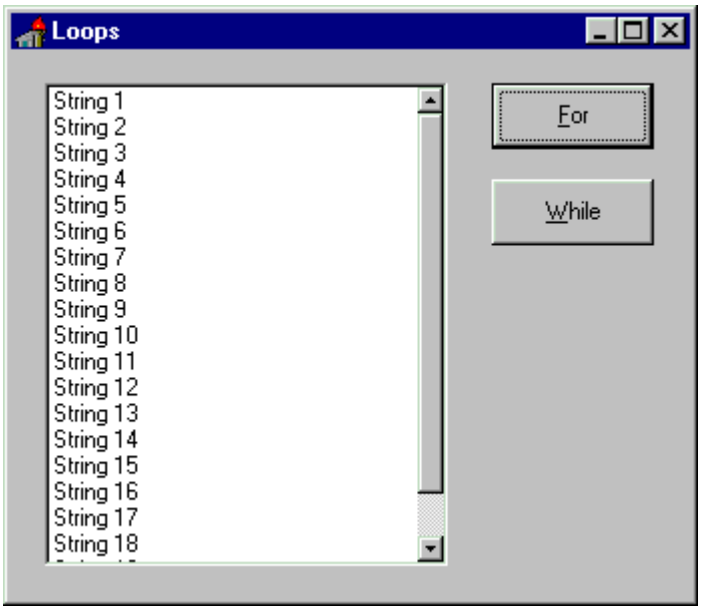
The other key difference between these two loops is that the *repeat-until* loop has a *reversed* condition. The loop is executed as long as the condition is *not* met. When the condition is met, the loop terminates. This is the opposite from a *while-do* loop, which is executed while the condition is true. For this reason I had to reverse the condition in the code above to obtain a similar statement.

An Example of Loops

To explore the details of loops, let's look at a small Delphi example. The Loops program highlights the difference between a loop with a fixed counter and a loop with an almost random counter. Start with a new blank project, place a list box and two buttons on the main form, and give the buttons a proper name (BtnFor and BtnWhile) by setting their *Name* property in the Object Inspector. You can also remove the word *Btn* from the *Caption* property (and eventually even add the & character to it to activate the following letter as a shortcut key). Here is a summary of the textual description of this form:

```
object Form1: TForm1
  Caption = 'Loops'
  object ListBox1: TListBox ...
  object BtnFor: TButton
    Caption = '&For'
    OnClick = BtnForClick
  end
  object BtnWhile: TButton
    Caption = '&While'
    OnClick = BtnWhileClick
  end
end
```

FIGURE 5.2: EACH TIME YOU PRESS THE FOR BUTTON OF THE LOOPS EXAMPLE, THE LIST BOX IS FILLED WITH CONSECUTIVE NUMBERS.



Now we can add some code to the *OnClick* events of the two buttons. The first button has a simple *for* loop to display a list of numbers, as you can see in Figure 5.2. Before executing this loop, which adds a number of strings to the *Items* property of the list box, you need to clear the contents of the list box itself:

```
procedure TForm1.BtnForClick(Sender: TObject);
var
  I: Integer;
begin
  ListBox1.Items.Clear;
  for I := 1 to 20 do
    Listbox1.Items.Add ('String ' + IntToStr (I));
end;
```

The code associated with the second button is slightly more complex. In this case, there is a while loop based on a counter, which is increased randomly. To accomplish this, I've called the *Randomize* procedure, which resets the random number generator, and the *Random* function with a range value of 100. The result of this function is a number between 0 and 99, chosen randomly. The series of random numbers control how many times the while loop is executed.

```
procedure TForm1.BtnWhileClick(Sender: TObject);
var
  I: Integer;
begin
  ListBox1.Items.Clear;
  Randomize;
  I := 0;
  while I < 1000 do
  begin
    I := I + Random (100);
    Listbox1.Items.Add ('Random Number: ' + IntToStr (I));
  end;
end;
```

Each time you click the While button, the numbers are different, because they depend on the random-number generator. Figure 5.3 shows the results from two separate button-clicks. Notice that not only are the generated numbers different each time, but so is the number of items. That is, this while loop is executed a random numbers of times. If you press the While button several times in a row, you'll see that the list box has a different number of lines.

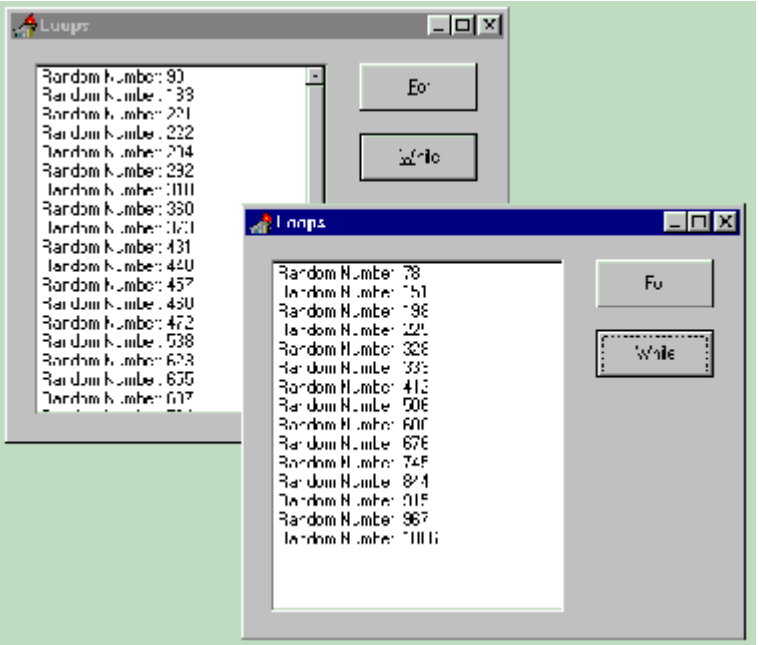


FIGURE 5.3: THE CONTENTS OF THE LIST BOX OF THE LOOPS EXAMPLE CHANGE EACH TIME YOU PRESS THE WHILE BUTTON.

You can alter the standard flow of a loop's execution using the *Break* and *Continue* system procedures. The first interrupts the loop; the second is used to jump directly to the loop test or counter increment, continuing with the next iteration of the loop (unless the condition is zero or the counter has reached its highest value). Two more system procedures, *Exit* and *Halt*, let you immediately return from the current function or procedure or terminate the program.

The With Statement

The last kind of Pascal statement I'll focus on is the *with* statement, which used to be peculiar to this programming language (although it has been recently introduced also in JavaScript and Visual Basic) and can be very useful in Delphi programming.

The *with* statement is nothing but shorthand. When you need to refer to a record type variable (or an object), instead of repeating its name every time, you can use a *with* statement. For example, while presenting the record type, I wrote this code:

```
type
  Date = record
    Year: Integer;
    Month: Byte;
    Day: Byte;
  end;

var
  BirthDay: Date;

begin
  BirthDay.Year := 1997;
  BirthDay.Month := 2;
  BirthDay.Day := 14;
```

Using a with statement, I can improve the final part of this code, as follows:

```
  with BirthDay do
```

```
  begin
    Year := 1995;
    Month := 2;
    Day := 14;
  end;
```

This approach can be used in Delphi programs to refer to components and other class types. For example, we can rewrite the final part of the last example, Loops, using a with statement to access the items of the list box:

```
procedure TForm1.WhileButtonClick(Sender: TObject);
var
  I: Integer;
begin
  with ListBox1.Items do
  begin
    Clear; // shortcut
    Randomize;
    I := 0;
    while I < 1000 do
    begin
      I := I + Random (100);
      // shortcut:
      Add ('Random Number: ' + IntToStr (I));
    end;
  end;
end;
```

When you work with components or classes in general, the *with* statement allows you to skip writing some code, particularly for nested fields. For example, suppose that you need to change the Width and the Color of the drawing pen for a form. You can write the following code:

```
Form1.Canvas.Pen.Width := 2;
Form1.Canvas.Pen.Color := clRed;
```

But it is certainly easier to write this code:

```
with Form1.Canvas.Pen do
begin
  Width := 2;
  Color := clRed;
end;
```

When you are writing complex code, the *with* statement can be effective and spares you the declaration of some temporary variables, but it has a drawback. It can make the code less readable, particularly when you are working with different objects that have similar or corresponding properties. A further drawback is that using the *with* statement can allow subtle logical errors in the code that the compiler will not detect. For example:

```
with Button1 do
begin
  Width := 200;
  Caption := 'New Caption';
  Color := clRed;
end;
```

This code changes the *Caption* and the *Width* of the button, but it affects the *Color* property of the form, not that of the button! The reason is that the *TButton* components don't have the *Color* property, and since the code is executed for a form object (we are writing a method of the form) this object is accessed by default. If we had instead written:

```
Button1.Width := 200;
Button1.Caption := 'New Caption';
```

```
Button1.Color := clRed; // error!
```

the compiler would have issued an error. In general, we can say that since the *with* statement introduces new identifiers in the current scope, we might hide existing identifiers, or wrongfully access another identifier in the same scope (as in the first version of this code fragment). Even considering this kind of drawback, I suggest you get used to *with* statements, because they can be really very handy, and at times even make the code more readable. You should, however, avoid using multiple *with* statements, such as:

```
with ListBox1, Button1 do...
```

The code following this would probably be highly unreadable, because for each property defined in this block you would need to think about which component it refers to, depending on the respective properties and the order of the components in the *with* statement.

Speaking of readability, Pascal has no *endif* or *endcase* statement. If an *if* statement has a *begin-end* block, then the end of the block marks the end of the statement. The *case* statement, instead, is always terminated by an *end*. All these *end* statements, often found one after the other, can make the code difficult to follow. Only by tracing the indentations can you see which statement a particular *end* refers to. A common way to solve this problem and make the code more readable is to add a comment after the *end* statement indicating its role, as in:

```
end; // if
```

Conclusion

This chapter has described how to code conditional statements and loops. Instead of writing long lists of such statements, programs are usually split in routines, procedures or functions. This is the topic of the next chapter, which introduces also some advanced elements.

Chapter 6
Procedures and Functions

Another important idea emphasized by Pascal is the concept of the routine, basically a series of statements with a unique name, which can be activated many times by using their name. This way you avoid repeating the same statements over and over, and having a single version of the code you can easily modify it all over the program. From this point of view, you can think of routines as the basic code encapsulation mechanism. I'll get back to this topic with an example after I introduce the Pascal routines syntax.

Pascal Procedures and Functions

In Pascal, a routine can assume two forms: a procedure and a function. In theory, a procedure is an operation you ask the computer to perform, a function is a computation returning a value. This difference is emphasized by the fact that a function has a result, a return value, while a procedure doesn't. Both types of routines can have multiple parameters, of given data types.

In practice, however, the difference between functions and procedures is very limited: you can call a function to perform some work and then skip the result (which might be an optional error code or something like that) or you can call a procedure which passes a result within its parameters (more on reference parameters later in this chapter).

Here are the definitions of a procedure and two versions of the same function, using a slightly different syntax:

```
procedure Hello;
begin
  ShowMessage ('Hello world!');
end;

function Double (Value: Integer) : Integer;
begin
  Double := Value * 2;
end;

// or, as an alternative
function Double2 (Value: Integer) : Integer;
begin
  Result := Value * 2;
end;
```

The use of *Result* instead of the function name to assign the return value of a function is becoming quite popular, and tends to make the code more readable, in my opinion. Once these routines have been defined, you can call them one or more times. You call the procedure to make it perform its task, and call a function to compute the value:

```
procedure TForm1.Button1Click (Sender: TObject);
begin
  Hello;
end;

procedure TForm1.Button2Click (Sender: TObject);
var
```

```
  X, Y: Integer;
begin
  X := Double (StrToInt (Edit1.Text));
  Y := Double (X);
  ShowMessage (IntToStr (Y));
end;
```

For the moment don't care about the syntax of the two procedures above, which are actually methods. Simply place two buttons on a Delphi form, click on them at design time, and the Delphi IDE will generate the proper support code: Now you simply have to fill in the lines between *begin* and *end*. To compile the code above you need to add also an Edit control to the form.

Now we can get back to the encapsulation code concept I've introduced before. When you call the *Double* function, you don't need to know the algorithm used to implement it. If you later find out a better way to double numbers, you can easily change the code of the function, but the calling code will remain unchanged (although executing it will be faster!). The same principle can be applied to the *Hello* procedure: We can modify the program output by changing the code of this procedure, and the *Button2Click* method will automatically change its effect. Here is how we can change the code:

```
procedure Hello;
begin
  MessageDlg ('Hello world!', mtInformation, [mbOK]);
end;
```

When you call an existing Delphi function or procedure, or any VCL method, you should remember the number and type of the parameters. Delphi editor helps you by suggesting the parameters list of a function or procedure with a fly-by hint as soon as you type its name and the open parenthesis. This feature is called Code Parameters and is part of the Code Insight technology.

Reference Parameters

Pascal routines allow parameter passing by value and by reference. Passing parameters by value is the default: the value is copied on the stack and the routine uses and manipulates the copy, not the original value.

Passing a parameter by reference means that its value is not copied onto the stack in the formal parameter of the routine (avoiding a copy often means that the program executes faster). Instead, the program refers to the original value, also in the code of the routine. This allows the procedure or function to change the value of the parameter. Parameter passing by reference is expressed by the *var* keyword.

This technique is available in most programming languages. It isn't present in C, but has been introduced in C++, where you use the & (pass by reference) symbol. In Visual Basic every parameter not specified as *ByVal* is passed by reference.

Here is an example of passing a parameter by reference using the *var* keyword:

```
procedure DoubleTheValue (var Value: Integer);
begin
  Value := Value * 2;
end;
```

In this case, the parameter is used both to pass a value to the procedure and to return a new value to the calling code. When you write:

```
var
  X: Integer;
begin
  X := 10;
  DoubleTheValue (X);
```

the value of the X variable becomes 20, because the function uses a reference to the original memory location of X, affecting its initial value.

Passing parameters by reference makes sense for ordinal types, for old-fashioned strings, and for large records. Delphi objects, in fact, are invariably passed by value, because they are references themselves. For this reason passing an object by reference makes little sense (apart from very special cases), because it corresponds to passing a "reference to a reference."

Delphi long strings have a slightly different behavior: they behave as references, but if you change one of the string variables referring to the same string in memory, this is copied before updating it. A long string passed as a value parameter behaves as a reference only in terms of memory usage and speed of the operation. But if you modify the value of the string, the original value is not affected. On the contrary, if you pass the long string by reference, you can alter the original value.

Delphi 3 introduced a new kind of parameter, out. An out parameter has no initial value and is used only to return a value. These parameters should be used only for COM procedures and functions; in general, it is better to stick with the more efficient var parameters. Except for not having an initial value, out parameters behave like var parameters.

Constant Parameters

As an alternative to reference parameters, you can use a `const` parameter. Since you cannot assign a new value to a constant parameter inside the routine, the compiler can optimize parameter passing. The compiler can choose an approach similar to reference parameters (or a const reference in C++ terms), but the behavior will remain similar to value parameters, because the original value won't be affected by the routine.

In fact, if you try to compile the following (silly) code, Delphi will issue an error:

```
function DoubleTheValue (const Value: Integer): Integer;
begin
  Value := Value * 2;      // compiler error
  Result := Value;
end;
```

Open Array Parameters

Unlike C, a Pascal function or procedure always has a fixed number of parameters. However, there is a way to pass a varying number of parameters to a routine using an open array. The basic definition of an open array parameter is that of a typed open array. This means you indicate the type of the parameter but do not know how many elements of that type the array is going to have. Here is an example of such a definition:

```
function Sum (const A: array of Integer): Integer;
var
  I: Integer;
```

```
begin
  Result := 0;
  for I := Low(A) to High(A) do
    Result := Result + A[I];
end;
```

Using High(A) we can get the size of the array. Notice also the use of the return value of the function, Result, to store temporary values. You can call this function by passing to it an array of Integer expressions:

```
X := Sum ([10, Y, 27*I]);
```

Given an array of Integers, of any size, you can pass it directly to a routine requiring an open array parameter or, instead, you can call the Slice function to pass only a portion of the array (as indicated by its second parameter). Here is an example, where the complete array is passed as parameter:

```
var
  List: array [1..10] of Integer;
  X, I: Integer;
begin
  // initialize the array
  for I := Low (List) to High (List) do
    List [I] := I * 2;
  // call
  X := Sum (List);
```

If you want to pass only a portion of the array to the Slice function, simply call it this way:

```
X := Sum (Slice (List, 5));
```

You can find all the code fragments presented in this section in the OpenArr example (see Figure 6.1, later on, for the form).

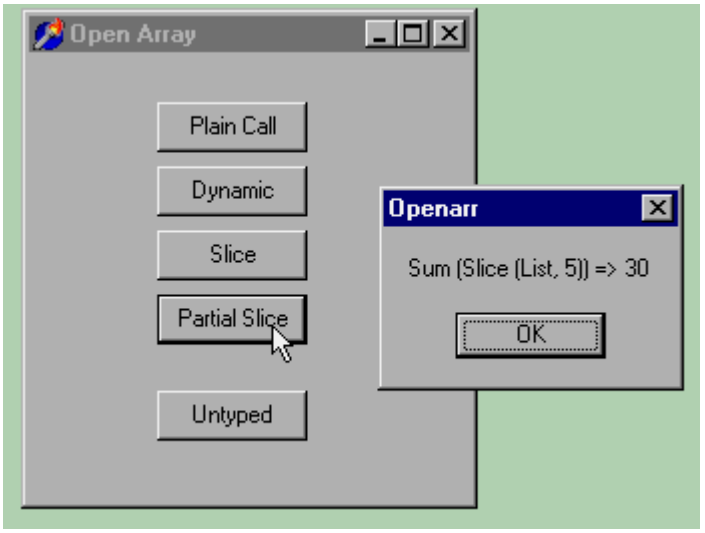


FIGURE 6.1: THE OPENARR EXAMPLE WHEN THE PARTIAL SLICE BUTTON IS PRESSED

Typed open arrays are fully compatible with dynamic arrays (introduced in Delphi 4 and covered in Chapter 8). Dynamic arrays use the same syntax as open arrays, with the difference that you can use a notation such as *array of Integer* to declare a variable, not just to pass a parameter.

Type-Variant Open Array Parameters

Besides these typed open arrays, Delphi allows you to define type-variant or untyped open arrays. This special kind of array has an undefined number of values, which can be handy for passing parameters.

Technically, the construct array of const allows you to pass an array with an undefined number of elements of different types to a routine at once. For example, here is the definition of the *Format* function (we'll see how to use this function in Chapter 7, covering strings):

```
function Format (const Format: string;
  const Args: array of const): string;
```

The second parameter is an open array, which gets an undefined number of values. In fact, you can call this function in the following ways:

```
N := 20;
S := 'Total:';
Label1.Caption := Format ('Total: %d', [N]);
Label2.Caption := Format ('Int: %d, Float: %f', [N, 12.4]);
Label3.Caption := Format ('%s %d', [S, N * 2]);
```

Notice that you can pass a parameter as either a constant value, the value of a variable, or an expression. Declaring a function of this kind is simple, but how do you code it? How do you know the types of the parameters? The values of a type-variant open array parameter are compatible with the *TVarRec* type elements.

> Do not confuse the *TVarRec* record with the *TVarData* record used by the Variant type itself. These two structures have a different aim and are not compatible. Even the list of possible types is different, because *TVarRec* can hold Delphi data types, while *TVarData* can hold OLE data types.

The *TVarRec* record has the following structure:

```
type
  TVarRec = record
    case Byte of
      vtInteger:    (VInteger: Integer; VType: Byte);
      vtBoolean:    (VBoolean: Boolean);
      vtChar:       (VChar: Char);
      vtExtended:   (VExtended: PExtended);
      vtString:     (VString: PShortString);
      vtPointer:    (VPointer: Pointer);
      vtPChar:      (VPChar: PChar);
      vtObject:     (VObject: TObject);
      vtClass:      (VClass: TClass);
      vtWideChar:   (VWideChar: WideChar);
      vtPWideChar:  (VPWideChar: PWideChar);
      vtAnsiString: (VAnsiString: Pointer);
      vtCurrency:   (VCurrency: PCurrency);
      vtVariant:    (VVariant: PVariant);
      vtInterface:  (VInterface: Pointer);
  end;
```

Each possible record has the *VType* field, although this is not easy to see at first because it is declared only once, along with the actual Integer-size data (generally a reference or a pointer). Using this information we can actually write a function capable of operating on different data types. In the *SumAll* function example, I want to be able to sum values of different types, transforming strings to integers, characters to the corresponding order value, and adding 1 for

True Boolean values. The code is based on a case statement, and is quite simple, although we have to dereference pointers quite often:

```
function SumAll (const Args: array of const): Extended;
var
  I: Integer;
begin
  Result := 0;
  for I := Low(Args) to High (Args) do
    case Args [I].VType of
      vtInteger: Result :=
        Result + Args [I].VInteger;
      vtBoolean:
        if Args [I].VBoolean then
          Result := Result + 1;
      vtChar:
        Result := Result + Ord (Args [I].VChar);
      vtExtended:
        Result := Result + Args [I].VExtended^;
      vtString, vtAnsiString:
        Result := Result + StrToIntDef ((Args [I].VString^), 0);
      vtWideChar:
        Result := Result + Ord (Args [I].VWideChar);
      vtCurrency:
        Result := Result + Args [I].VCurrency^;
    end; // case
end;
```

I've added this code to the OpenArr example, which calls the *SumAll* function when a given button is pressed:

```
procedure TForm1.Button4Click(Sender: TObject);
var
  X: Extended;
  Y: Integer;
begin
  Y := 10;
  X := SumAll ([Y * Y, 'k', True, 10.34, '99999']);
  ShowMessage (Format (
    'SumAll ([Y*Y, ''k'', True, 10.34, ''99999'']) => %n', [X]));
end;
```

You can see the output of this call, and the form of the OpenArr example, in Figure 6.2.

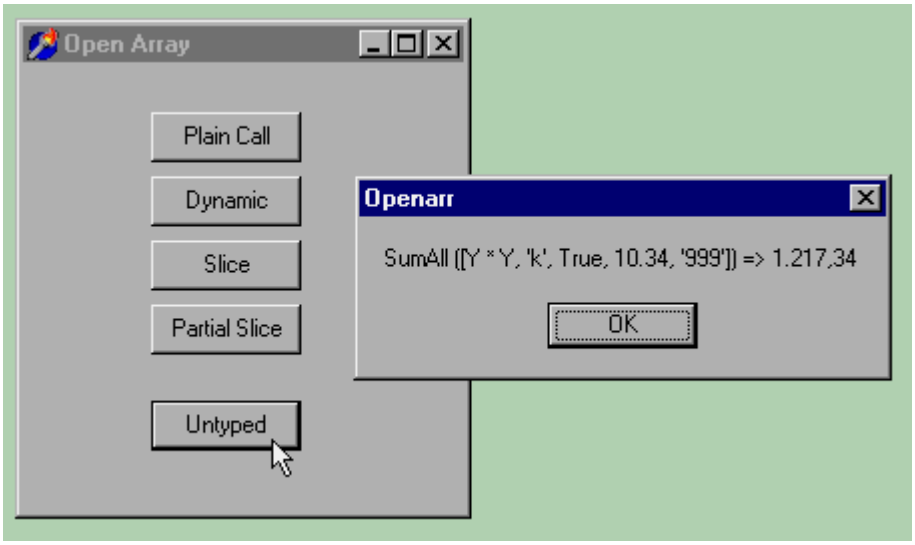


FIGURE 6.2: THE FORM OF THE OPENARR EXAMPLE, WITH THE MESSAGE BOX DISPLAYED WHEN THE UNTYPED BUTTON IS PRESSED.

Delphi Calling Conventions

The 32-bit version of Delphi has introduced a new approach to passing parameters, known as fastcall: Whenever possible, up to three parameters can be passed in CPU registers, making the function call much faster. The fast calling convention (used by default in Delphi 3) is indicated by the register keyword.

The problem is that this is the default convention, and functions using it are not compatible with Windows: the functions of the Win32 API must be declared using the stdcall calling convention, a mixture of the original Pascal calling convention of the Win16 API and the cdecl calling convention of the C language.

There is generally no reason not to use the new fast calling convention, unless you are making external Windows calls or defining Windows callback functions. We'll see an example using the *stdcall* convention before the end of this chapter. You can find a summary of Delphi calling conventions in the Calling conventions topic under Delphi help.

What Is a Method?

If you have already worked with Delphi or read the manuals, you have probably heard about the term "method". A method is a special kind of function or procedure that is related to a data type, a class. In Delphi, every time we handle an event, we need to define a method, generally a procedure. In general, however, the term method is used to indicate both functions and procedures related to a class.

We have already seen a number of methods in the examples in this and the previous chapters. Here is an empty method automatically added by Delphi to the source code of a form:

```
procedure TForm1.Button1Click(Sender: TObject);
begin
  {here goes your code}
end;
```

Forward Declarations

When you need to use an identifier (of any kind), the compiler must have already seen some sort of declaration to know what the identifier refers to. For this reason, you usually provide a full declaration before using any routine. However, there are cases in which this is not possible. If procedure A calls procedure B, and procedure B calls procedure A, when you start writing the code, you will need to call a routine for which the compiler still hasn't seen a declaration.

If you want to declare the existence of a procedure or function with a certain name and given parameters, without providing its actual code, you can write the procedure or function followed by the forward keyword:

```
procedure Hello; forward;
```

Later on, the code should provide a full definition of the procedure, but this can be called even before it is fully defined. Here is a silly example, just to give you the idea:

```
procedure DoubleHello; forward;

procedure Hello;
begin
  if MessageDlg ('Do you want a double message?',
      mtConfirmation, [mbYes, mbNo], 0) = mrYes then
    DoubleHello
  else
    ShowMessage ('Hello');
end;

procedure DoubleHello;
begin
  Hello;
  Hello;
end;
```

This approach allows you to write mutual recursion: *DoubleHello* calls Hello, but Hello might call *DoubleHello*, too. Of course there must be a condition to terminate the recursion, to avoid a stack overflow. You can find this code, with some slight changes, in the DoubleH example.

Although a forward procedure declaration is not very common in Delphi, there is a similar case that is much more frequent. When you declare a procedure or function in the interface portion of a unit (more on units in the next chapter), it is considered a forward declaration, even if the forward keyword is not present. Actually you cannot write the body of a routine in the interface portion of a unit. At the same time, you must provide in the same unit the actual implementation of each routine you have declared.

The same holds for the declaration of a method inside a class type that was automatically generated by Delphi (as you added an event to a form or its components). The event handlers declared inside a *TForm* class are forward declarations: the code will be provided in the implementation portion of the unit. Here is an excerpt of the source code of an earlier example, with the declaration of the *Button1Click* method:

```
type
  TForm1 = class(TForm)
    ListBox1: TListBox;
    Button1: TButton;
    procedure Button1Click(Sender: TObject);
  end;
```

Procedural Types

Another unique feature of Object Pascal is the presence of procedural types. These are really an advanced language topic, which only a few Delphi programmers will use regularly. However, since we will discuss related topics in later chapters (specifically, method pointers, a technique heavily used by Delphi), it's worth a quick look at them here. If you are a novice programmer, you can skip this section for now, and come back to it when you feel ready.

In Pascal, there is the concept of procedural type (which is similar to the C language concept of function pointer). The declaration of a procedural type indicates the list of parameters and, in the case of a function, the return type. For example, you can declare a new procedural type, with an Integer parameter passed by reference, with this code:

```
type
  IntProc = procedure (var Num: Integer);
```

This procedural type is compatible with any routine having exactly the same parameters (or the same function signature, to use C jargon). Here is an example of a compatible routine:

```
procedure DoubleTheValue (var Value: Integer);
begin
  Value := Value * 2;
end;
```

> In the 16-bit version of Delphi, routines must be declared using the far directive in order to be used as actual values of a procedural type.

Procedural types can be used for two different purposes: you can declare variables of a procedural type or pass a procedural type (that is, a function pointer) as parameter to another routine. Given the preceding type and procedure declarations, you can write this code:

```
var
  IP: IntProc;
  X: Integer;
begin
  IP := DoubleTheValue;
  X := 5;
  IP (X);
end;
```

This code has the same effect as the following shorter version:

```
var
  X: Integer;
begin
  X := 5;
  DoubleTheValue (X);
end;
```

The first version is clearly more complex, so why should we use it? In some cases, being able to decide which function to call and actually calling it later on can be useful. It is possible to build a complex example showing this approach. However, I prefer to let you explore a fairly simple one, named ProcType. This example is more complex than those we have seen so far, to make the situation a little more realistic.

Simply create a blank project and place two radio buttons and a push button, as shown in Figure 6.3. This example is based on two procedures. One procedure is used to double the value of the parameter. This procedure is similar to the version I've already shown in this section. A

second procedure is used to triple the value of the parameter, and therefore is named `TripleTheValue`:

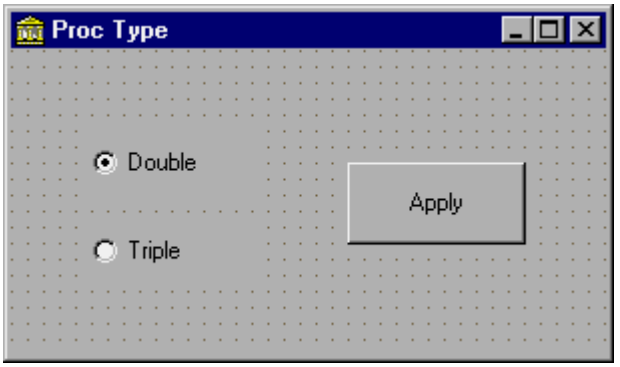


FIGURE 6.3: THE FORM OF THE PROCTYPE EXAMPLE.

```
procedure TripleTheValue (var Value: Integer);
begin
  Value := Value * 3;
  ShowMessage ('Value tripled: ' + IntToStr (Value));
end;
```

Both procedures display what is going on, to let us know that they have been called. This is a simple debugging feature you can use to test whether or when a certain portion of code is executed, instead of adding a breakpoint in it.

Each time a user presses the Apply button, one of the two procedures is executed, depending on the status of the radio buttons. In fact, when you have two radio buttons in a form, only one of them can be selected at a time. This code could have been implemented by testing the value of the radio buttons inside the code for the *OnClick* event of the Apply button. To demonstrate the use of procedural types, I've instead used a longer but interesting approach. Each time a user clicks on one of the two radio buttons, one of the procedures is stored in a variable:

```
procedure TForm1.DoubleRadioButtonClick(Sender: TObject);
begin
  IP := DoubleTheValue;
end;
```

When the user clicks on the push button, the procedure we have stored is executed:

```
procedure TForm1.ApplyButtonClick(Sender: TObject);
begin
  IP (X);
end;
```

To allow three different functions to access the IP and X variables, we need to make them visible to the whole form; they cannot be declared locally (inside one of the methods). A solution to this problem is to place these variables inside the form declaration:

```
type
  TForm1 = class(TForm)
    ...
  private
    { Private declarations }
    IP: IntProc;
    X: Integer;
  end;
```

We will see exactly what this means in the next chapter, but for the moment, you need to modify the code generated by Delphi for the class type as indicated above, and add the definition

of the procedural type I've shown before. To initialize these two variables with suitable values, we can handle the *OnCreate* event of the form (select this event in the Object Inspector after you have activated the form, or simply double-click on the form). I suggest you refer to the listing to study the details of the source code of this example.

> You can see a practical example of the use of procedural types in Chapter 9, in the section *A Windows Callback Function*.

Function Overloading

The idea of overloading is simple: The compiler allows you to define two functions or procedures using the same name, provided that the parameters are different. By checking the parameters, in fact, the compiler can determine which of the versions of the routine you want to call. Consider this series of functions extracted from the Math unit of the VCL:

```
function Min (A,B: Integer): Integer; overload;
function Min (A,B: Int64): Int64; overload;
function Min (A,B: Single): Single; overload;
function Min (A,B: Double): Double; overload;
function Min (A,B: Extended): Extended; overload;
```

When you call Min (10, 20), the compiler easily determines that you're calling the first function of the group, so the return value will be an Integer.

The basic rules are two:

- Each version of the routine must be followed by the overload keyword.
- The differences must be in the number or type of the parameters, or both. The return type, instead, cannot be used to distinguish among two routines.

Here are three overloaded versions of a ShowMsg procedure I've added to the OverDef example (an application demonstrating overloading and default parameters):

```
procedure ShowMsg (str: string); overload;
begin
  MessageDlg (str, mtInformation, [mbOK], 0);
end;

procedure ShowMsg (FormatStr: string;
  Params: array of const); overload;
begin
  MessageDlg (Format (FormatStr, Params),
    mtInformation, [mbOK], 0);
end;

procedure ShowMsg (I: Integer; Str: string); overload;
begin
  ShowMsg (IntToStr (I) + ' ' + Str);
end;
```

The three functions show a message box with a string, after optionally formatting the string in different ways. Here are the three calls of the program:

```
ShowMsg ('Hello');
ShowMsg ('Total = %d.', [100]);
ShowMsg (10, 'MBytes');
```

What surprised me in a positive way is that Delphi's Code Parameters technology works very nicely with overloaded procedures and functions. As you type the open parenthesis after the

routine name, all the available alternatives are listed. As you enter the parameters, Delphi uses their type to determine which of the alternatives are still available. In Figure 6.4 you can see that after starting to type a constant string Delphi shows only the compatible versions (omitting the version of the ShowMsg procedure that has an integer as first parameter).

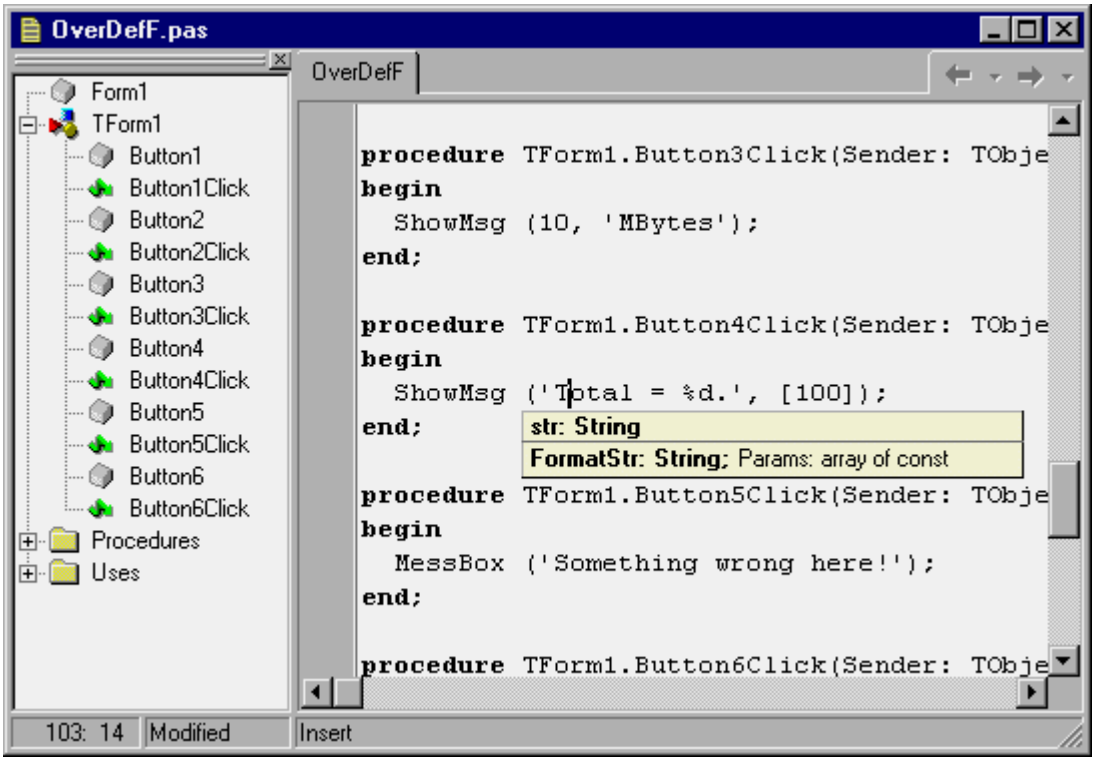


FIGURE 6.4: THE MULTIPLE ALTERNATIVES OFFERED BY CODE PARAMETERS FOR OVERLOADED ROUTINES ARE FILTERED ACCORDING TO THE PARAMETERS ALREADY AVAILABLE.

The fact that each version of an overloaded routine must be properly marked implies that you cannot overload an existing routine of the same unit that is not marked with the overload keyword. (The error message you get when you try is: "Previous declaration of '<name>' was not marked with the 'overload' directive.") However, you can overload a routine that was originally declared in a different unit. This is for compatibility with previous versions of Delphi, which allowed different units to reuse the same routine name. Notice, anyway, that this special case is not an extra feature of overloading, but an indication of the problems you can face.

For example, you can add to a unit the following code:

```
procedure MessageDlg (str: string); overload;
begin
  Dialogs.MessageDlg (str, mtInformation, [mbOK], 0);
end;
```

This code doesn't really overload the original MessageDlg routine. In fact if you write:

```
MessageDlg ('Hello');
```

you'll get a nice error message indicating that some of the parameters are missing. The only way to call the local version instead of the one of the VCL is to refer explicitly to the local unit, something that defeats the idea of overloading:

```
OverDefF.MessageDlg ('Hello');
```

Default Parameters

A related new feature of Delphi 4 is that you can give a default value for the parameter of a function, and you can call the function with or without the parameter. Let me show an example. We can define the following encapsulation of the MessageBox method of the Application global object, which uses PChar instead of strings, providing two default parameters:

```
procedure MessBox (Msg: string;
  Caption: string = 'Warning';
  Flags: LongInt = mb_OK or mb_IconHand);
begin
  Application.MessageBox (PChar (Msg),
    PChar (Caption), Flags);
end;
```

With this definition, we can call the procedure in each of the following ways:

```
MessBox ('Something wrong here!');
MessBox ('Something wrong here!', 'Attention');
MessBox ('Hello', 'Message', mb_OK);
```

In Figure 6.5 you can see that Delphi's Code Parameters properly use a different style to indicate the parameters that have a default value, so you can easily determine which parameters can be omitted.

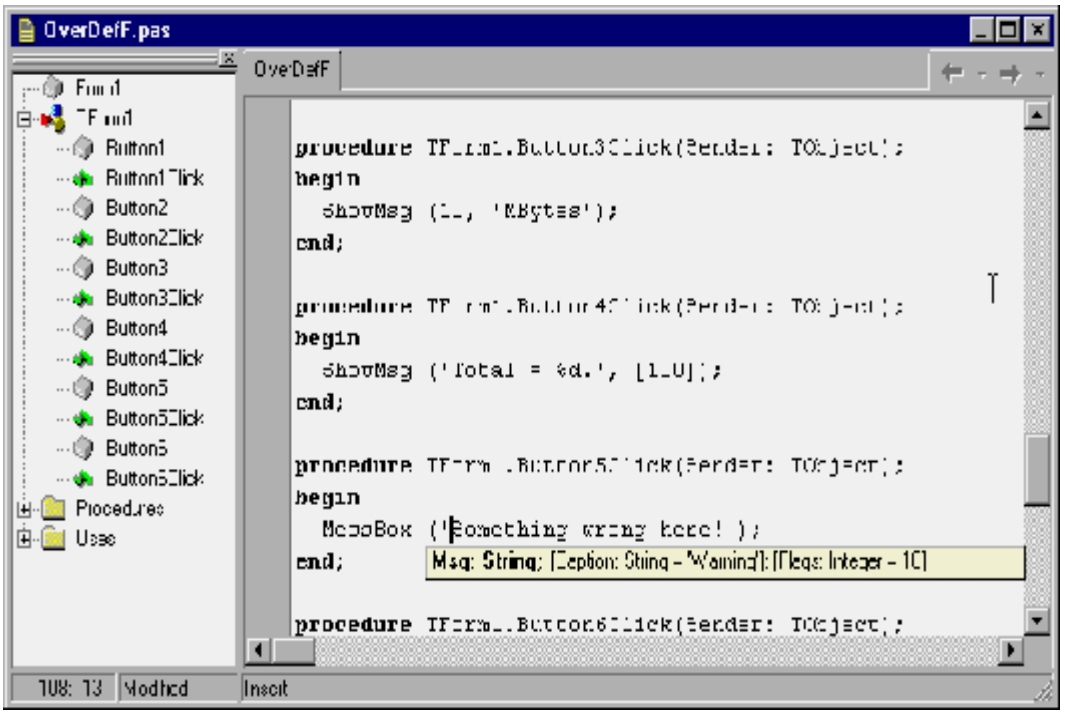


FIGURE 6.5: DELPHI'S CODE PARAMETERS MARK OUT WITH SQUARE BRACKETS THE PARAMETERS THAT HAVE DEFAULT VALUES; YOU CAN OMIT THESE IN THE CALL.

Notice that Delphi doesn't generate any special code to support default parameters; nor does it create multiple copies of the routines. The missing parameters are simply added by the compiler to the calling code.

There is one important restriction affecting the use of default parameters: You cannot "skip" parameters. For example, you can't pass the third parameter to the function after omitting the second one:

```
MessBox ('Hello', mb_OK); // error
```

This is the main rule for default parameters: In a call, you can only omit parameters starting from the last one. In other words, if you omit a parameter you must omit also the following ones.

There are a few other rules for default parameters as well:

- Parameters with default values must be at the end of the parameters list.
- Default values must be constants. Obviously, this limits the types you can use with default parameters. For example, a dynamic array or an interface type cannot have a default parameter other than nil; records cannot be used at all.
- Default parameters must be passed by value or as const. A reference (var) parameter cannot have a default value.

Using default parameters and overloading at the same time can cause quite a few problems, as the two features might conflict. For example, if I add to the previous example the following new version of the *ShowMsg* procedure:

```
procedure ShowMsg (Str: string; I: Integer = 0); overload;
begin
  MessageDlg (Str + ': ' + IntToStr (I),
    mtInformation, [mbOK], 0);
end;
```

then the compiler won't complain-this is a legal definition. However, the call:

```
ShowMsg ('Hello');
```

is flagged by the compiler as *Ambiguous overloaded call to 'ShowMsg'*. Notice that this error shows up in a line of code that compiled correctly before the new overloaded definition. In practice, we have no way to call the *ShowMsg* procedure with one string parameter, as the compiler doesn't know whether we want to call the version with only the string parameter or the one with the string parameter and the integer parameter with a default value. When it has a similar doubt, the compiler stops and asks the programmer to state his or her intentions more clearly.

Conclusion

Writing procedure and functions is a key element of programming, although in Delphi you'll tend to write methods -- procedures and functions connected with classes and objects.

Instead of moving on to object-oriented features, however, the next few chapters give you some details on other Pascal programming elements, starting with strings.

Chapter 7
Handling Strings

String handling in Delphi is quite simple, but behind the scenes the situation is quite complex. Pascal has a traditional way of handling strings, Windows has its own way, borrowed from the C language, and 32-bit versions of Delphi include a powerful long string data type, which is the default string type in Delphi.

Types of Strings

In Borland's Turbo Pascal and in 16-bit Delphi, the typical string type is a sequence of characters with a length byte at the beginning, indicating the current size of the string. Because the length is expressed by a single byte, it cannot exceed 255 characters, a very low value that creates many problems for string manipulation. Each string is defined with a fixed size (which by default is the maximum, 255), although you can declare shorter strings to save memory space.

A string type is similar to an array type. In fact, a string is almost an array of characters. This is demonstrated by the fact that you can access a specific string character using the [] notation.

To overcome the limits of traditional Pascal strings, the 32-bit versions of Delphi support long strings. There are actually three string types:

- The ShortString type corresponds to the typical Pascal strings, as described before. These strings have a limit of 255 characters and correspond to the strings in the 16-bit version of Delphi. Each element of a short string is of type ANSIChar (the standard character type).
- The ANSIString type corresponds to the new variable-length long strings. These strings are allocated dynamically, are reference counted, and use a copy-on-write technique. The size of these strings is almost unlimited (they can store up to two billion characters!). They are also based on the ANSIChar type.
- The WideString type is similar to the ANSIString type but is based on the WideChar type-it stores Unicode characters.

Using Long Strings

If you simply use the string data type, you get either short strings or ANSI strings, depending on the value of the $H compiler directive. $H+ (the default) stands for long strings (the ANSIString type), which is what is used by the components of the Delphi library.

Delphi long strings are based on a reference-counting mechanism, which keeps track of how many string variables are referring to the same string in memory. This reference-counting is used also to free the memory when a string isn't used anymore-that is, when the reference count reaches zero.

If you want to increase the size of a string in memory but there is something else in the adjacent memory, then the string cannot grow in the same memory location, and a full copy of the string must therefore be made in another location. When this situation occurs, Delphi's run-time support reallocates the string for you in a completely transparent way. You simply set the

maximum size of the string with the *SetLength* procedure, effectively allocating the required amount of memory:

```
SetLength (String1, 200);
```

The *SetLength* procedure performs a memory request, not an actual memory allocation. It reserves the required memory space for future use, without actually using the memory. This technique is based on a feature of the Windows operating systems and is used by Delphi for all dynamic memory allocations. For example, when you request a very large array, its memory is reserved but not allocated.

Setting the length of a string is seldom necessary. The only case in which you must allocate memory for the long string using *SetLength* is when you have to pass the string as a parameter to an API function (after the proper typecast), as I'll show you shortly.

Looking at Strings in Memory

To help you better understand the details of memory management for strings, I've written the simple StrRef example. In this program I declare two global strings: Str1 and Str2. When the first of the two buttons is pressed, the program assigns a constant string to the first of the two variables and then assigns the second variable to the first:

```
Str1 := 'Hello';
Str2 := Str1;
```

Besides working on the strings, the program shows their internal status in a list box, using the following StringStatus function:

```
function StringStatus (const Str: string): string;
begin
  Result := 'Address: ' + IntToStr (Integer (Str)) +
    ', Length: ' + IntToStr (Length (Str)) +
    ', References: ' + IntToStr (PInteger (Integer (Str) - 8)^) +
    ', Value: ' + Str;
end;
```

It is vital in the *StringStatus* function to pass the string parameter as a const parameter. Passing this parameter by copying will cause the side effect of having one extra reference to the string while the function is being executed. By contrast, passing the parameter via a reference (var) or constant (const) parameter doesn't imply a further reference to the string. In this case I've used a const parameter, as the function is not supposed to modify the string.

To obtain the memory address of the string (useful to determine its actual identity and to see when two different strings refer to the same memory area), I've simply made a hard-coded typecast from the string type to the Integer type. Strings are references-in practice, they're pointers: Their value holds the actual memory location of the string.

To extract the reference count, I've based the code on the little-known fact that the length and reference count are actually stored in the string, before the actual text and before the position the string variable points to. The (negative) offset is -4 for the length of the string (a value you can extract more easily using the Length function) and -8 for the reference count.

Keep in mind that this internal information about offsets might change in future versions of Delphi; there is also no guarantee that similar undocumented features will be maintained in the future.

By running this example, you should get two strings with the same content, the same memory location, and a reference count of 2, as shown in the upper part of the list box of Figure 2.1. Now if you change the value of one of the two strings (it doesn't matter which one), the

memory location of the updated string will change. This is the effect of the copy-on-write technique.

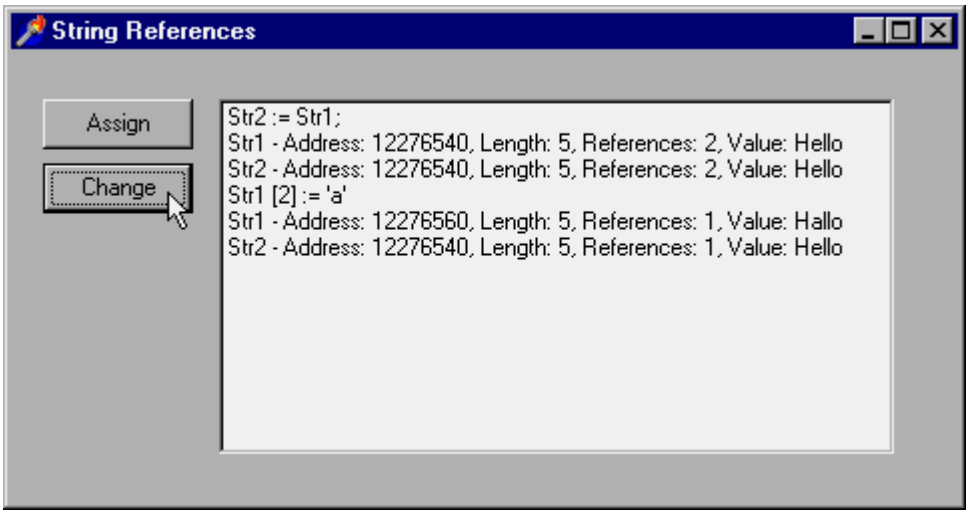


FIGURE 7.1: THE STRREF EXAMPLE SHOWS THE INTERNAL STATUS OF TWO STRINGS, INCLUDING THE CURRENT REFERENCE COUNT.

We can actually produce this effect, shown in the second part of the list box of Figure 7.1, by writing the following code for the *OnClick* event handler of the second button:

```
procedure TFormStrRef.BtnChangeClick(Sender: TObject);
begin
  Str1 [2] := 'a';
  ListBox1.Items.Add ('Str1 [2] := ''a''');
  ListBox1.Items.Add ('Str1 - ' + StringStatus (Str1));
  ListBox1.Items.Add ('Str2 - ' + StringStatus (Str2));
end;
```

Notice that the code of the *BtnChangeClick* method can be executed only after the *BtnAssignClick* method. To enforce this, the program starts with the second button disabled (its Enabled property is set to False); it enables the button at the end of the first method. You can freely extend this example and use the *StringStatus* function to explore the behavior of long strings in many other circumstances.

Delphi Strings and Windows PChars

Another important point in favor of using long strings is that they are null-terminated. This means that they are fully compatible with the C language null-terminated strings used by Windows. A null-terminated string is a sequence of characters followed by a byte that is set to zero (or null). This can be expressed in Delphi using a zero-based array of characters, the data type typically used to implement strings in the C language. This is the reason null-terminated character arrays are so common in the Windows API functions (which are based on the C language). Since Pascal's long strings are fully compatible with C null-terminated strings, you can simply use long strings and cast them to PChar when you need to pass a string to a Windows API function.

For example, to copy the caption of a form into a PChar string (using the API function GetWindowText) and then copy it into the Caption of the button, you can write the following code:

```
procedure TForm1.Button1Click (Sender: TObject);
var
```

```
  S1: String;
begin
  SetLength (S1, 100);
  GetWindowText (Handle, PChar (S1), Length (S1));
  Button1.Caption := S1;
end;
```

You can find this code in the LongStr example. Note that if you write this code but fail to allocate the memory for the string with SetLength, the program will probably crash. If you are using a PChar to pass a value (and not to receive one as in the code above), the code is even simpler, because there is no need to define a temporary string and initialize it. The following line of code passes the Caption property of a label as a parameter to an API function, simply by typecasting it to PChar:

```
SetWindowText (Handle, PChar (Label1.Caption));
```

When you need to cast a WideString to a Windows-compatible type, you have to use PWideChar instead of PChar for the conversion. Wide strings are often used for OLE and COM programs.

Having presented the nice picture, now I want to focus on the pitfalls. There are some problems that might arise when you convert a long string into a PChar. Essentially, the underlying problem is that after this conversion, you become responsible for the string and its contents, and Delphi won't help you anymore. Consider the following limited change to the first program code fragment above, Button1Click:

```
procedure TForm1.Button2Click(Sender: TObject);
var
  S1: String;
begin
  SetLength (S1, 100);
  GetWindowText (Handle, PChar (S1), Length (S1));
  S1 := S1 + ' is the title'; // this won't work
  Button1.Caption := S1;
end;
```

This program compiles, but when you run it, you are in for a surprise: The Caption of the button will have the original text of the window title, without the text of the constant string you have added to it. The problem is that when Windows writes to the string (within the *GetWindowText* API call), it doesn't set the length of the long Pascal string properly. Delphi still can use this string for output and can figure out when it ends by looking for the null terminator, but if you append further characters after the null terminator, they will be skipped altogether.

How can we fix this problem? The solution is to tell the system to convert the string returned by the GetWindowText API call back to a Pascal string. However, if you write the following code:

```
S1 := String (S1);
```

the system will ignore it, because converting a data type back into itself is a useless operation. To obtain the proper long Pascal string, you need to recast the string to a PChar and let Delphi convert it back again properly to a string:

```
S1 := String (PChar (S1));
```

Actually, you can skip the string conversion, because PChar-to-string conversions are automatic in Delphi. Here is the final code:

```
procedure TForm1.Button3Click(Sender: TObject);
var
  S1: String;
begin
  SetLength (S1, 100);
  GetWindowText (Handle, PChar (S1), Length (S1));
```

```
  S1 := String (PChar (S1));
  S1 := S1 + ' is the title';
  Button3.Caption := S1;
end;
```

An alternative is to reset the length of the Delphi string, using the length of the PChar string, by writing:

```
SetLength (S1, StrLen (PChar (S1)));
```

You can find three versions of this code in the LongStr example, which has three buttons to execute them. However, if you just need to access the title of a form, you can simply use the Caption property of the form object itself. There is no need to write all this confusing code, which was intended only to demonstrate the string conversion problems. There are practical cases when you need to call Windows API functions, and then you have to consider this complex situation.

Formatting Strings

Using the plus (+) operator and some of the conversion functions (such as IntToStr) you can indeed build complex strings out of existing values. However, there is a different approach to formatting numbers, currency values, and other strings into a final string. You can use the powerful Format function or one of its companion functions.

The Format function requires as parameters a string with the basic text and some placeholders (usually marked by the % symbol) and an array of values, one for each placeholder. For example, to format two numbers into a string you can write:

```
Format ('First %d, Second %d', [n1, n2]);
```

where n1 and n2 are two Integer values. The first placeholder is replaced by the first value, the second matches the second, and so on. If the output type of the placeholder (indicated by the letter after the % symbol) doesn't match the type of the corresponding parameter, a runtime error occurs. Having no compile-time type checking is actually the biggest drawback of using the Format function.

The Format function uses an open-array parameter (a parameter that can have an arbitrary number of values), something I'll discuss toward the end of this chapter. For the moment, though, notice only the array-like syntax of the list of values passed as the second parameter.

Besides using %d, you can use one of many other placeholders defined by this function and briefly listed in Table 7.1. These placeholders provide a default output for the given data type. However, you can use further format specifiers to alter the default output. A width specifier, for example, determines a fixed number of characters in the output, while a precision specifier indicates the number of decimal digits. For example,

```
Format ('%8d', [n1]);
```

converts the number n1 into an eight-character string, right-aligning the text (use the minus (-) symbol to specify left-justification) filling it with white spaces.

TABLE 7.1: TYPE SPECIFIERS FOR THE FORMAT FUNCTION

TYPE SPECIFIER	DESCRIPTION
d (decimal)	The corresponding integer value is converted to a string of decimal digits.
x (hexadecimal)	The corresponding integer value is converted to a string of hexadecimal digits.
p (pointer)	The corresponding pointer value is converted to a string expressed with hexadecimal digits.

s (string)	The corresponding string, character, or PChar value is copied to the output string.
e (exponential)	The corresponding floating-point value is converted to a string based on exponential notation.
f (floating point)	The corresponding floating-point value is converted to a string based on floating point notation.
g (general)	The corresponding floating-point value is converted to the shortest possible decimal string using either floating-point or exponential notation.
n (number)	The corresponding floating-point value is converted to a floating-point string but also uses thousands separators.
m (money)	The corresponding floating-point value is converted to a string representing a currency amount. The conversion is based on regional settings-see the Delphi Help file under Currency and date/time formatting variables.

The best way to see examples of these conversions is to experiment with format strings yourself. To make this easier I've written the FmtTest program, which allows a user to provide formatting strings for integer and floating-point numbers. As you can see in Figure 7.2, this program displays a form divided into two parts. The left part is for Integer numbers, the right part for floating-point numbers.

Each part has a first edit box with the numeric value you want to format to a string. Below the first edit box there is a button to perform the formatting operation and show the result in a message box. Then comes another edit box, where you can type a format string. As an alternative you can simply click on one of the lines of the ListBox component, below, to select a predefined formatting string. Every time you type a new formatting string, it is added to the corresponding list box (note that by closing the program you lose these new items).

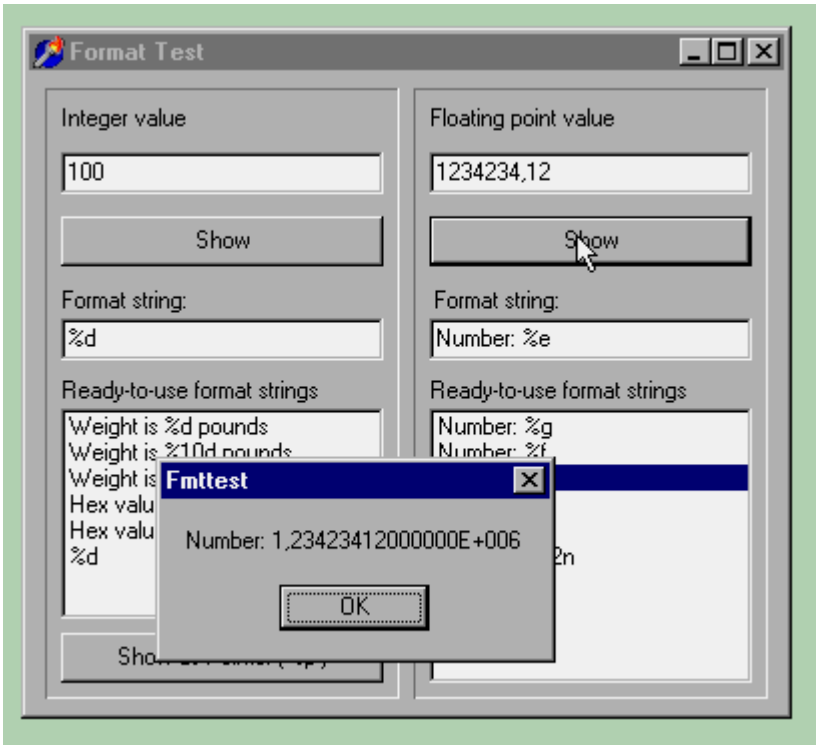


FIGURE 7.2: THE OUTPUT OF A FLOATING-POINT VALUE FROM THE FMTTEST PROGRAM

The code of this example simply uses the text of the various controls to produce its output. This is one of the three methods connected with the Show buttons:

```
procedure TFormFmtTest.BtnIntClick(Sender: TObject);
begin
  ShowMessage (Format (EditFmtInt.Text,
    [StrToInt (EditInt.Text)]));
  // if the item is not there, add it
  if ListBoxInt.Items.IndexOf (EditFmtInt.Text) < 0 then
    ListBoxInt.Items.Add (EditFmtInt.Text);
end;
```

The code basically does the formatting operation using the text of the EditFmtInt edit box and the value of the EditInt control. If the format string is not already in the list box, it is then added to it. If the user instead clicks on an item in the list box, the code moves that value to the edit box:

```
procedure TFormFmtTest.ListBoxIntClick(Sender: TObject);
begin
  EditFmtInt.Text := ListBoxInt.Items [
    ListBoxInt.ItemIndex];
end;
```

Conclusion

Strings a certainly a very common data type. Although you can safely use them in most cases without understanding how they work, this chapter should have made clear the exact behavior of strings, making it possible for you to use all the power of this data type.

Strings are handled in memory in a special dynamic way, as happens with dynamic arrays. This is the topic of the next chapter.

Chapter 8
Memory

Author's Note: This chapter will cover memory handling, discuss the various memory areas, and introduce dynamic arrays. Temporarily only this last part is available.

Dynamic Arrays

Traditionally, the Pascal language has always had fixed-size arrays. When you declare a data type using the array construct, you have to specify the number of elements of the array. As expert programmers probably know, there were a few techniques you could use to implement dynamic arrays, typically using pointers and manually allocating and freeing the required memory.

Delphi 4 introduced a very simple implementation of dynamic arrays, modeling them after the dynamic long string type I've just covered. As long strings, dynamic arrays are dynamically allocated and reference counted, but they do not offer a copy-on-write technique. That's not a big problem, as you can deallocate an array by setting its variable to nil.

You can simply declare an array without specifying the number of elements and then allocate it with a given size using the *SetLength* procedure. The same procedure can also be used to resize an array without losing its content. There are also other string-oriented procedures, such as the *Copy* function, that you can use on arrays. Here is a small code excerpt, underscoring the fact that you must both declare and allocate memory for the array before you can start using it:

```
procedure TForm1.Button1Click(Sender: TObject);
var
  Array1: array of Integer;
begin
  Array1 [1] := 100; // error
  SetLength (Array1, 100);
  Array1 [99] := 100; // OK
end;
```

As you indicate only the number of elements of the array, the index invariably starts from 0. Generic arrays in Pascal account for a non-zero low bound and for non-integer indexes, two features that dynamic arrays don't support. To learn the status of a dynamic array, you can use the Length, High, and Low functions, as with any other array. For dynamic arrays, however, Low always returns 0, and High always returns the length minus one. This implies that for an empty array High returns -1 (which, when you think about it, is a strange value, as it is lower than that returned by Low).

FIGURE 8.1: THE FORM OF THE DYNARR EXAMPLE

After this short introduction I can show you a simple example, called DynArr and shown in Figure 8.1. It is indeed simple because there is nothing very complex about dynamic arrays. I'll also use it to show a few possible errors programmers might make. The program declares two global arrays and initializes the first in the *OnCreate* handler:

```
var
  Array1, Array2: array of Integer;

procedure TForm1.FormCreate(Sender: TObject);
begin
  // allocate
  SetLength (Array1, 100);
end;
```

This sets all the values to zero. This initialization code makes it possible to start reading and writing values of the array right away, without any fear of memory errors. (Assuming, of course, that you don't try to access items beyond the upper bound of the array.) For an even better initialization, the program has a button that writes into each cell of the array:

```
procedure TForm1.btnFillClick(Sender: TObject);
var
  I: Integer;
begin
  for I := Low (Array1) to High (Array1) do
    Array1 [I] := I;
end;
```

The Grow button allows you to modify the size of the array without losing its contents. You can test this by using the Get value button after pressing the Grow button:

```
procedure TForm1.btnGrowClick(Sender: TObject);
begin
  // grow keeping existing values
  SetLength (Array1, 200);
end;

procedure TForm1.btnGetClick(Sender: TObject);
begin
  // extract
  Caption := IntToStr (Array1 [99]);
end;
```

The only slightly complex code is in the *OnClick* event of the Alias button. The program copies one array to the other one with the := operator, effectively creating an alias (a new variable referring to the same array in memory). At this point, however, if you modify one of the arrays, the other is affected as well, as they both refer to the same memory area:

```
procedure TForm1.btnAliasClick(Sender: TObject);
begin
  // alias
  Array2 := Array1;
  // change one (both change)
  Array2 [99] := 1000;
  // show the other
  Caption := IntToStr (Array1 [99]);
```

The *btnAliasClick* method does two more operations. The first is an equality test on the arrays. This tests not the actual elements of the structures but rather the memory areas the arrays refer to, checking whether the variables are two aliases of the same array in memory:

```
procedure TForm1.btnAliasClick(Sender: TObject);
begin
  ...
```

```
  if Array1 = Array2 then
    Beep;
  // truncate first array
  Array1 := Copy (Array2, 0, 10);
end;
```

The second is a call to the *Copy* function, which not only moves data from one array to the other, but also replaces the first array with a new one created by the function. The effect is that the *Array1* variable now refers to an array of 11 elements, so that pressing the Get value or Set value buttons produces a memory error and raises an exception (unless you have range-checking turned off, in which case the error remains but the exception is not displayed). The code of the Fill button continues to work fine even after this change, as the items of the array to modify are determined using its current bounds.

Conclusion

This chapter temporarily covers only dynamic arrays, certainly an important element for memory management, but only a portion of the entire picture. More material will follow.

The memory structure described in this chapter is typical of Windows programming, a topic I'll introduce in the next chapter (without going to the full extent of using the VCL, though).

Chapter 9
Windows Programming

Delphi provides a complete encapsulation of the low-level Windows API using Object Pascal and the Visual Component Library (VCL), so it is rarely necessary to build Windows applications using plain Pascal and calling Windows API functions directly. Nonetheless, programmers who want to use some special techniques not supported by the VCL still have that option in Delphi. You would only want to take this approach for very special cases, such as the development of new Delphi components based on unusual API calls, and I don't want to cover the details. Instead, we'll look at a few elements of Delphi's interaction with the operating system and a couple of techniques that Delphi programmers can benefit from.

Windows Handles

Among the data types introduced by Windows in Delphi, handles represent the most important group. The name of this data type is *THandle*, and the type is defined in the Windows unit as:

```
type
  THandle = LongWord;
```

Handle data types are implemented as numbers, but they are not used as such. In Windows, a handle is a reference to an internal data structure of the system. For example, when you work with a window (or a Delphi form), the system gives you a handle to the window. The system informs you that the window you are working with is window number 142, for example. From that point on, your application can ask the system to operate on window number 142—moving it, resizing it, reducing it to an icon, and so on. Many Windows API functions, in fact, have a handle as the first parameter. This doesn't apply only to functions operating on windows; other Windows API functions have as their first parameter a GDI handle, a menu handle, an instance handle, a bitmap handle, or one of the many other handle types.

In other words, a handle is an internal code you can use to refer to a specific element handled by the system, including a window, a bitmap, an icon, a memory block, a cursor, a font, a menu, and so on. In Delphi, you seldom need to use handles directly, since they are hidden inside forms, bitmaps, and other Delphi objects. They become useful when you want to call a Windows API function that is not supported by Delphi.

To complete this description, here is a simple example demonstrating Windows handles. The WHandle program has a simple form, containing just a button. In the code, I respond to the OnCreate event of the form and the OnClick event of the button, as indicated by the following textual definition of the main form:

```
object FormWHandle: TFormWHandle
  Caption = 'Window Handle'
  OnCreate = FormCreate
  object BtnCallAPI: TButton
    Caption = 'Call API'
    OnClick = BtnCallAPIClick
  end
end
```

As soon as the form is created, the program retrieves the handle of the window corresponding to the form, by accessing the Handle property of the form itself. We call IntToStr

to convert the numeric value of the handle into a string, and we append that to the caption of the form, as you can see in Figure 9.1:

```
procedure TFormWHandle.FormCreate(Sender: TObject);
begin
  Caption := Caption + ' ' + IntToStr (Handle);
end;
```

Because `FormCreate` is a method of the form's class, it can access other properties and methods of the same class directly. Therefore, in this procedure we can simply refer to the `Caption` of the form and its `Handle` property directly.

FIGURE 9.1: THE WHANDLE EXAMPLE SHOWS THE HANDLE OF THE FORM WINDOW. EVERY TIME YOU RUN THIS PROGRAM YOU'LL GET A DIFFERENT VALUE.

If you run this program several times you'll generally get different values for the handle. This value, in fact, is determined by Windows and is sent back to the application. (Handles are never determined by the program, and they have no predefined values; they are determined by the system, which generates new values each time you run a program.)

When the user presses the button, the program simply calls a Windows API function, SetWindowText, which changes the text or caption of the window passed as the first parameter. To be more precise, the first parameter of this API function is the handle of the window we want to modify:

```
procedure TFormWHandle.BtnCallAPIClick(Sender: TObject);
begin
  SetWindowText (Handle, 'Hi');
end;
```

This code has the same effect as the previous event handler, which changed the text of the window by giving a new value to the Caption property of the form. In this case calling an API function makes no sense, because there is a simpler Delphi technique. Some API functions, however, have no correspondence in Delphi, as we'll see in more advanced examples later in the book.

External Declarations

Another important element for Windows programming is represented by external declarations. Originally used to link the Pascal code to external functions that were written in assembly language, the external declaration is used in Windows programming to call a function from a DLL (a dynamic link library). In Delphi, there are a number of such declarations in the Windows unit:

```
// forward declaration
function LineTo (DC: HDC; X, Y: Integer): BOOL; stdcall;

// external declaration (instead of actual code)
function LineTo; external 'gdi32.dll' name 'LineTo';
```

This declaration means that the code of the function LineTo is stored in the GDI32.DLL dynamic library (one of the most important Windows system libraries) with the same name we are

using in our code. Inside an external declaration, in fact, we can specify that our function refer to a function of a DLL that originally had a different name.

You seldom need to write declarations like the one just illustrated, since they are already listed in the Windows unit and many other Delphi system units. The only reason you might need to write this external declaration code is to call functions from a custom DLL, or to call undocumented Windows functions.

> In the 16-bit version of Delphi, the external declaration used the name of the library without the extension, and was followed by the name directive (as in the code above) or by an alternative index directive, followed by the ordinal number of the function inside the DLL. The change reflects a system change in the way libraries are accessed: Although Win32 still allows access to DLL functions by number, Microsoft has stated this won't be supported in the future. Notice also that the Windows unit replaces the WinProcs and WinTypes units of the 16-bit version of Delphi.

A Windows Callback Function

We've seen in Chapter 6 that Objet Pascal supports procedural types. A common use of procedural types is to provide callback functions to a Windows API function.

First of all, what is a callback function? The idea is that some API function performs a given action over a number of internal elements of the system, such as all of the windows of a certain kind. Such a function, also called an enumerated function, requires as a parameter the action to be performed on each of the elements, which is passed as a function or procedure compatible with a given procedural type. Windows uses callback functions in other circumstances, but we'll limit our study to this simple case.

Now consider the EnumWindows API function, which has the following prototype (copied from the Win32 Help file):

```
BOOL EnumWindows(
  WNDENUMPROC lpEnumFunc,  // address of callback function
  LPARAM lParam // application-defined value
  );
```

Of course, this is the C language definition. We can look inside the Windows unit to retrieve the corresponding Pascal language definition:

```
function EnumWindows (
  lpEnumFunc: TFNWndEnumProc;
  lParam: LPARAM): BOOL; stdcall;
```

Consulting the help file, we find that the function passed as a parameter should be of the following type (again in C):

```
BOOL CALLBACK EnumWindowsProc (
  HWND hwnd, // handle of parent window
  LPARAM lParam // application-defined value
  );
```

This corresponds to the following Delphi procedural type definition:

```
type
  EnumWindowsProc = function (Hwnd: THandle;
    Param: Pointer): Boolean; stdcall;
```

The first parameter is the handle of each main window in turn, while the second is the value we've passed when calling the *EnumWindows* function. Actually in Pascal the *TFNWndEnumProc* type is not properly defined; it is simply a pointer. This means we need to provide a function with the proper parameters and then use it as a pointer, taking the address of

the function instead of calling it. Unfortunately, this also means that the compiler will provide no help in case of an error in the type of one of the parameters.

> Windows requires programmers to follow the stdcall calling convention every time we call a Windows API function or pass a callback function to the system. Delphi, by default, uses a different and more efficient calling convention, indicated by the register keyword.

Here is the definition of a proper compatible function, which reads the title of the window into a string, then adds it to a ListBox of a given form:

```
function GetTitle (Hwnd: THandle; Param: Pointer): Boolean; stdcall;
var
  Text: string;
begin
  SetLength (Text, 100);
  GetWindowText (Hwnd, PChar (Text), 100);
  FormCallBack.ListBox1.Items.Add (
    IntToStr (Hwnd) + ': ' + Text);
  Result := True;
end;
```

The form has a ListBox covering almost its whole area, along with a small panel on the top hosting a button. When the button is pressed, the *EnumWindows* API function is called, and the *GetTitle* function is passed as its parameter:

```
procedure TFormCallback.BtnTitlesClick(Sender: TObject);
var
  EWProc: EnumWindowsProc;
begin
  ListBox1.Items.Clear;
  EWProc := GetTitle;
  EnumWindows (@EWProc, 0);
end;
```

I could have called the function without storing the value in a temporary procedural type variable first, but I wanted to make clear what is going on in this example. The effect of this program is actually quite interesting, as you can see in Figure 9.2. The Callback example shows a list of all the existing main windows running in the system. Most of them are hidden windows you usually never see (and many actually have no caption).

FIGURE 9.2: THE OUTPUT OF THE CALLBACK EXAMPLE, LISTING THE CURRENT MAIN WINDOWS (VISIBLE AND HIDDEN).

A Minimal Windows Program

To complete the coverage of Windows programming and the Pascal language, I want to show you a very simple but complete application built without using the VCL. The program simply takes the command-line parameter (stored by the system in the cmdLine global variable) and then extracts information from it with the ParamCount and ParamStr Pascal functions. The first of these functions returns the number of parameters; the second returns the parameter in a given position.

Although users seldom specify command-line parameters in a graphical user interface environment, the Windows command-line parameters are important to the system. For example, once you have defined an association between a file extension and an application, you can simply run a program by selecting an associated file. In practice, when you double-click on a file, Windows starts the associated program and passes the selected file as a command-line parameter.

Here is the complete source code of the project (a DPR file, not a PAS file):

```
program Strparam;

uses
  Windows;

begin
  // show the full string
  MessageBox (0, cmdLine,
    'StrParam Command Line', MB_OK);

  // show the first parameter
  if ParamCount > 0 then
    MessageBox (0, PChar (ParamStr (1)),
      '1st StrParam Parameter', MB_OK)
```

```
  else
    MessageBox (0, PChar ('No parameters'),
      '1st StrParam Parameter', MB_OK);
end.
```

The output code uses the *MessageBox* API function, simply to avoid getting the entire VCL into the project. A pure Windows program as the one above, in fact, has the advantage of a very small memory footprint: The executable file of the program is about 16 Kbytes.

To provide a command-line parameter to this program, you can use Delphi's Run > Parameters menu command. Another technique is to open the Windows Explorer, locate the directory that contains the executable file of the program, and drag the file you want to run onto the executable file. The Windows Explorer will start the program using the name of the dropped file as a command-line parameter. Figure 9.3 shows both the Explorer and the corresponding output.

FIGURE 9.3: YOU CAN PROVIDE A COMMAND-LINE PARAMETER TO THE STRPARAM EXAMPLE BY DROPPING A FILE OVER THE EXECUTABLE FILE IN THE WINDOWS EXPLORER.

Conclusion

In this chapter we've seen a low-level introduction to Windows programming, discussing handles and a very simple Windows program. For normal Windows programming tasks, you'll generally use the visual development support provided by Delphi and based on the VCL. But this is beyond the scope of this book, which is the Pascal language.

Next chapter covers variants, a very strange addition to Pascal type system, introduced to provide full OLE support.

Chapter 10
Variants

To provide full OLE support, the 32-bit version of Delphi includes the Variant data type. Here I want to discuss this data type from a general perspective. The Variant type, in fact, has a pervasive effect on the whole language, and the Delphi components library also uses them in ways not related to OLE programming.

Variants Have No Type

In general, you can use variants to store any data type and perform numerous operations and type conversions. Notice that this goes against the general approach of the Pascal language and against good programming practices. A variant is type-checked and computed at run time. The compiler won't warn you of possible errors in the code, which can be caught only with extensive testing. On the whole, you can consider the code portions that use variants to be interpreted code, because, as with interpreted code, many operations cannot be resolved until run time. This affects in particular the speed of the code.

Now that I've warned you against the use of the Variant type, it is time to look at what it can do. Basically, once you've declared a variant variable such as the following:

```
var
  V: Variant;
```

you can assign to it values of several different types:

```
V := 10;
V := 'Hello, World';
V := 45.55;
```

Once you have the variant value, you can copy it to any compatible-or incompatible-data type. If you assign a value to an incompatible data type, Delphi performs a conversion, if it can. Otherwise it issues a run-time error. In fact, a variant stores type information along with the data, allowing a number of run-time operations; these operations can be handy but are both slow and unsafe.

Consider the following example (called VariTest), which is an extension of the code above. I placed three edit boxes on a new form, added a couple of buttons, and then wrote the following code for the *OnClick* event of the first button:

```
procedure TForm1.Button1Click(Sender: TObject);
var
  V: Variant;
begin
  V := 10;
  Edit1.Text := V;
  V := 'Hello, World';
  Edit2.Text := V;
  V := 45.55;
  Edit3.Text := V;
end;
```

Funny, isn't it? Besides assigning a variant holding a string to the Text property of an edit component, you can assign to the Text a variant holding an integer or a floating-point number. As you can see in Figure 10.1, everything works.

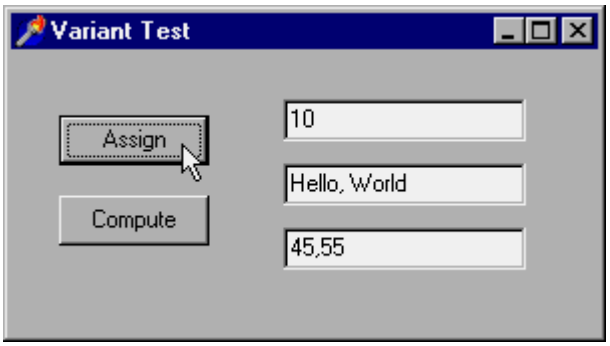


FIGURE 10.1: THE OUTPUT OF THE VARITEST EXAMPLE AFTER THE ASSIGN BUTTON HAS BEEN PRESSED.

Even worse, you can use the variants to compute values, as you can see in the code related to the second button:

```
procedure TForm1.Button2Click(Sender: TObject);
var
  V: Variant;
  N: Integer;
begin
  V := Edit1.Text;
  N := Integer(V) * 2;
  V := N;
  Edit1.Text := V;
end;
```

Writing this kind of code is risky, to say the least. If the first edit box contains a number, everything works. If not, an exception is raised. Again, you can write similar code, but without a compelling reason to do so, you shouldn't use the Variant type; stick with the traditional Pascal data types and type-checking approach. In Delphi and in the VCL (Visual Component Library), variants are basically used for OLE support and for accessing database fields.

Variants in Depth

Delphi includes a variant record type, *TVarData*, which has the same memory layout as the Variant type. You can use this to access the actual type of a variant. The *TVarData* structure includes the type of the Variant, indicated as *VType*, some reserved fields, and the actual value.

The possible values of the *VType* field correspond to the data types you can use in OLE automation, which are often called OLE types or variant types. Here is a complete alphabetical list of the available variant types:

```
varArray        varBoolean      varByRef
varCurrency     varDate         varDispatch
varDouble       varEmpty        varError
varInteger      varNull         varOleStr
varSingle       varSmallint     varString
varTypeMask     varUnknown      varVariant
```

You can find descriptions of these types in the Values in variants topic in the Delphi Help system. There are also many functions for operating on variants that you can use to make specific type conversions or to ask for information about the type of a variant (see, for example, the *VarType* function). Most of these type conversion and assignment functions are actually called automatically when you write expressions using variants. Other variant support routines (look for the topic Variant support routines in the Help file) actually operate on variant arrays.

Variants Are Slow!

Code that uses the Variant type is slow, not only when you convert data types, but also when you add two variant values holding an integer each. They are almost as slow as the interpreted code of Visual Basic! To compare the speed of an algorithm based on variants with that of the same code based on integers, you can look at the VSpeed example.

This program runs a loop, timing its speed and showing the status in a progress bar. Here is the first of the two very similar loops, based on integers and variants:

```
procedure TForm1.Button1Click(Sender: TObject);
var
  time1, time2: TDateTime;
  n1, n2: Variant;
begin
  time1 := Now;
  n1 := 0;
  n2 := 0;
  ProgressBar1.Position := 0;
  while n1 < 5000000 do
  begin
    n2 := n2 + n1;
    Inc (n1);
    if (n1 mod 50000) = 0 then
    begin
      ProgressBar1.Position := n1 div 50000;
      Application.ProcessMessages;
    end;
  end;
  // we must use the result
  Total := n2;
  time2 := Now;
  Label1.Caption := FormatDateTime ('n:ss', Time2-Time1) + ' seconds';
end;
```

The timing code is worth looking at, because it's something you can easily adapt to any kind of performance test. As you can see, the program uses the Now function to get the current time and the FormatDateTime function to output the time difference, asking only for the minutes ("n") and the seconds ("ss") in the format string. As an alternative, you can use the Windows API's *GetTickCount* function, which returns a very precise indication of the milliseconds elapsed since the operating system was started.

In this example the speed difference is actually so great that you'll notice it even without a precise timing. Anyway, you can see the results for my own computer in Figure 10.2. The actual values depend on the computer you use to run this program, but the proportion won't change much.

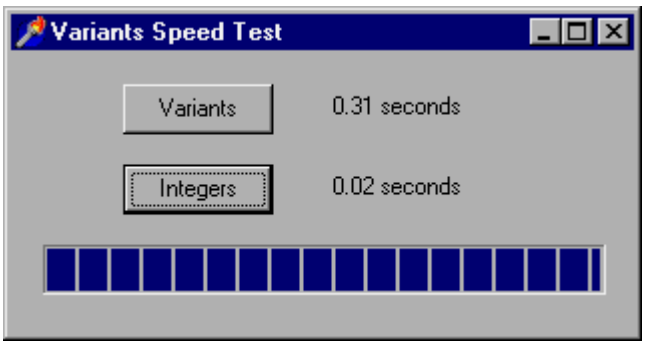


FIGURE 10.2: THE DIFFERENT SPEEDS OF THE SAME ALGORITHM, BASED ON INTEGERS AND VARIANTS (THE ACTUAL TIMING VARIES DEPENDING ON THE COMPUTER), AS SHOWN BY THE VSPEED EXAMPLE.

Conclusion

Variants are so different from traditional Pascal data types that I've decided to cover them in this short separate chapter. Although their role is in OLE programming, they can be handy to write *quick and dirty* programs without having even to think about data types. As we have seen, this affects performance by far.

Now that we have covered most of the language features, let me discuss the overall structure of a program and the modularization offered by units.

Chapter 11
Program and Units

Delphi applications make intensive use of units, or program modules. Units, in fact, were the basis of the modularity in the language before classes were introduced. In a Delphi application, every form has a corresponding unit behind it. When you add a new form to a project (with the corresponding toolbar button or the File > New Form menu command), Delphi actually adds a new unit, which defines the class for the new form.

Units

Although every form is defined in a unit, the reverse is not true. Units do not need to define forms; they can simply define and make available a collection of routines. By selecting the File > New menu command and then the Unit icon in the New page of the Object Repository, you add a new blank unit to the current project. This blank unit contains the following code, delimiting the sections a unit is divided into:

```
unit Unit1;

interface

implementation

end.
```

The concept of a unit is simple. A unit has a unique name corresponding to its filename, an interface section declaring what is visible to other units, and an implementation section with the real code and other hidden declarations. Finally, the unit can have an optional initialization section with some startup code, to be executed when the program is loaded into memory; it can also have an optional finalization section, to be executed on program termination.

The general structure of a unit, with all its possible sections, is the following:

```
unit unitName;

interface

// other units we need to refer to
uses
  A, B, C;

// exported type definition
type
  newType = TypeDefinition;

// exported constants
const
  Zero = 0;

// global variables
var
  Total: Integer;

// list of exported functions and procedures
```

```
procedure MyProc;

implementation

uses
  D, E;

// hidden global variable
var
  PartialTotal: Integer;

// all the exported functions must be coded
procedure MyProc;
begin
  // ... code of procedure MyProc
end;

initialization
  // optional initialization part

finalization
  // optional clean-up code

end.
```

The uses clause at the beginning of the interface section indicates which other units we need to access in the interface portion of the unit. This includes the units that define the data types we refer to in the definition of other data types, such as the components used within a form we are defining.

The second uses clause, at the beginning of the implementation section, indicates more units we need to access only in the implementation code. When you need to refer to other units from the code of the routines and methods, you should add elements in this second uses clause instead of the first one. All the units you refer to must be present in the project directory or in a directory of the search path (you can set the search path for a project in the Directories/Conditionals page of the project's Options dialog box).

> C++ programmers should be aware that the uses statement does not correspond to an include directive. The effect of a uses statement is to import just the pre-compiled interface portion of the units listed. The implementation portion of the unit is considered only when that unit is compiled. The units you refer to can be both in source code format (PAS) or compiled format (DCU), but the compilation must have taken place with the same version of the Delphi.

The interface of a unit can declare a number of different elements, including procedures, functions, global variables, and data types. In Delphi applications, the data types are probably used the most often. Delphi automatically places a new class data type in a unit each time you create a form. However, containing form definitions is certainly not the only use for units in Delphi. You can continue to have traditional units, with functions and procedures, and you can have units with classes that do not refer to forms or other visual elements.

Units and Scope

In Pascal, units are the key to encapsulation and visibility, and they are probably even more important than the private and public keywords of a class. (In fact, as we'll see in the next

chapter, the effect of the private keyword is related to the scope of the unit containing the class.) The scope of an identifier (such as a variable, procedure, function, or a data type) is the portion of the code in which the identifier is accessible. The basic rule is that an identifier is meaningful only within its scope—that is, only within the block in which it is declared. You cannot use an identifier outside its scope. Here are some examples.

- **Global hidden variables**: If you declare an identifier in the implementation portion of a unit, you cannot use it outside the unit, but you can use it in any block and procedure defined within the unit. The memory for this variable is allocated as soon as the program starts and exists until it terminates. You can use the initialization section of the unit to provide a specific initial value.
- **Local variables**: If you declare a variable within the block defining a routine or a method, you cannot use this variable outside that procedure. The scope of the identifier spans the whole procedure, including nested routines (unless an identifier with the same name in the nested routine hides the outer definition). The memory for this variable is allocated on the stack when the program executes the routine defining it. As soon as the routine terminates, the memory on the stack is automatically released.
- **Global variables**: If you declare an identifier in the interface portion of the unit, its scope extends to any other unit that uses the one declaring it. This variable uses memory and has the same lifetime as the previous group; the only difference is in its visibility.

Any declarations in the interface portion of a unit are accessible from any part of the program that includes the unit in its uses clause. Variables of form classes are declared in the same way, so that you can refer to a form (and its public fields, methods, properties, and components) from the code of any other form. Of course, it's poor programming practice to declare everything as global. Besides the obvious memory consumption problems, using global variables makes a program less easy to maintain and update. In short, you should use the smallest possible number of global variables.

Units as Namespaces

The uses statement is the standard technique to access the scope of another unit. At that point you can access the definitions of the unit. But it might happen that two units you refer to declare the same identifier; that is, you might have two classes or two routines with the same name.

In this case you can simply use the unit name to prefix the name of the type or routine defined in the unit. For example, you can refer to the *ComputeTotal* procedure defined in the given *Totals* unit as *Totals.ComputeTotal*. This should not be required very often, as you are strongly advised against using the same name for two different things in a program.

However, if you look into the VCL library and the Windows files, you'll find that some Delphi functions have the same name as (but generally different parameters than) some Windows API functions available in Delphi itself. An example is the simple *Beep* procedure.

If you create a new Delphi program, add a button, and write the following code:

```
procedure TForm1.Button1Click(Sender: TObject);
begin
  Beep;
end;
```

then as soon as you press the button you'll hear a short sound. Now, move to the uses statement of the unit and change the code from this:

```
uses
  Windows, Messages, SysUtils, Classes, ...
```

to this very similar version (simply moving the *SysUtils* unit before the *Windows* unit):

```
uses
  SysUtils, Windows, Messages, Classes, ...
```

If you now try to recompile this code, you'll get a compiler error: "Not enough actual parameters." The problem is that the Windows unit defines another Beep function with two parameters. Stated more generally, what happens in the definitions of the first units you include in the uses statement might be hidden by corresponding definitions of later units. The safe solution is actually quite simple:

```
procedure TForm1.Button1Click(Sender: TObject);
begin
  SysUtils.Beep;
end;
```

This code will compile regardless of the order of the units in the uses statements. There are few other name clashes in Delphi, simply because Delphi code is generally hosted by methods of classes. Having two methods with the same name in two different classes doesn't create any problem. The problems arise only with global routines.

Units and Programs

A Delphi application consists of two kinds of source code files: one or more units and one program file. The units can be considered secondary files, which are referred to by the main part of the application, the program. In theory, this is true. In practice, the program file is usually an automatically generated file with a limited role. It simply needs to start up the program, running the main form. The code of the program file, or Delphi project file (DPR), can be edited either manually or by using the Project Manager and some of the Project Options related to the application object and the forms.

The structure of the program file is usually much simpler than the structure of the units. Here is the source code of a sample program file:

```
program Project1;

uses
  Forms,
  Unit1 in 'Unit1.PAS' {Form1DateForm};

begin
  Application.Initialize;
  Application.CreateForm (TForm1, Form1);
  Application.Run;
end.
```

As you can see, there is simply a uses section and the main code of the application, enclosed by the begin and end keywords. The program's uses statement is particularly important, because it is used to manage the compilation and linking of the application.

Conclusion

Units were the Pascal (actually Turbo Pascal) technique for module programming. Even if they were later followed b objects and classes, they still play a key role for encapsulation, for the definition of some sort of name spaces, and for the overall structure of Delphi programs. Also, units have influence on scope and global memory allocations.

Chapter 12
Files in the Pascal Language

One of the peculiarities of Pascal compared with other programming languages is its built-in support for files. As you might recall from Chapter 2, the language has a `file` keyword, which is a type specifier, like `array` or `record`. You use file to define a new type, and then you can use the new data type to declare new variables:

```
type
  IntFile: file of Integers;
var
  IntFile1: IntFile;
```

It is also possible to use the `file` keyword without indicating a data type, to specify an untyped file. Alternatively, you can use the `TextFile` type, defined in the System units to declare files of ASCII characters. Each kind of file has its own predefined routines, as we will see later in this chapter.

Routines for Working with Files

Once you have declared a file variable, you can assign it to a real file in the file system using the `AssignFile` method. The next step is usually to call `Reset` to open the file for reading at the beginning, `Rewrite` to open (or create) it for writing, and `Append` to add new items to the end of the file without removing the older items. Once the input or output operations are done, you should call `CloseFile`.

As an example look at the following code, which simply saves some numbers to a file:

```
type
  IntFile: file of Integers;
var
  IntFile1: IntFile;
begin
  AssignFile (IntFile1, 'c:/tmp/test.my')
  Rewrite (IntFile1);
  Write (IntFile1, 1);
  Write (IntFile1, 2);
  CloseFile (IntFile1);
end;
```

> The `CloseFile` operation should typically be done inside a `finally` block, to avoid leaving the file open in case the file handling code generates an exception. Actually file based operations generate exceptions or not depending on the `$I` compiler settings. In case the system doesn't raise exceptions, you can check the `IOResult` global variable to see if anything went wrong.

Delphi includes many other file management routines, some of which are includes in the list below:

Append	FileClose	Flush
AssignFile	FileCreate	GetDir
BlockRead	FileDateToDateTime	IOResult
BlockWrite	FileExists	MkDir

ChangeFileExt	FileGetAttr	Read
CloseFile	FileGetDate	Readln
DateTimeToFileDate	FileOpen	Rename
DeleteFile	FilePos	RenameFile
DiskFree	FileRead	Reset
DiskSize	FileSearch	Rewrite
Eof	FileSeek	RmDir
Eoln	FileSetAttr	Seek
Erase	FileSetDate	SeekEof
ExpandFileName	FileSize	SeekEoln
ExtractFileExt	FileWrite	SetTextBuf
ExtractFileName	FindClose	Truncate
ExtractFilePath	FindFirst	Write
FileAge	FindNext	Writeln

Not all of these routines are defined in standard Pascal, but many of them have been part of Borland Pascal for a long time. You can find detailed information about these routines in Delphi's Help files. Here, I'll show you three simple examples to demonstrate how these features can be used.

Handling Text Files

One of the most commonly used file formats is that of text files. As I mentioned before, Delphi has some specific support for text files, most notably the `TextFile` data type defined by the System unit. Ignoring the fact that Delphi's string lists can automatically save themselves to a file (with the `SaveToFile` method, based on the use of streams), you could easily save the content of a string list to a `TextFile` by writing the following code (in which the file name is requested to the user, using Delphi's SaveDialog component):

```
var
  OutputFile: TextFile;
  I: Integer;
begin
  // choose a file
  if SaveDialog1.Execute then
  begin
    // output the text to a file
    AssignFile (OutputFile, SaveDialog1.FileName);
    Rewrite (OutputFile);
    try
      // save listbox data to file
      for I := 0 to ListBox1.Items.Count - 1 do
        Writeln (OutputFile, ListBox1.Items[I]);
    finally
      CloseFile (OutputFile);
    end;
  end;
end;
```

Instead of being connected to a physical file, a Pascal file type variable can be hooked directly to the printer, so that the output will be printed instead of being saved to a file. To accomplish this, simple use the `AssignPrn` procedure. For example, in the code above you could replace the line `AssignFile (OutputFile, SaveDialog1.FileName);` with the line `AssignPrn (OutputFile);`

A Text File Converter

Up to now we've seen simple examples of creating new files. In our next example, we'll process an existing file, creating a new one with a modified version of the contents. The program, named Filter, can convert all the characters in a text file to uppercase, capitalize only the initial word of each sentence, or ignore the characters from the upper portion of the ASCII character set.

The form of the program has two read-only edit boxes for the names of the input and output files, and two buttons to select input and output files using the standard dialog boxes. The form's lower portion contains a RadioGroup component and a bitmap button (named `ConvertBitBtn`) to apply the current conversion to the selected files. The radio group has three items, as you can see from the following portion of the form's textual description:

```
object RadioGroup1: TRadioGroup
  Caption = 'Conversion'
  Items.Strings = (
    '&Uppercase'
    'Capitalize &sentences'
    'Remove s&ymbols')
```

The user can click on the two buttons to choose the names of the input and output files, displayed in the two edit boxes:

```
procedure TForm1.Button1Click(Sender: TObject);
begin
  if OpenDialog1.Execute then
    Edit1.Text := OpenDialog1.Filename;
end;
```

The second button activates the `SaveDialog1` dialog box. The real code of the example is in the three conversion routines that are called by the bitmap button's `OnClick` event-handler. These calls take place inside a case statement in the middle of the `ConvertBitBtn` button's `OnClick` handler:

```
case RadioGroup1.ItemIndex of
  0: ConvUpper;
  1: ConvCapitalize;
  2: ConvSymbols;
end;
```

Once again, you can see the entire source code among the download files. Before calling one of the conversion procedures, the `ConvertBitBtnClick` method displays a dialog box (`ConvertForm`) with a ProgressBar component, to show the user that the conversion is taking place. This method does most of the work related to handling the files-it opens the input file as a file of bytes (a file storing data as plain bytes) the first time, so that it can use the `FileSize` procedure, which is not available for text files. Then this file is closed and reopened as a text file.

Since the program opens two files, and each of these operations can fail, it uses two nested `try` blocks to ensure a high level of protection, although using the standard dialog boxes to select file names already provides a good confirmation of file selection. Now, let's take a look at one of the conversion routines in detail. The simplest of the three conversion routines is `ConvUpper`, which converts every character in the text file to uppercase. Here is its code:

```
procedure TForm1.ConvUpper;
var
  Ch: Char;
  Position: LongInt;
begin
  Position := 0;
  while not Eof (FileIn) do
  begin
    Read (FileIn, Ch);
    Ch := UpCase (Ch);
    Write (FileOut, Ch);
    Inc (Position);
    ConvertForm.ProgressBar1.Position :=
      Position * 100 div FileLength;
    Application.ProcessMessages;
  end;
end;
```

This method reads each character from the source file until the program reaches the end of the file (*Eof*). Each single character is converted and copied to the output file. As an alternative, it is possible to read and convert one line at a time (that is, a string at a time) using string handling routines. This will make the program significantly faster. The approach I've used here is reasonable only for an introductory example.

The conversion procedure's actual code, however, is complicated by the fact that it has to update the dialog box's progress bar. At each step of the conversion, a long integer variable with the current position in the file is incremented. This variable's value is used to compute the percentage of work completed, as you can see in the code above.

The conversion procedure for removing symbols is very simple:

```
while not Eof (FileIn) do
begin
  Read (FileIn, Ch);
  if Ch < Chr (127) then
    Write (FileOut, Choose);
  ...
```

The procedure used to capitalize the text, in contrast, is really a complex piece of code, which you can find in the code of the example. The conversion is based on a `case` statement with four branches:

- If the letter is uppercase, and it is the first letter after an ending punctuation mark (as indicated by the Period Boolean variable), it is left as is; otherwise, it is converted to lowercase. This conversion is not done by a standard procedure, simply because there isn't one for single characters. It's done with a low-level function I've written, called `LowCase`.
- If the letter is lowercase, it is converted to uppercase only if it was at the beginning of a new sentence.
- If the character is an ending punctuation mark (period, question mark, or exclamation mark), Period is set to True.
- If the character is anything else, it is simply copied to the destination file, and Period is set to False.

Figure 12.1 shows an example of this code's effect; it shows a text file before and after the conversion. This program is far from adequate for professional use, but it is a first step toward building a full-scale case conversion program. Its biggest drawbacks are that it frequently

converts proper nouns to lowercase, and capitalizes any letter after a period (even if it's the first letter of a filename extension).

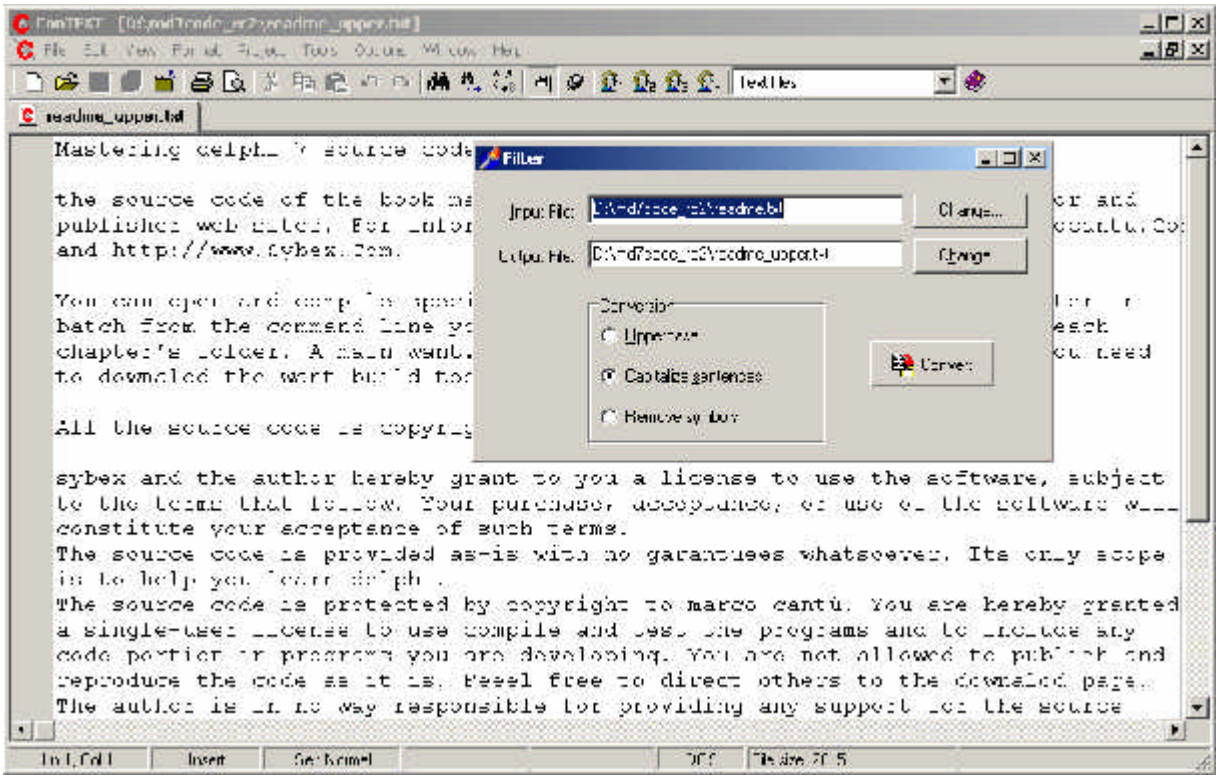


FIGURE 12.1: THE RESULT OF RUNNING THE FILTER EXAMPLE'S CAPITALIZE CONVERSION.

Saving Generic Data

In addition to using text files, you can save other data types to a file, including integers, real numbers, arrays, and records. Using a custom file type instead of a text file may be an advantage because it might take less space (the textual representation of a number usually takes much more space than its binary value), but this approach won't let the user browse through the files using a text editor (which might be an advantage, too).

How do you save a series of integers to a file? First you have to define a file as shown:

```
SaveFile: file of Integer;
```

Then you need to assign the real file to the file variable, open the file, operate on it , and close it. For example the following code saves all the numeric data collected in a 5x4 string grid:

```
{save to the current file}
AssignFile (SaveFile, CurrentFile);
Rewrite (SaveFile);
try
  {write the value of each grid element}
  for I := 1 to 5 do
    for J := 1 to 4 do
    begin
      Value := StrToIntDef (Trim (
        StringGrid1.Cells [I, J]), 0);
      Write (SaveFile, Value);
    end;
finally
  CloseFile (SaveFile);
```

```
end;
```

To save the data to a file, the program saves each value of the string grid (after converting it into a number). To accomplish this, the program uses two nested for loops to scan the grid. Notice the use of the temporary `Value` variable: the `Write` and `Read` procedures require a parameter passed by reference (`var`), so you cannot pass the property of a Delphi component, since it doesn't correspond directly to a memory location.

Of course, the data should be read in the same order it is written, as you can see in the `Open1Click` method:

```
{load from the current file}
AssignFile (LoadFile, CurrentFile);
Reset (LoadFile);
try
  {read the value of each grid element}
  for I := 1 to 5 do
    for J := 1 to 4 do
    begin
      Read (LoadFile, Value);
      StringGrid1.Cells [I, J] := IntToStr(Value);
    end;
finally
  CloseFile (LoadFile);
end;
```

From Files to Streams

Although direct handling of files, using the traditional Pascal-language approach is certainly still an interesting technique, a strongly urge you to use streams (the `TStream` and derived classes) to handle any complex files. Streams represent virtual files, which can be mapped to physical files, to a memory block, to a socket, or any other continuous series of bytes. You can find more on streams in the Delphi help file and in my Mastering Delphi book.

Conclusion

At least for the moment, this chapter on files is the last of the book. Feel free to send me feedback as suggested in the introduction (newsgroup or email), sending me your comment and requests. If after this introduction on the Pascal language you want to delve into the object-oriented elements of Object Pascal in Delphi, you can refer to my printed book of the series ***Mastering Delphi*** (Sybex).

As I mentioned earlier, buying one of my printed books (possibly through the Amazon link on my web site) and donating me some cash for this book, is the best way to support its future development, so that other programmers can benefit from this effort. Helping me with the update (providing corrections and suggestions) is another very good way to contribute.

For more information on the latest edition of Mastering Delphi and more advanced books of mine (and of other authors as well) you can refer to my web site, **www.marcocantu.com**. The same site hosts updated versions of this book, and its examples. Keep also an eye for the companion book **Essential Delphi**.

Happy coding!

Appendix A
Glossary

This is a short glossary of technical terms used throughout the book. They might also be defined elsewhere in the text, but I've decided to collect them here anyway, to make it easier to find them.

Heap (Memory)

The term *Heap* indicates a portion of the memory available to a program, also called dynamic memory area. The heap is the area in which the allocation and deallocation of memory happens in random order. This means that if you allocate three blocks of memory in sequence, they can be destroyed later on in any order. The heap manager takes care of all the details for you, so you simply ask for new memory with GetMem or by calling a constructor to create an object, and Delphi will return you a new memory block (optionally reusing memory blocks already discarded).

The heap is one of the three memory areas available to an application. The other two are the global area (this is where global variables live) and the stack. Contrary to the heap, global variables are allocated when the program starts and remain there until it terminates. For the stack see the specific entry in this glossary.

Delphi uses the heap for allocating the memory of each and every object, the text of the strings, for dynamic arrays, and for specific requests of dynamic memory (GetMem).

Windows allows an application to have up to 2 GigaBytes of address space, most of which can be used by the heap.

Stack (Memory)

The term Stack indicates a portion of the memory available to a program, which is dynamic but is allocated and deallocated following specific order. The stack allocation is LIFO, Last In First Out. This means that the last memory object you've allocated will be the first to be deleted. Stack memory is typically used by routines (procedure, function, and method calls). When you call a routine, its parameters and return type are placed on the stack (unless you optimize the call, as Delphi does by default). Also the variables you declare within a routine (using a *var* block before the begin statement) are stored on the stack, so that when the routine terminates they'll be automatically removed (before getting back to the calling routine, in LIFO order).

The stack is one of the three memory areas available to an application. The other two are called global memory and heap. See the heap entry in this glossary..

Delphi uses the stack for routine parameters and return values (unless you use the default register calling convention), for local routine variables, for Windows API function calls, and so on.

Windows applications can reserve a large amount of memory for the stack. In Delphi you set this in the linker page of the project options, however, the default generally does it. If you receive a stack full error message this is probably because you have a function recursively calling itself forever, not because the stack space is too limited.

More Terms for the Glossary

[*** TODO: Finish glossary. It is really incomplete!]

- Dynamic
- Static
- Virtual
- memory leak
- painting
- literal
- array
- API
- class reference
- class method
- parent
- owner
- self

Appendix B: Examples

This is a list of the examples which are part of Essential Pascal and available for download:

Chapter 3

ResStr: resource strings
Range: ordinal types ranges
TimeNow: time manipulation

Chapter 4

GPF: general protection faults with null pointers

Chapter 5

IfTest: if statements
Loops: for and while statements

Chapter 6

OpenArr: open array parameters
DoubleH: simple procedures
ProcType: procedural types
OverDef: overloading and default parameters

Chapter 7

StrRef: strings reference counting
LongStr: using long strings
FmtTest: formatting examples

Chapter 8

DynArr: dynamic arrays
WHandle: Windows handles
Callback: Windows callback functions
StrParam: command line parameters

Chapter 10

VariTest: simple variant operations
VariSpeed: the speed of variants