This chapter is an extract from sample chapters of the book
A Practical Guide to Commands, Editors, and Shell Programming, Third Edition
located at
http://www.sobell.com/CR2/sample.pdf

11

Programming the Bourne Again Shell

In This Chapter

Chapter 7 introduced the shells and Chapter 9 went into detail about the Bourne Again Shell. This chapter introduces additional Bourne Again Shell commands, builtins, and concepts that carry shell programming to a point where it can be useful. The first part of this chapter covers programming control structures, which are also known as control flow constructs. These structures allow you to write scripts that can loop over command line arguments, make decisions based on the value of a variable, set up menus, and more. The Bourne Again Shell uses the same constructs found in such high-level programming languages as C.

Although you may make use of shell programming as a system administrator, reading this chapter is not required to perform system administration tasks. Feel free to skip this chapter and come back to it when you will find it most useful.

The next part of this chapter discusses parameters and variables, going into detail about array variables, local versus global variables, special parameters, and positional parameters. The exploration of builtin commands covers type, which displays information about a command, and read, which allows you to accept user input in a shell script. The section on the exec builtin demonstrates how exec provides an efficient way to execute a command by replacing a process and explains how you can use it to redirect input and output from within a script. The next section covers the trap builtin, which provides a way to detect and respond to operating system signals (such as that which is generated when you press CONTROL-C). The discussion of builtins concludes with a discussion of kill, which can abort a process, and getopts, which makes it easy to parse options for a shell script. (Table 11-6 on page 457 lists some of the more commonly used builtins.)

Next the chapter examines arithmetic and logical expressions and the operators that work with them. The final section walks through the design and implementation of two major shell scripts.

This chapter contains many examples of shell programs. Although they illustrate certain concepts, most use information from earlier examples as well. This overlap not only reinforces your overall knowledge of shell programming but also demonstrates how you can combine commands to solve complex tasks. Running, modifying, and experimenting with the examples in this book is a good way to become comfortable with the underlying concepts.

Do not name a shell script test

tip You can unwittingly create a problem if you give a shell script the name **test** because a Linux utility has the same name. Depending on how the **PATH** variable is set up and how you call the program, you may run your script or the utility, leading to confusing results.

This chapter illustrates concepts with simple examples, which are followed by more complex ones in sections marked "Optional." The more complex scripts illustrate traditional shell programming practices and introduce some Linux utilities often used in scripts. You can skip these sections without loss of continuity the first time you read the chapter. Return to them later when you feel comfortable with the basic concepts.

Control Structures

The *control flow* commands alter the order of execution of commands within a shell script. Control structures include the **if...then**, **for...in**, **while**, **until**, and **case** statements. In addition, the **break** and **continue** statements work in conjunction with the control structures to alter the order of execution of commands within a script.

if...then

The **if...then** control structure has the following syntax:

if ***test-command***
    then
        commands
fi

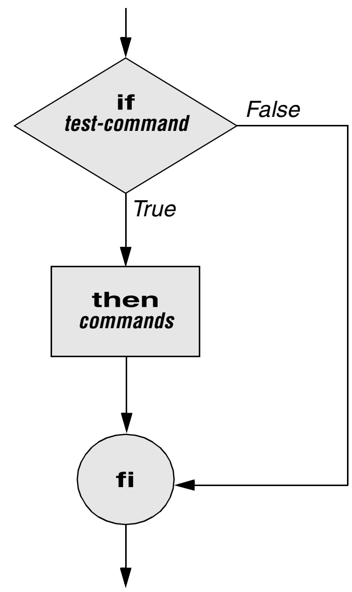

Figure 11-1 An **if...then** flowchart

The ***bold*** words in the syntax description are the items you supply to cause the structure to have the desired effect. The *nonbold* words are the keywords the shell uses to identify the control structure.

test builtin Figure 11-1 shows that the **if** statement tests the status returned by the ***test-command*** and transfers control based on this status. The end of the **if** structure is marked by a **fi** statement, (*if* spelled backward). The following script prompts for two words, reads them, and then uses an **if** structure to execute commands based on the result returned by the test builtin when it compares the two words. (See the test info page for information on the test utility, which is similar to the test builtin.) The test builtin returns a status of *true* if the two words are the same and *false* if they are not. Double quotation marks around **$word1** and **$word2** make sure that test works properly if you enter a string that contains a SPACE or other special character:

```
$ cat if1
echo -n "word 1: "
read word1
echo -n "word 2: "
read word2

if test "$word1" = "$word2"
    then
        echo "Match"
fi
echo "End of program."
```

```
$ if1
word 1: peach
word 2: peach
Match
End of program.
```

In the preceding example the ***test-command*** is **test "$word1" = "$word2"**. The test builtin returns a *true* status if its first and third arguments have the relationship specified by its second argument. If this command returns a *true* status (= 0), the shell executes the commands between the **then** and **fi** statements. If the command returns a *false* status (not = 0), the shell passes control to the statement following **fi** without executing the statements between **then** and **fi**. The effect of this **if** statement is to display **Match** if the two words are the same. The script always displays **End of program.**

Builtins In the Bourne Again Shell, test is a builtin—part of the shell. It is also a stand-alone utility kept in **/usr/bin/test**. This chapter discusses and demonstrates many Bourne Again Shell builtins. You usually use the builtin version if it is available and the utility if it is not. Each version of a command may vary slightly from one shell to the next and from the utility to any of the shell builtins. See page 444 for more information on shell builtins.

Checking arguments The next program uses an **if** structure at the beginning of a script to check that you have supplied at least one argument on the command line. The **–eq** test operator compares two integers, where the **$#** special parameter (page 439) takes on the value of the number of command line arguments. This structure displays a message and exits from the script with an exit status of 1 if you do not supply at least one argument:

```
$ cat chkargs
if test $# -eq 0
    then
        echo "You must supply at least one argument."
        exit 1
fi
echo "Program running."
$ chkargs
You must supply at least one argument.
$ chkargs abc
Program running.
```

A test like the one shown in **chkargs** is a key component of any script that requires arguments. To prevent the user from receiving meaningless or confusing information from the script, the script needs to check whether the user has supplied the appropriate arguments. Sometimes the script simply tests whether arguments exist (as in **chkargs**). Other scripts test for a specific number or specific kinds of arguments.

You can use test to ask a question about the status of a file argument or the relationship between two file arguments. After verifying that at least one argument has been given on the command line, the following script tests whether the argument is the name of an ordinary file (not a directory or other type of file) in the working directory. The test builtin with the **–f** option and the first command line argument (**$1**) check the file:

```
$ cat is_ordfile
if test $# -eq 0
    then
        echo "You must supply at least one argument."
        exit 1
fi
if test -f "$1"
    then
        echo "$1 is an ordinary file in the working directory"
    else
        echo "$1 is NOT an ordinary file in the working directory"
fi
```

You can test many other characteristics of a file with test and various options. Table 11-1 lists some of these options.

Table 11-1 Options to the test builtin

Option	Tests file to see if it
–d	Exists and is a directory file
–e	Exists
–f	Exists and is an ordinary file (not a directory)
–r	Exists and is readable
–s	Exists and has a size greater than 0 bytes
–w	Exists and is writable
–x	Exists and is executable

Other test options provide ways to test relationships between two files, such as whether one file is newer than another. Refer to later examples in this chapter for more detailed information.

Always test the arguments

tip To keep the examples in this book short and focused on specific concepts, the code to verify arguments is often omitted or abbreviated. It is a good practice to test arguments in shell programs that other people will use. Doing so results in scripts that are easier to run and debug.

[] is a synonym for test

The following example—another version of **chkargs**—checks for arguments in a way that is more traditional for Linux shell scripts. The example uses the bracket ([]) synonym for test. Rather than using the word test in scripts, you can surround the arguments to test with brackets. The brackets must be surrounded by whitespace (SPACEs or TABs).

```
$ cat chkargs2
if [ $# -eq 0 ]
    then
        echo "Usage: chkargs2 argument..." 1>&2
        exit 1
fi
echo "Program running."
exit 0
$ chkargs2
Usage: chkargs2 arguments
$ chkargs2 abc
Program running.
```

Usage message The error message that **chkargs2** displays is called a *usage message* and uses the **1>&2** notation to redirect its output to standard error (page 280). After issuing the usage message, **chkargs2** exits with an exit status of 1, indicating that an error has occurred. The **exit 0** command at the end of the script causes **chkargs2** to exit with a 0 status after the program runs without an error. The Bourne Again Shell returns a 0 status if you omit the status code.

The usage message is commonly employed to specify the type and number of arguments the script takes. Many Linux utilities provide usage messages similar to the one in **chkargs2**. If you call a utility or other program with the wrong number or kind of arguments, you will often see a usage message. Following is the usage message that cp displays when you call it without any arguments:

```
$ cp
cp: missing file argument
Try 'cp --help' for more information.
```

if...then...else

The introduction of an **else** statement turns the **if** structure into the two-way branch shown in Figure 11-2. The **if...then...else** control structure has the following syntax:

if ***test-command***
    then
        commands
    else
        commands
fi

Because a semicolon (**;**) ends a command just as a NEWLINE does, you can place **then** on the same line as **if** by preceding it with a semicolon. (Because **if** and **then** are separate builtins, they require a command separator between them; a semicolon and NEWLINE work equally well.) Some people prefer this notation for aesthetic reasons, while others like it because it saves space:

if ***test-command;*** *then*
        commands
    else
        commands
fi

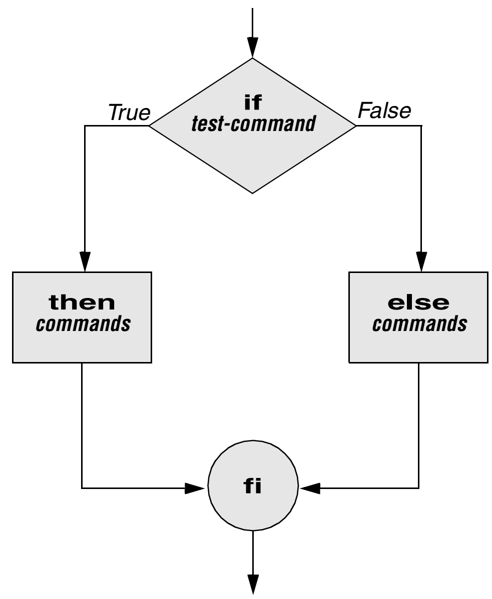

Figure 11-2 An **if...then...else** flowchart

If the ***test-command*** returns a *true* status, the **if** structure executes the commands between the **then** and **else** statements and then diverts control to the statement following **fi**. If the ***test-command*** returns a *false* status, the **if** structure executes the commands following the **else** statement.

When you run the next script, named **out**, with arguments that are filenames, it displays the files on the terminal. If the first argument is **–v** (called an option in this case), **out** uses less (page 148) to display the files one page at a time. After determining that it was called with at least one argument, **out** tests its first argument to see whether it is **–v**. If the result of the test is *true* (if the first argument is **–v**), **out** uses the shift builtin to shift the arguments to get rid of the **–v** and displays the files using less. If the result of the test is *false* (if the first argument is *not* **–v**), the script uses cat to display the files:

```
$ cat out
if [ $# -eq 0 ]
    then
        echo "Usage: out [-v] filenames..." 1>&2
        exit 1
fi

if [ "$1" = "-v" ]
    then
        shift
        less -- "$@"
    else
        cat -- "$@"
fi
```

optional In **out** the **––** argument to cat and less tells these utilities that no more options follow on the command line and not to consider leading hyphens (**–**) in the following list as indicating options. Thus **––** allows you to view a file with a name that starts with a hyphen. Although not common, filenames beginning with a hyphen do occasionally occur. (You can create such a file by using the command **cat > –fname**.) The **––** argument works with all Linux utilities that use the getopts builtin (page 454) to parse their options; it does not work with more and a few other utilities. This argument is particularly useful when used in conjunction with rm to remove a file whose name starts with a hyphen (**rm –– –fname**), including any that you create while experimenting with the **––** argument.

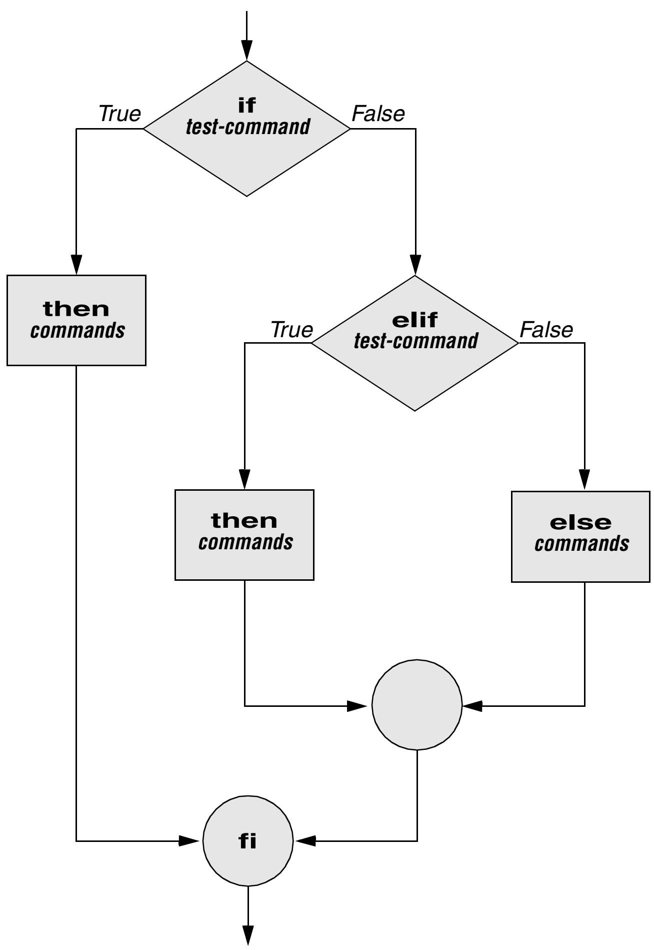

Figure 11-3 An **if...then...elif** flowchart

if...then...elif

The **if...then...elif** control structure (Figure 11-3) has the following syntax:

if ***test-command***
    then
        commands
    elif ***test-command***
        then
            commands
. . .
    else
        commands
fi

The **elif** statement combines the **else** statement and the **if** statement and allows you to construct a nested set of **if...then...else** structures (Figure 11-3). The difference between the **else** statement and the **elif** statement is that each **else** statement must be paired with a **fi** statement, whereas multiple nested **elif** statements require only a single closing **fi** statement.

The following example shows an **if...then...elif** control structure. This shell script compares three words that the user enters. The first **if** statement uses the Boolean operator AND (**–a**) as an argument to test. The test builtin returns a *true* status only if the first and second logical comparisons are *true* (that is, if **word1** matches **word2** and **word2** matches **word3**). If test returns a *true* status, the script executes the command following the next **then** statement, passes control to the statement following **fi**, and terminates:

```
$ cat if3
echo -n "word 1: "
read word1
echo -n "word 2: "
read word2
echo -n "word 3: "
read word3

if [ "$word1" = "$word2" -a "$word2" = "$word3" ]
    then
        echo "Match: words 1, 2, & 3"
    elif [ "$word1" = "$word2" ]
    then
        echo "Match: words 1 & 2"
    elif [ "$word1" = "$word3" ]
    then
        echo "Match: words 1 & 3"
    elif [ "$word2" = "$word3" ]
    then
        echo "Match: words 2 & 3"
    else
        echo "No match"
fi
```

```
$ if3
word 1: apple
word 2: orange
word 3: pear
No match
$ if3
word 1: apple
word 2: orange
word 3: apple
Match: words 1 & 3
$ if3
word 1: apple
word 2: apple
word 3: apple
Match: words 1, 2, & 3
```

If the three words are not the same, the structure passes control to the first **elif**, which begins a series of tests to see if any pair of words is the same. As the nesting continues, if any one of the **if** statements is satisfied, the structure passes control to the next **then** statement and subsequently to the statement following **fi**. Each time an **elif** statement is not satisfied, the structure passes control to the next **elif** statement. The double quotation marks around the arguments to echo that contain ampersands (&) prevent the shell from interpreting the ampersands as special characters.

optional

The lnks Script

The following script, named **lnks**, demonstrates the **if...then** and **if...then...elif** control structures. This script finds hard links to its first argument, a filename. If you provide the name of a directory as the second argument, **lnks** searches for links in that directory and all subdirectories. If you do not specify a directory, **lnks** searches the working directory and its subdirectories. This script does not locate symbolic links.

```
$ cat lnks
#!/bin/bash
# Identify links to a file
# Usage: lnks file [directory]

if [ $# -eq 0 -o $# -gt 2 ]; then
    echo "Usage: lnks file [directory]" 1>&2
    exit 1
fi
if [ -d "$1" ]; then
    echo "First argument cannot be a directory." 1>&2
    echo "Usage: lnks file [directory]" 1>&2
    exit 1
else
    file="$1"
fi
```

```
if [ $# -eq 1 ]; then
        directory="."
    elif [ -d "$2" ]; then
        directory="$2"
    else
        echo "Optional second argument must be a directory." 1>&2
        echo "Usage: lnks file [directory]" 1>&2
        exit 1
fi

# Check that file exists and is an ordinary file:
if [ ! -f "$file" ]; then
    echo "lnks: $file not found or special file" 1>&2
    exit 1
fi
# Check link count on file
set -- $(ls -l "$file")
linkcnt=$2
if [ "$linkcnt" -eq 1 ]; then
    echo "lnks: no other hard links to $file" 1>&2
    exit 0
fi

# Get the inode of the given file
set $(ls -i "$file")

inode=$1

# Find and print the files with that inode number
echo "lnks: using find to search for links..." 1>&2
find "$directory" -xdev -inum $inode -print
```

Alex has a file named **letter** in his home directory. He wants to find links to this file in his and other users' home directory file trees. In the following example, Alex calls **lnks** from his home directory to perform the search. The second argument to **lnks**, **/home**, is the pathname of the directory he wants to start the search in. The **lnks** script reports that **/home/alex/letter** and **/home/jenny/draft** are links to the same file:

```
$ lnks letter /home
lnks: using find to search for links...
/home/alex/letter
/home/jenny/draft
```

In addition to the **if...then...elif** control structure, **lnks** introduces other features that are commonly used in shell programs. The following discussion describes **lnks** section by section.

Specify the shell The first line of the **lnks** script uses **#!** (page 284) to specify the shell that will execute the script:

```
#!/bin/bash
```

In this chapter the **#!** notation appears only in more complex examples. It ensures that the proper shell executes the script, even when the user is running a different shell or the script is called from another shell script.

Comments The second and third lines of **lnks** are comments; the shell ignores the text that follows a pound sign up to the next NEWLINE character. These comments in **lnks** briefly identify what the file does and how to use it:

```
# Identify links to a file
# Usage: lnks file [directory]
```

Usage messages The first **if** statement tests whether **lnks** was called with zero arguments or more than two arguments:

```
if [ $# -eq 0 -o $# -gt 2 ]; then
    echo "Usage: lnks file [directory]" 1>&2
    exit 1
fi
```

If either of these conditions is *true*, **lnks** sends a usage message to standard error and exits with a status of 1. The double quotation marks around the usage message prevent the shell from interpreting the brackets as special characters. The brackets in the usage message indicate that the **directory** argument is optional.

The second **if** statement tests whether the first command line argument (**$1**) is a directory (the **–d** argument to test returns a *true* value if the file exists and is a directory):

```
if [ -d "$1" ]; then
    echo "First argument cannot be a directory." 1>&2
    echo "Usage: lnks file [directory]" 1>&2
    exit 1
else
    file="$1"
fi
```

If the first argument is a directory, **lnks** displays a usage message and exits. If it is not a directory, **lnks** saves the value of **$1** in the **file** variable because later in the script set resets the command line arguments. If the value of **$1** is not saved before the **set** command is issued, its value will be lost.

Test the arguments The next section of **lnks** is an **if...then...elif** statement:

```
if [ $# -eq 1 ]; then
        directory="."
    elif [ -d "$2" ]; then
        directory="$2"
    else
        echo "Optional second argument must be a directory." 1>&2
        echo "Usage: lnks file [directory]" 1>&2
        exit 1
fi
```

The first ***test-command*** determines whether the user specified a single argument on the command line. If the ***test-command*** returns 0 (*true*), the user-created variable named **directory** is assigned the value of the working directory (**.**). If the ***test-command*** returns *false,* the **elif** statement tests whether the second argument is a directory. If it is a directory, the **directory** variable is set equal to the second command line argument, **$2**. If **$2** is not a directory, **lnks** sends a usage message to standard error and exits with a status of 1.

The next **if** statement in **lnks** tests whether **$file** does not exist. This test keeps **lnks** from wasting time looking for links to a nonexistent file.

The test builtin with the three arguments **!**, **–f**, and **$file** evaluates to *true* if the file **$file** does *not* exist:

```
[ ! -f "$file" ]
```

The **!** operator preceding the **–f** argument to test negates its result, yielding *false* if the file **$file** *does* exist and is an ordinary file.

Next **lnks** uses set and **ls –l** to check the number of links **$file** has:

```
# Check link count on file
set -- $(ls -l "$file")
linkcnt=$2
if [ "$linkcnt" -eq 1 ]; then
    echo "lnks: no other hard links to $file" 1>&2
    exit 0
fi
```

The set builtin uses command substitution (page 344) to set the positional parameters to the output of **ls –l**. The second field in this output is the link count, so the user-created variable **linkcnt** is set equal to **$2**. The **––** used with set prevents set from interpreting as an option the first argument produced by **ls –l** (the first argument is the access permissions for the file and typically begins with **–**). The **if** statement checks whether **$linkcnt** is equal to 1; if it is, **lnks** displays a message and exits. Although this message is not truly an error message, it is redirected to standard error. The way **lnks** has been written, all informational messages are sent to standard error. Only the final product of **lnks**—the pathnames of links to the specified file—is sent to standard output, so you can redirect the output as you please.

If the link count is greater than one, **lnks** goes on to identify the *inode* (page 1041) for **$file**. As explained on page 212, comparing the inodes associated with filenames is a good way to determine whether the filenames are links to the same file. The **lnks** script uses set to set the positional parameters to the output of **ls –i**. The first argument to set is the inode number for the file, so the user-created variable named **inode** is assigned the value of **$1**:

```
# Get the inode of the given file
set $(ls -i "$file")

inode=$1
```

Finally **lnks** uses the find utility to search for files having inode numbers that match **$inode**:

```
# Find and print the files with that inode number
echo "lnks: using find to search for links..." 1>&2
find "$directory" -xdev -inum $inode -print
```

The find utility searches for files that meet the criteria specified by its arguments, beginning its search with the directory specified by its first argument (**$directory**) and searching all subdirectories. The remaining arguments specify that the filenames of files having inodes matching **$inode** should be sent to standard output. Because files in different filesystems can have the same inode number and not be linked, find must search only directories in the same filesystem as **$directory**. The **–xdev** argument prevents find from searching directories on other filesystems. Refer to page 209 for more information about filesystems and links.

The echo command preceding the find command in **lnks**, which tells the user that find is running, is included because find frequently takes a long time to run. Because **lnks** does not include a final exit statement, the exit status of **lnks** is that of the last command it runs, find.

Debugging Shell Scripts

When you are writing a script such as **lnks**, it is easy to make mistakes. You can use the shell's **–x** option to help debug a script. This option causes the shell to display each command before it runs the command. Tracing a script's execution in this way can give you information about where a problem lies.

You can run **lnks** as in the previous example and cause the shell to display each command before it is executed. Either set the **–x** option for the current shell (**set –x**) so that all scripts display commands as they are run or use the **–x** option to affect only the shell that is running the script called by the command line.

```
$ bash -x lnks letter /home
+ '[' 2 -eq 0 -o 2 -gt 2 ']'
+ '[' -d letter ']'
+ file=letter
+ '[' 2 -eq 1 ']'
+ '[' -d /home ']'
+ directory=/home
+ '[' '!' -f letter ']'
...
```

PS4 Each command that the script executes is preceded by the value of the **PS4** variable—a plus sign (**+**) by default, so you can distinguish debugging output from script-produced output. You must export **PS4** if you set it in the shell that calls the script. The next command sets **PS4** to **>>>>** followed by a SPACE and exports it:

```
$ export PS4='>>>> '
```

You can also set the **–x** option of the shell running the script by putting the following set command at the top of the script:

```
set -x
```

Put **set –x** anywhere in the script you want to turn debugging on. Turn the debugging option off with a plus sign.

```
set +x
```

The **set –o xtrace** and **set +o xtrace** commands do the same things as **set –x** and **set +x**, respectively.

for...in

The **for...in** control structure has the following syntax:

for ***loop-index*** *in* ***argument-list***
do
    commands
done

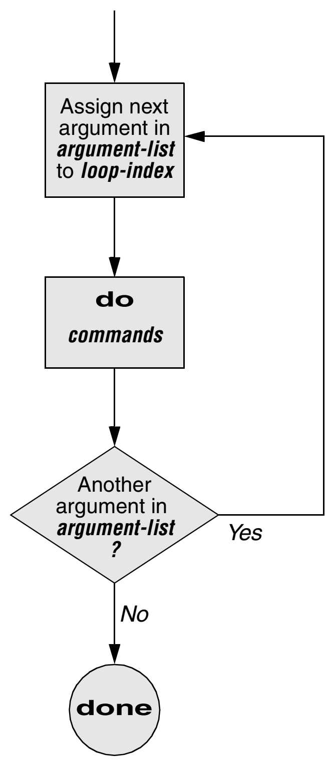

Figure 11-4 A **for...in** flowchart

The **for...in** structure (Figure 11-4, previous page) assigns the value of the first argument in the ***argument-list*** to the ***loop-index*** and executes the ***commands*** between the **do** and **done** statements. The **do** and **done** statements mark the beginning and end of the **for** loop.

After it passes control to the **done** statement, the structure assigns the value of the second argument in the ***argument-list*** to the ***loop-index*** and repeats the ***commands***. The structure repeats the ***commands*** between the **do** and **done** statements one time for each argument in the ***argument-list***. When the structure exhausts the ***argument-list***, it passes control to the statement following **done**.

The following **for...in** structure assigns **apples** to the user-created variable **fruit** and then displays the value of **fruit**, which is **apples**. Next the structure assigns **oranges** to **fruit** and repeats the process. When it exhausts the argument list, the structure transfers control to the statement following **done**, which displays a message.

```
$ cat fruit
for fruit in apples oranges pears bananas
do
    echo "$fruit"
done
echo "Task complete."

$ fruit
apples
oranges
pears
bananas
Task complete.
```

The next script lists the names of the directory files in the working directory by looping over all the files, using test to determine which files are directories:

```
$ cat dirfiles
for i in *
do
    if [ -d "$i" ]
        then
            echo "$i"
    fi
done
```

The ambiguous file reference character * matches the names of all files (except hidden files) in the working directory. Prior to executing the **for** loop, the shell expands the * and uses the resulting list to assign successive values to the index variable **i**.