SCons User Guide 0.96

Steven Knight

SCons User Guide 0.96
by Steven Knight

Revision 0.96.D001 (2004/08/18 09:26:41) Edition
Published 2004
Copyright © 2004 by Steven Knight

SCons User's Guide Copyright (c) 2004 Steven Knight

Table of Contents

Preface ..... **i**

SCons Principles i
A Caveat About This Guide's Completeness i
Acknowledgements ii
Contact ii

1. Building and Installing SCons **1**

Installing Python 1
Installing SCons From Pre-Built Packages 1
Installing SCons on Red Hat (and Other RPM-based) Linux Systems 1
Installing SCons on Debian Linux Systems 2
Installing SCons on Windows Systems 2
Building and Installing SCons on Any System 2
Building and Installing SCons Without Administrative Privileges 2
Building and Installing Multiple Versions of SCons Side-by-Side 3

2. Simple Builds **5**

Building Simple C / C++ Programs 5
Building Object Files 6
Simple Java Builds 6
Cleaning Up After a Build 6
The SConstruct File 7
SConstruct Files Are Python Scripts 7
SCons Functions Are Order-Independent 8
Making the SCons Output Less Verbose 8

3. Less Simple Things to Do With Builds **11**

Specifying the Name of the Target (Output) File 11
Compiling Multiple Source Files 11
Specifying Single Files Vs. Lists of Files 12
Making Lists of Files Easier to Read 13
Keyword Arguments 13
Compiling Multiple Programs 14
Sharing Source Files Between Multiple Programs 14

4. Building and Linking with Libraries **17**

Building Libraries 17
Building Static Libraries Explicitly: the StaticLibrary Builder 17
Building Shared (DLL) Libraries: the SharedLibrary Builder 17
Linking with Libraries 18
Finding Libraries: the LIBPATH Construction Variable 19

5. Node Objects **21**

Builder Methods Return Lists of Target Nodes 21
Explicitly Creating File and Directory Nodes 21
Printing Node File Names 22
Using a Node's File Name as a String 23

6. Dependencies **25**

Deciding When a Source File Has Changed: the SourceSignatures Function 25
MD5 Source File Signatures 25
Source File Time Stamps 26
Deciding When a Target File Has Changed: the TargetSignatures Function 26
Build Signatures 26
File Contents 27
Implicit Dependencies: The CPPPATH Construction Variable 27
Caching Implicit Dependencies 29
The --implicit-deps-changed Option 29
The --implicit-deps-unchanged Option 29
Ignoring Dependencies: the Ignore Method 30

Explicit Dependencies: the `Depends` Method 30
7. Construction Environments 33
Multiple `Construction Environments` 33
Copying `Construction Environments` 34
Fetching Values From a `Construction Environment` 35
Expanding Values From a `Construction Environment` 36
Modifying a `Construction Environment` 37
Replacing Values in a `Construction Environment` 37
Appending to the End of Values in a `Construction Environment` 38
Appending to the Beginning of Values in a `Construction Environment` 38
8. Controlling the External Environment Used to Execute Build Commands 41
Propagating `PATH` From the External Environment 41
9. Controlling a Build From the Command Line 43
Not Having to Specify Command-Line Options Each Time: the `SCONSFLAGS` Environment Variable 43
Getting at Command-Line Targets 43
Controlling the Default Targets 44
Getting at the List of Default Targets 45
Getting at the List of Build Targets, Regardless of Origin 46
Command-Line `variable=value` Build Options 47
Controlling Command-Line Build Options 48
Providing Help for Command-Line Build Options 49
Reading Build Options From a File 49
Canned Build Options 50
True/False Values: the `BoolOption` Build Option 50
Single Value From a List: the `EnumOption` Build Option 51
Multiple Values From a List: the `ListOption` Build Option 53
Path Names: the `PathOption` Build Option 53
Enabled/Disabled Path Names: the `PackageOption` Build Option 54
Adding Multiple Command-Line Build Options at Once 54
10. Providing Build Help: the `Help` Function 57
11. Installing Files in Other Directories: the `Install` Builder 59
Installing Multiple Files in a Directory 59
Installing a File Under a Different Name 60
Installing Multiple Files Under Different Names 60
12. Preventing Removal of Targets: the `Precious` Function 63
13. Hierarchical Builds 65
`SConscript` Files 65
Path Names Are Relative to the `SConscript` Directory 65
Top-Level Path Names in Subsidiary `SConscript` Files 66
Absolute Path Names 66
Sharing Environments (and Other Variables) Between `SConscript` Files 67
Exporting Variables 67
Importing Variables 68
Returning Values From an `SConscript` File 68
14. Separating Source and Build Directories 71
Specifying a Build Directory as Part of an `SConscript` Call 71
Why `SCons` Duplicates Source Files in a Build Directory 71
Telling `SCons` to Not Duplicate Source Files in the Build Directory 72
The `BuildDir` Function 72
Using `BuildDir` With an `SConscript` File 73

15. Variant Builds **75**
16. Writing Your Own Builders **77**
Writing Builders That Execute External Commands 77
Attaching a Builder to a `Construction Environment` 77
Letting `SCons` Handle The File Suffixes 78
Builders That Execute Python Functions 78
Builders That Create Actions Using a `Generator` 79
Builders That Modify the Target or Source Lists Using an `Emitter` 80
17. Not Writing a Builder: the `Command` Builder **83**
18. Writing Scanners **85**
A Simple Scanner Example 85
19. Building From Code Repositories **87**
The `Repository` Method 87
Finding source files in repositories 87
Finding the `SConstruct` file in repositories 88
Finding derived files in repositories 88
Guaranteeing local copies of files 88
20. Multi-Platform Configuration (`Autoconf` Functionality) **91**
`Configure Contexts` 91
Checking for the Existence of Header Files 91
Checking for the Availability of a Function 91
Checking for the Availability of a Library 92
Checking for the Availability of a `typedef` 92
Adding Your Own Custom Checks 93
21. Caching Built Files **95**
Specifying the Shared Cache Directory 95
Keeping Build Output Consistent 95
Not Retrieving Files From a Shared Cache 96
Populating a Shared Cache With Already-Built Files 96
22. Alias Targets **99**
23. Java Builds **101**
Building Java Class Files: the `Java` Builder 101
How `SCons` Handles Java Dependencies 101
Building Java Archive (`.jar`) Files: the `Jar` Builder 102
Building C Header and Stub Files: the `JavaH` Builder 102
Building RMI Stub and Skeleton Class Files: the `RMIC` Builder 103
24. Troubleshooting **105**
Why is That Target Being Rebuilt? the `--debug=explain` Option 105
A. Handling Common Tasks **107**

Preface

Thank you for taking the time to read about SCons. SCons is a next-generation software construction tool, or make tool--that is, a software utility for building software (or other files) and keeping built software up-to-date whenever the underlying input files change.

The most distinctive thing about SCons is that its configuration files are actually *scripts*, written in the Python programming language. This is in contrast to most alternative build tools, which typically invent a new language to configure the build. SCons still has a learning curve, of course, because you have to know what functions to call to set up your build properly, but the underlying syntax used should be familiar to anyone who has ever looked at a Python script.

Paradoxically, using Python as the configuration file format makes SCons *easier* for non-programmers to learn than the cryptic languages of other build tools, which are usually invented by programmers for other programmers. This is in no small part due to the consistency and readability that are built in to Python. It just so happens that making a real, live scripting language the basis for the configuration files makes it a snap for more accomplished programmers to do more complicated things with builds, as necessary.

SCons Principles

There are a few overriding principles we try to live up to in designing and implementing SCons:

Correctness

First and foremost, by default, SCons guarantees a correct build even if it means sacrificing performance a little. We strive to guarantee the build is correct regardless of how the software being built is structured, how it may have been written, or how unusual the tools are that build it.

Performance

Given that the build is correct, we try to make SCons build software as quickly as possible. In particular, wherever we may have needed to slow down the default SCons behavior to guarantee a correct build, we also try to make it easy to speed up SCons through optimization options that let you trade off guaranteed correctness in all end cases for a speedier build in the usual cases.

Convenience

SCons tries to do as much for you out of the box as reasonable, including detecting the right tools on your system and using them correctly to build the software.

In a nutshell, we try hard to make SCons just "do the right thing" and build software correctly, with a minimum of hassles.

A Caveat About This Guide's Completeness

One word of warning as you read through this Guide: Like too much Open Source software out there, the SCons documentation lags the available features. In other words, there's a lot that SCons can do that isn't yet covered in this User's Guide. (Come to think of it, that also describes a lot of proprietary software, doesn't it?)

Although this User's Guide isn't as complete as we'd like it to be, our development process does emphasize making sure that the SCons man page is kept up-to-date with new features. So if you're trying to figure out how to do something that SCons supports but can't find enough (or any) information here, it would be worth your

while to look at the man page to see if the information is covered there. And if you do, maybe you'd even consider contributing a section to the User's Guide so the next person looking for that information won't have to go through the same thing...?

Acknowledgements

SCons would not exist without a lot of help from a lot of people, many of whom may not even be aware that they helped or served as inspiration. So in no particular order, and at the risk of leaving out someone:

First and foremost, SCons owes a tremendous debt to Bob Sidebotham, the original author of the classic Perl-based Cons tool which Bob first released to the world back around 1996. Bob's work on Cons classic provided the underlying architecture and model of specifying a build configuration using a real scripting language. My real-world experience working on Cons informed many of the design decisions in SCons, including the improved parallel build support, making Builder objects easily definable by users, and separating the build engine from the wrapping interface.

Greg Wilson was instrumental in getting SCons started as a real project when he initiated the Software Carpentry design competition in February 2000. Without that nudge, marrying the advantages of the Cons classic architecture with the readability of Python might have just stayed no more than a nice idea.

The entire SCons team have been absolutely wonderful to work with, and SCons would be nowhere near as useful a tool without the energy, enthusiasm and time people have contributed over the past few years. The "core team" of Chad Austin, Anthony Roach, Charles Crain, Steve Leblanc, Gary Oberbrunner, Greg Spencer and Christoph Wiedemann have been great about reviewing my (and other) changes and catching problems before they get in the code base. Of particular technical note: Anthony's outstanding and innovative work on the tasking engine has given SCons a vastly superior parallel build model; Charles has been the master of the crucial Node infrastructure; Christoph's work on the Configure infrastructure has added crucial Autoconf-like functionality; and Greg has provided excellent support for Microsoft Visual Studio.

Special thanks to David Snopek for contributing his underlying "Autoscons" code that formed the basis of Christoph's work with the Configure functionality. David was extremely generous in making this code available to SCons, given that he initially released it under the GPL and SCons is released under a less-restrictive MIT-style license.

Thanks to Peter Miller for his splendid change management system, Aegis, which has provided the SCons project with a robust development methodology from day one, and which showed me how you could integrate incremental regression tests into a practical development cycle (years before eXtreme Programming arrived on the scene).

And last, thanks to Guido van Rossum for his elegant scripting language, which is the basis not only for the SCons implementation, but for the interface itself.

Contact

The best way to contact people involved with SCons, including the author, is through the SCons mailing lists.

If you want to ask general questions about how to use SCons send email to users@scons.tigris.org.

If you want to contact the SCons development community directly, send email to dev@scons.tigris.org.

If you want to receive announcements about `SCons`, join the low-volume `announce@scons.tigris.org` mailing list.

Chapter 1. Building and Installing SCons

This chapter will take you through the basic steps of installing SCons on your system, and building SCons if you don't have a pre-built package available (or simply prefer the flexibility of building it yourself). Before that, however, this chapter will also describe the basic steps involved in installing Python on your system, in case that is necessary. Fortunately, both SCons and Python are very easy to install on almost any system, and Python already comes installed on many systems.

Installing Python

Because SCons is written in Python, you must obviously have Python installed on your system to use SCons Before you try to install Python, you should check to see if Python is already available on your system by typing **python** at your system's command-line prompt. You should see something like the following on a UNIX or Linux system that has Python installed:

```
$ python
Python 2.2.2 (#1, Feb 24 2003, 19:13:11)
[GCC 3.2.2 20030222 (Red Hat Linux 3.2.2-4)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> ^D
```

And on a Windows system with Python installed:

```
C:\>python
Python 2.2.2 (#34, Apr 9 2002, 19:34:33) [MSC 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> ^Z
```

The >>> is the input prompt for the Python interpreter. The **^D** and **^Z** represent the CTRL-D and CTRL-Z characters that you will need to type to get out of the interpreter before proceeding to installing SCons.

If Python is not installed on your system, you will see an error message stating something like "command not found" (on UNIX or Linux) or "'python' is not recognized as an internal or external command, operable progam or batch file" (on Windows). In that case, you need to install Python before you can install SCons.

The standard location for information about downloading and installing Python is http://www.python.org/download/. See that page for information about how to download and install Python on your system.

Installing SCons From Pre-Built Packages

SCons comes pre-packaged for installation on a number of systems, including Linux and Windows systems. You do not need to read this entire section, you should only need to read the section appropriate to the type of system you're running on.

Installing SCons on Red Hat (and Other RPM-based) Linux Systems

SCons comes in RPM (Red Hat Package Manager) format, pre-built and ready to install on Red Hat Linux, or any other Linux distribution that uses RPM. Your distribution may already have an SCons RPM built specifically for it; many do, including SuSe, Mandrake and Fedora. You can check for the availability of an SCons RPM on your distribution's download servers, or by consulting an RPM search site like http://www.rpmfind.net/ or http://rpm.pbone.net/.

If your Linux distribution does not already have a specific SCons RPM file, you can download and install from the generic RPM provided by the SCons project. This will install the SCons script(s) in /usr/bin, and the SCons library modules in /usr/lib/scons.

To install from the command line, simply download the appropriate .rpm file, and then run:

```
# rpm -Uvh scons-0.96-1.noarch.rpm
```

Or, you can use a graphical RPM package manager like gnorpm. See your package manager application's documention for specific instructions about how to use it to install a downloaded RPM.

Installing SCons on Debian Linux Systems

Debian Linux systems use a different package management format that also makes it very easy to install SCons.

If your system is connected to the Internet, you can install the latest official Debian package by running:

```
# apt-get install scons
```

Installing SCons on Windows Systems

SCons provides a Windows installer that makes installation extremely easy. Download the scons-0.95.win32.exe file from the SCons download page at http://www.scons.org/download.html. Then all you need to do is execute the file (usually by clicking on its icon in Windows Explorer). These will take you through a small sequence of windows that will install SCons on your system.

Building and Installing SCons on Any System

If a pre-built SCons package is not available for your system, then you can still easily build and install SCons using the native Python distutils package.

The first step is to download either the scons-0.96.tar.gz or scons-0.96.zip, which are available from the SCons download page at http://www.scons.org/download.html.

Unpack the archive you downloaded, using a utility like tar on Linux or UNIX, or WinZip on Windows. This will create a directory called scons-0.96, usually in your local directory. Then change your working directory to that directory and install SCons by executing the following commands:

```
# cd scons-0.96
# python setup.py install
```

This will build SCons, install the scons script in the default system scripts directory (/usr/local/bin or C:\Python2.2\Scripts), and will install the SCons build engine in an appropriate stand-alone library directory (/usr/local/lib/scons or C:\Python2.2\scons). Because these are system directories, you may need root (on Linux or UNIX) or Administrator (on Windows) privileges to install SCons like this.

Building and Installing SCons Without Administrative Privileges

If you don't have the right privileges to install SCons in a system location, you can install it in a location of your choosing by specifying the --prefix= option:

```
# python setup.py install --prefix=$HOME
```

This would install SCons in appropriate locations relative to the user's $HOME directory, the scons script in $HOME/bin and the build engine in $HOME/lib/scons. You may, of course, specify any other location you prefer.

Building and Installing Multiple Versions of SCons Side-by-Side

The SCons setup.py script has some extensions that support easy installation of multiple versions of SCons in side-by-side locations. This makes it easier to download and experiment with different versions of SCons before moving your official build process to a new version, for example.

To install SCons in a version-specific location, add the --version-lib option when you call setup.py:

```
# python setup.py install --version-lib
```

This will install the SCons build engine in the /usr/lib/scons-0.96 or C:\Python2.2\scons-0.96 directory, for example. You can also specify --prefix=, in which case setup.py will install the build engine in a version-specific directory relative to the specified prefix.

If you use the --version-lib option the first time you install SCons, you do not need to specify it each time you install a new version. The SCons setup.py script will detect the version-specific directory name(s) and assume you want to install all versions in version-specific directories. You can override that assumption in the future by explicitly specifying the --standalone-lib option.

Notes

1. http://www.python.org/download/
2. http://www.rpmfind.net/
3. http://rpm.pbone.net/
4. http://www.scons.org/download.html
5. http://www.scons.org/download.html

Chapter 2. Simple Builds

In this chapter, you will see several examples of very simple build configurations using SCons, which will demonstrate how easy it is to use SCons to build programs from several different programming languages on different types of systems.

Building Simple C / C++ Programs

Here's the famous "Hello, World!" program in C:

```
int
main()
{
    printf("Hello, world!\n");
}
```

And here's how to build it using SCons. Enter the following into a file named SConstruct:

```
Program('hello.c')
```

This minimal configuration file gives SCons two pieces of information: what you want to build (an executable program), and the input file from which you want it built (the hello.c file). Program is a builder method, a Python call that tells SCons that you want to build an executable program.

That's it. Now run the scons command to build the program. On a POSIX-compliant system like Linux or UNIX, you'll see something like:

```
% scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o hello.o hello.c
cc -o hello hello.o
scons: done building targets.
```

On a Windows system with the Microsoft Visual C++ compiler, you'll see something like:

```
C:\>scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cl /nologo /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj
scons: done building targets.
```

First, notice that you only need to specify the name of the source file, and that SCons correctly deduces the names of the object and executable files to be built from the base of the source file name.

Second, notice that the same input SConstruct file, without any changes, generates the correct output file names on both systems: hello.o and hello on POSIX systems, hello.obj and hello.exe on Windows systems. This is a simple example of how SCons makes it extremely easy to write portable software builds.

(Note that we won't provide duplicate side-by-side POSIX and Windows output for all of the examples in this guide; just keep in mind that, unless otherwise specified, any of the examples should work equally well on both types of systems.)

Building Object Files

The `Program` builder method is only one of many builder methods that `SCons` provides to build different types of files. Another is the `Object` builder method, which tells `SCons` to build an object file from the specified source file:

```
Object('hello.c')
```

Now when you run the `scons` command to build the program, it will build just the `hello.o` object file on a POSIX system:

```
% scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o hello.o hello.c
scons: done building targets.
```

And just the `hello.obj` object file on a Windows system (with the Microsoft Visual C++ compiler):

```
C:\>scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cl /nologo /c hello.c /Fohello.obj
scons: done building targets.
```

Simple Java Builds

`SCons` also makes building with Java extremely easy. Unlike the `Program` and `Object` builder methods, however, the `Java` builder method requires that you specify the name of a destination directory in which you want the class files placed, followed by the source directory in which the `.java` files live:

```
Java('classes', 'src')
```

If the `src` directory contains a single `hello.java` file, then the output from running the `scons` command would look something like this (on a POSIX system):

```
% scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
javac -d classes -sourcepath src src/hello.java
scons: done building targets.
```

We'll cover Java builds in more detail, including building Java archive (`.jar`) and other types of file, in Chapter 23.

Cleaning Up After a Build

When using SCons, it is unnecessary to add special commands or target names to clean up after a build. Instead, you simply use the -c or --clean option when you invoke SCons, and SCons removes the appropriate built files. So if we build our example above and then invoke scons -c afterwards, the output on POSIX looks like:

```
% scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o hello.o hello.c
cc -o hello hello.o
scons: done building targets.
% scons -c
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Cleaning targets ...
Removed hello.o
Removed hello
scons: done cleaning targets.
```

And the output on Windows looks like:

```
C:\>scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cl /nologo /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj
scons: done building targets.
C:\>scons -c
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Cleaning targets ...
Removed hello.obj
Removed hello.exe
scons: done cleaning targets.
```

Notice that SCons changes its output to tell you that it is Cleaning targets ... and done cleaning targets.

The SConstruct File

If you're used to build systems like Make you've already figured out that the SConstruct file is the SCons equivalent of a Makefile. That is, the SConstruct file is the input file that SCons reads to control the build.

SConstruct Files Are Python Scripts

There is, however, an important difference between an SConstruct file and a Makefile: the SConstruct file is actually a Python script. If you're not already familiar with Python, don't worry. This User's Guide will introduce you step-by-step to the relatively small amount of Python you'll need to know to be able to use SCons effectively. And Python is very easy to learn.

One aspect of using Python as the scripting language is that you can put comments in your SConstruct file using Python's commenting convention; that is, everything between a '#' and the end of the line will be ignored:

```
# Arrange to build the "hello" program.
Program('hello.c')    # "hello.c" is the source file.
```

You'll see throughout the remainder of this Guide that being able to use the power of a real scripting language can greatly simplify the solutions to complex requirements of real-world builds.

SCons Functions Are Order-Independent

One important way in which the SConstruct file is not exactly like a normal Python script, and is more like a Makefile, is that the order in which the SCons functions are called in the SConstruct file does *not* affect the order in which SCons actually builds the programs and object files you want it to build.[1] In other words, when you call the Program builder (or any other builder method), you're not telling SCons to build the program at the instant the builder method is called. Instead, you're telling SCons to build the program that you want, for example, a program built from a file named hello.c, and it's up to SCons to build that program (and any other files) whenever it's necessary. (We'll learn more about how SCons decides when building or rebuilding a file is necessary in Chapter 6, below.)

SCons reflects this distinction between *calling a builder method like* Program> and *actually building the program* by printing the status messages that indicate when it's "just reading" the SConstruct file, and when it's actually building the target files. This is to make it clear when SCons is executing the Python statements that make up the SConstruct file, and when SCons is actually executing the commands or other actions to build the necessary files.

Let's clarify this with an example. Python has a print statement that prints a string of characters to the screen. If we put print statements around our calls to the Program builder method:

```
print "Calling Program('hello.c')"
Program('hello.c')
print "Calling Program('goodbye.c')"
Program('goodbye.c')
print "Finished calling Program()"
```

Then when we execute SCons, we see the output from the print statements in between the messages about reading the SConscript files, indicating that that is when the Python statements are being executed:

```
% scons
scons: Reading SConscript files ...
Calling Program('hello.c')
Calling Program('goodbye.c')
Finished calling Program()
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
cc -c -o hello.o hello.c
cc -o hello hello.o
scons: done building targets.
```

Notice also that SCons built the goodbye program first, even though the "reading SConscript" output shows that we called Program('hello.c') first in the SConstruct file.

Making the SCons Output Less Verbose

You've already seen how SCons prints some messages about what it's doing, surrounding the actual commands used to build the software:

```
C:\>scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
cl /nologo /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj
scons: done building targets.
```

These messages emphasize the order in which SCons does its work: all of the configuration files (generically referred to as SConscript files) are read and executed first, and only then are the target files built. Among other benefits, these messages help to distinguish between errors that occur while the configuration files are read, and errors that occur while targets are being built.

One drawback, of course, is that these messages clutter the output. Fortunately, they're easily disabled by using the -Q option when invoking SCons:

```
C:\>scons -Q
cl /nologo /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj
```

Because we want this User's Guide to focus on what SCons is actually doing, we're going use the -Q option to remove these messages from the output of all the remaining examples in this Guide.

Notes

1. In programming parlance, the SConstruct file is *declarative*, meaning you tell SCons what you want done and let it figure out the order in which to do it, rather than strictly *imperative*, where you specify explicitly the order in which to do things.

Chapter 3. Less Simple Things to Do With Builds

In this chapter, you will see several examples of very simple build configurations using SCons, which will demonstrate how easy it is to use SCons to build programs from several different programming languages on different types of systems.

Specifying the Name of the Target (Output) File

You've seen that when you call the Program builder method, it builds the resulting program with the same base name as the source file. That is, the following call to build an executable program from the hello.c source file will build an executable program named hello on POSIX systems, and an executable program named hello.exe on Windows systems:

```
Program('hello.c')
```

If you want to build a program with a different name than the base of the source file name, you simply put the target file name to the left of the source file name:

```
Program('new_hello', 'hello.c')
```

(SCons requires the target file name first, followed by the source file name, so that the order mimics that of an assignment statement in most programming languages, including Python: "program = source files".)

Now SCons will build an executable program named new_hello when run on a POSIX system:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o new_hello hello.o
```

And SCons will build an executable program named new_hello.exe when run on a Windows system:

```
C:\>scons -Q
cl /nologo /c hello.c /Fohello.obj
link /nologo /OUT:new_hello.exe hello.obj
```

Compiling Multiple Source Files

You've just seen how to configure SCons to compile a program from a single source file. It's more common, of course, that you'll need to build a program from many input source files, not just one. To do this, you need to put the source files in a Python list (enclosed in square brackets), like so:

```
Program(['main.c', 'file1.c', 'file2.c'])
```

A build of the above example would look like:

```
% scons -Q
cc -c -o file1.o file1.c
cc -c -o file2.o file2.c
cc -c -o main.o main.c
cc -o main main.o file1.o file2.o
```

Notice that SCons deduces the output program name from the first source file specified in the list--that is, because the first source file was prog.c, SCons will name the resulting program prog (or prog.exe on a Windows system). If you want to specify a different program name, then (as we've seen in the previous section) you slide the list of source files over to the right to make room for the output program file name. (SCons puts the output file name to the left of the source file names so that the order mimics that of an assignment statement: "program = source files".) This makes our example:

```
Program('program', ['main.c', 'file1.c', 'file2.c'])
```

On Linux, a build of this example would look like:

```
% scons -Q
cc -c -o file1.o file1.c
cc -c -o file2.o file2.c
cc -c -o main.o main.c
cc -o program main.o file1.o file2.o
```

Or on Windows:

```
C:\>scons -Q
cl /nologo /c file1.c /Fofile1.obj
cl /nologo /c file2.c /Fofile2.obj
cl /nologo /c main.c /Fomain.obj
link /nologo /OUT:program.exe main.obj file1.obj file2.obj
```

Specifying Single Files Vs. Lists of Files

We've now shown you two ways to specify the source for a program, one with a list of files:

```
Program('hello', ['file1.c', 'file2'])
```

And one with a single file:

```
Program('hello', 'hello.c')
```

You could actually put a single file name in a list, too, which you might prefer just for the sake of consistency:

```
Program('hello', ['hello.c'])
```

SCons functions will accept a single file name in either form. In fact, internally, SCons treats all input as lists of files, but allows you to omit the square brackets to cut down a little on the typing when there's only a single file name.

Important: Although SCons functions are forgiving about whether or not you use a string vs. a list for a single file name, Python itself is more strict about treating lists and strings differently. So where SCons allows either a string or list:

```
# The following two calls both work correctly:
Program('program1', 'program1.c')
Program('program2', ['program2.c'])
```

Trying to do "Python things" that mix strings and lists will cause errors or lead to incorrect results:

```
common_sources = ['file1.c', 'file2.c']

# THE FOLLOWING IS INCORRECT AND GENERATES A PYTHON ERROR
# BECAUSE IT TRIES TO ADD A STRING TO A LIST:
Program('program1', common_sources + 'program1.c')

# The following works correctly, because it's adding two
# lists together to make another list.
Program('program2', common_sources + ['program2.c'])
```

Making Lists of Files Easier to Read

One drawback to the use of a Python list for source files is that each file name must be enclosed in quotes (either single quotes or double quotes). This can get cumbersome and difficult to read when the list of file names is long. Fortunately, `SCons` and Python provide a number of ways to make sure that the `SConstruct` file stays easy to read.

To make long lists of file names easier to deal with, `SCons` provides a `Split` function that takes a quoted list of file names, with the names separated by spaces or other white-space characters, and turns it into a list of separate file names. Using the `Split` function turns the previous example into:

```
Program('program', Split('main.c file1.c file2.c'))
```

(If you're already familiar with Python, you'll have realized that this is similar to the `split()` method in the Python standard `string` module. Unlike the `string.split()` method, however, the `Split` function does not require a string as input and will wrap up a single non-string object in a list, or return its argument untouched if it's already a list. This comes in handy as a way to make sure arbitrary values can be passed to `SCons` functions without having to check the type of the variable by hand.)

Putting the call to the `Split` function inside the `Program` call can also be a little unwieldy. A more readable alternative is to assign the output from the `Split` call to a variable name, and then use the variable when calling the `Program` function:

```
list = Split('main.c file1.c file2.c')
Program('program', list)
```

Lastly, the `Split` function doesn't care how much white space separates the file names in the quoted string. This allows you to create lists of file names that span multiple lines, which often makes for easier editing:

```
list = Split("""main.c
                file1.c
                file2.c""")
Program('program', list)
```

(Note in this example that we used the Python "triple-quote" syntax, which allows a string to contain multiple lines. The three quotes can be either single or double quotes.)

Keyword Arguments

SCons also allows you to identify the output file and input source files using Python keyword arguments. The output file is known as the *target*, and the source file(s) are known (logically enough) as the *source*. The Python syntax for this is:

```
list = Split('main.c file1.c file2.c')
Program(target = 'program', source = list)
```

Because the keywords explicitly identify what each argument is, you can actually reverse the order if you prefer:

```
list = Split('main.c file1.c file2.c')
Program(source = list, target = 'program')
```

Whether or not you choose to use keyword arguments to identify the target and source files, and the order in which you specify them when using keywords, are purely personal choices; SCons functions the same regardless.

Compiling Multiple Programs

In order to compile multiple programs within the same SConstruct file, simply call the Program method multiple times, once for each program you need to build:

```
Program('foo.c')
Program('bar', ['bar1.c', 'bar2.c'])
```

SCons would then build the programs as follows:

```
% scons -Q
cc -c -o bar1.o bar1.c
cc -c -o bar2.o bar2.c
cc -o bar bar1.o bar2.o
cc -c -o foo.o foo.c
cc -o foo foo.o
```

Notice that SCons does not necessarily build the programs in the same order in which you specify them in the SConstruct file. SCons does, however, recognize that the individual object files must be built before the resulting program can be built. We'll discuss this in greater detail in the "Dependencies" section, below.

Sharing Source Files Between Multiple Programs

It's common to re-use code by sharing source files between multiple programs. One way to do this is to create a library from the common source files, which can then be linked into resulting programs. (Creating libraries is discussed in Chapter 4, below.)

A more straightforward, but perhaps less convenient, way to share source files between multiple programs is simply to include the common files in the lists of source files for each program:

```
Program(Split('foo.c common1.c common2.c'))
Program('bar', Split('bar1.c bar2.c common1.c common2.c'))
```

SCons recognizes that the object files for the common1.c and common2.c source files each only need to be built once, even though the resulting object files are each linked in to both of the resulting executable programs:

```
% scons -Q
cc -c -o bar1.o bar1.c
cc -c -o bar2.o bar2.c
cc -c -o common1.o common1.c
cc -c -o common2.o common2.c
cc -o bar bar1.o bar2.o common1.o common2.o
cc -c -o foo.o foo.c
cc -o foo foo.o common1.o common2.o
```

If two or more programs share a lot of common source files, repeating the common files in the list for each program can be a maintenance problem when you need to change the list of common files. You can simplify this by creating a separate Python list to hold the common file names, and concatenating it with other lists using the Python + operator:

```
common = ['common1.c', 'common2.c']
foo_files = ['foo.c'] + common
bar_files = ['bar1.c', 'bar2.c'] + common
Program('foo', foo_files)
Program('bar', bar_files)
```

This is functionally equivalent to the previous example.

Chapter 4. Building and Linking with Libraries

It's often useful to organize large software projects by collecting parts of the software into one or more libraries. SCons makes it easy to create libraries and to use them in the programs.

Building Libraries

You build your own libraries by specifying Library instead of Program:

```
Library('foo', ['f1.c', 'f2.c', 'f3.c'])
```

SCons uses the appropriate library prefix and suffix for your system. So on POSIX or Linux systems, the above example would build as follows (although ranlib may not be called on all systems):

```
% scons -Q
cc -c -o f1.o f1.c
cc -c -o f2.o f2.c
cc -c -o f3.o f3.c
ar r libfoo.a f1.o f2.o f3.o
ranlib libfoo.a
```

On a Windows system, a build of the above example would look like:

```
C:\>scons -Q
cl /nologo /c f1.c /Fof1.obj
cl /nologo /c f2.c /Fof2.obj
cl /nologo /c f3.c /Fof3.obj
lib /nologo /OUT:foo.lib f1.obj f2.obj f3.obj
```

The rules for the target name of the library are similar to those for programs: if you don't explicitly specify a target library name, SCons will deduce one from the name of the first source file specified, and SCons will add an appropriate file prefix and suffix if you leave them off.

Building Static Libraries Explicitly: the StaticLibrary Builder

The Library function builds a traditional static library. If you want to be explicit about the type of library being built, you can use the synonym StaticLibrary function instead of Library:

```
StaticLibrary('foo', ['f1.c', 'f2.c', 'f3.c'])
```

There is no functional difference between the StaticLibrary and Library functions.

Building Shared (DLL) Libraries: the SharedLibrary Builder

If you want to build a shared library (on POSIX systems) or a DLL file (on Windows systems), you use the SharedLibrary function:

```
SharedLibrary('foo', ['f1.c', 'f2.c', 'f3.c'])
```

The output on POSIX:

```
% scons -Q
cc -c -o f1.os f1.c
cc -c -o f2.os f2.c
cc -c -o f3.os f3.c
cc -shared -o libfoo.so f1.os f2.os f3.os
```

And the output on Windows:

```
C:\>scons -Q
cl /nologo /c f1.c /Fof1.obj
cl /nologo /c f2.c /Fof2.obj
cl /nologo /c f3.c /Fof3.obj
link /nologo /dll /out:foo.dll /implib:foo.lib f1.obj f2.obj f3.obj
```

Notice again that SCons takes care of building the output file correctly, adding the -shared option for a POSIX compilation, and the /dll option on Windows.

Linking with Libraries

Usually, you build a library because you want to link it with one or more programs. You link libraries with a program by specifying the libraries in the LIBS construction variable, and by specifying the directory in which the library will be found in the LIBPATH construction variable:

```
Library('foo', ['f1.c', 'f2.c', 'f3.c'])
Program('prog.c', LIBS=['foo', 'bar'], LIBPATH='.')
```

Notice, of course, that you don't need to specify a library prefix (like lib) or suffix (like .a or .lib). SCons uses the correct prefix or suffix for the current system.

On a POSIX or Linux system, a build of the above example would look like:

```
% scons -Q
cc -c -o f1.o f1.c
cc -c -o f2.o f2.c
cc -c -o f3.o f3.c
ar r libfoo.a f1.o f2.o f3.o
ranlib libfoo.a
cc -c -o prog.o prog.c
cc -o prog prog.o -L. -lfoo -lbar
```

On a Windows system, a build of the above example would look like:

```
C:\>scons -Q
cl /nologo /c f1.c /Fof1.obj
cl /nologo /c f2.c /Fof2.obj
cl /nologo /c f3.c /Fof3.obj
lib /nologo /OUT:foo.lib f1.obj f2.obj f3.obj
cl /nologo /c prog.c /Foprog.obj
link /nologo /OUT:prog.exe /LIBPATH:. foo.lib bar.lib prog.obj
```

As usual, notice that SCons has taken care of constructing the correct command lines to link with the specified library on each system.

Note also that, if you only have a single library to link with, you can specify the library name in single string, instead of a Python list, so that:

```
Program('prog.c', LIBS='foo', LIBPATH='.')
```

is equivalent to:

```
Program('prog.c', LIBS=['foo'], LIBPATH='.')
```

This is similar to the way that SCons handles either a string or a list to specify a single source file.

Finding Libraries: the LIBPATH Construction Variable

By default, the linker will only look in certain system-defined directories for libraries. SCons knows how to look for libraries in directories that you specify with the LIBPATH construction variable. LIBPATH consists of a list of directory names, like so:

```
Program('prog.c', LIBS = 'm',
                  LIBPATH = ['/usr/lib', '/usr/local/lib'])
```

Using a Python list is preferred because it's portable across systems. Alternatively, you could put all of the directory names in a single string, separated by the system-specific path separator character: a colon on POSIX systems:

```
LIBPATH = '/usr/lib:/usr/local/lib'
```

or a semi-colon on Windows systems:

```
LIBPATH = 'C:\\lib;D:\\lib'
```

(Note that Python requires that the backslash separators in a Windows path name be escaped within strings.)

When the linker is executed, SCons will create appropriate flags so that the linker will look for libraries in the same directories as SCons. So on a POSIX or Linux system, a build of the above example would look like:

```
% scons -Q
cc -c -o prog.o prog.c
cc -o prog prog.o -L/usr/lib -L/usr/local/lib -lm
```

On a Windows system, a build of the above example would look like:

```
C:\>scons -Q
cl /nologo /c prog.c /Foprog.obj
link /nologo /OUT:prog.exe /LIBPATH:\usr\lib /LIBPATH:\usr\local\lib m.lib prog.o
```

Note again that SCons has taken care of the system-specific details of creating the right command-line options.

Chapter 5. Node Objects

Internally, SCons represents all of the files and directories it knows about as Nodes. These internal objects (not object *files*) can be used in a variety of ways to make your SConscript files portable and easy to read.

Builder Methods Return Lists of Target Nodes

All builder methods return a list of Node objects that identify the target file or files that will be built. These returned Nodes can be passed as source files to other builder methods,

For example, suppose that we want to build the two object files that make up a program with different options. This would mean calling the Object builder once for each object file, specifying the desired options:

```
Object('hello.c', CCFLAGS='-DHELLO')
Object('goodbye.c', CCFLAGS='-DGOODBYE')
```

One way to combine these object files into the resulting program would be to call the Program builder with the names of the object files listed as sources:

```
Object('hello.c', CCFLAGS='-DHELLO')
Object('goodbye.c', CCFLAGS='-DGOODBYE')
Program(['hello.o', 'goodbye.o'])
```

The problem with listing the names as strings is that our SConstruct file is no longer portable across operating systems. It won't, for example, work on Windows because the object files there would be named hello.obj and goodbye.obj, not hello.o and goodbye.o.

A better solution is to assign the lists of targets returned by the calls to the Object builder to variables, which we can then concatenate in our call to the Program builder:

```
hello_list = Object('hello.c', CCFLAGS='-DHELLO')
goodbye_list = Object('goodbye.c', CCFLAGS='-DGOODBYE')
Program(hello_list + goodbye_list)
```

This makes our SConstruct file portable again, the build output on Linux looking like:

```
% scons -Q
cc -DGOODBYE -c -o goodbye.o goodbye.c
cc -DHELLO -c -o hello.o hello.c
cc -o hello hello.o goodbye.o
```

And on Windows:

```
C:\>scons -Q
cl -DGOODBYE /c goodbye.c /Fogoodbye.obj
cl -DHELLO /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj goodbye.obj
```

We'll see examples of using the list of nodes returned by builder methods throughout the rest of this guide.

Explicitly Creating File and Directory Nodes

It's worth mentioning here that `SCons` maintains a clear distinction between Nodes that represent files and Nodes that represent directories. `SCons` supports `File` and `Dir` functions that, repectively, return a file or directory Node:

```
hello_c = File('hello.c')
Program(hello_c)

classes = Dir('classes')
Java(classes, 'src')
```

Normally, you don't need to call `File` or `Dir` directly, because calling a builder method automatically treats strings as the names of files or directories, and translates them into the Node objects for you. The `File` and `Dir` functions can come in handy in situations where you need to explicitly instruct `SCons` about the type of Node being passed to a builder or other function, or unambiguously refer to a specific file in a directory tree.

There are also times when you may need to refer to an entry in a file system without knowing in advance whether it's a file or a directory. For those situations, `SCons` also supports an `Entry` function, which returns a Node that can represent either a file or a directory.

```
xyzzy = Entry('xyzzy')
```

The returned `xyzzy` Node will be turned into a file or directory Node the first time it is used by a builder method or other function that requires one vs. the other.

Printing `Node` File Names

One of the most common things you can do with a Node is use it to print the file name that the node represents. For example, the following `SConstruct` file:

```
hello_c = File('hello.c')
Program(hello_c)

classes = Dir('classes')
Java(classes, 'src')

object_list = Object('hello.c')
program_list = Program(object_list)
print "The object file is:", object_list[0]
print "The program file is:", program_list[0]
```

Would print the following file names on a POSIX system:

```
% scons -Q
The object file is: hello.o
The program file is: hello
cc -c -o hello.o hello.c
cc -o hello hello.o
```

And the following file names on a Windows system:

```
C:\>scons -Q
The object file is: hello.obj
The program file is: hello.exe
cl /nologo /c hello.c /Fohello.obj
```

```
link /nologo /OUT:hello.exe hello.obj
```

Using a Node's File Name as a String

Printing a Node's name as described in the previous section works because the string representation of a Node is the name of the file. If you want to do something other than print the name of the file, you can fetch it by using the builtin Python str function. For example, if you want to use the Python os.path.exists to figure out whether a file exists while the SConstruct file is being read and executed, you can fetch the string as follows:

```
import os.path
program_list = Program('hello.c')
program_name = str(program_list[0])
if not os.path.exists(program_name)
    print program_name, "does not exist!"
```

Which executes as follows on a POSIX system:

```
% scons -Q
The object file is: hello.o
The program file is: hello
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Chapter 6. Dependencies

So far we've seen how SCons handles one-time builds. But the real point of a build tool like SCons is to rebuild only the necessary things when source files change--or, put another way, SCons should *not* waste time rebuilding things that have already been built. You can see this at work simply be re-invoking SCons after building our simple hello example:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q
scons: `.' is up to date.
```

The second time it is executed, SCons realizes that the hello program is up-to-date with respect to the current hello.c source file, and avoids rebuilding it. You can see this more clearly by naming the hello program explicitly on the command line:

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q hello
scons: `hello' is up to date.
```

Note that SCons reports "...is up to date" only for target files named explicitly on the command line, to avoid cluttering the output.

Deciding When a Source File Has Changed: the SourceSignatures Function

The other side of avoiding unnecessary rebuilds is the fundamental build tool behavior of *rebuilding* things when a source file changes, so that the built software is up to date. SCons keeps track of this through a signature for each source file, and allows you to configure whether you want to use the source file contents or the modification time (timestamp) as the signature.

MD5 Source File Signatures

By default, SCons keeps track of whether a source file has changed based on the file's contents, not the modification time. This means that you may be surprised by the default SCons behavior if you are used to the Make convention of forcing a rebuild by updating the file's modification time (using the touch command, for example):

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% touch hello.c
% scons -Q hello
scons: `hello' is up to date.
```

Even though the file's modification time has changed, SCons realizes that the contents of the hello.c file have *not* changed, and therefore that the hello program need not be rebuilt. This avoids unnecessary rebuilds when, for example, someone rewrites the contents of a file without making a change. But if the contents of the file really do change, then SCons detects the change and rebuilds the program as required:

```
% scons -Q hello
cc -c -o hello.o hello.c
```

```
cc -o hello hello.o
% edit hello.c
    [CHANGE THE CONTENTS OF hello.c]
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Note that you can, if you wish, specify this default behavior (MD5 signatures) explicitly using the `SourceSignatures` function as follows:

```
Program('hello.c')
SourceSignatures('MD5')
```

Source File Time Stamps

If you prefer, you can configure `SCons` to use the modification time of source files, not the file contents, when deciding if something needs to be rebuilt. To do this, call the `SourceSignatures` function as follows:

```
Program('hello.c')
SourceSignatures('timestamp')
```

This makes `SCons` act like `Make` when a file's modification time is updated (using the `touch` command, for example):

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% touch hello.c
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Deciding When a Target File Has Changed: the `TargetSignatures` Function

As you've just seen, `SCons` uses signatures to decide whether a target file is up to date or must be rebuilt. When a target file depends on another target file, `SCons` allows you to configure separately how the signatures of "intermediate" target files are used when deciding if a dependent target file must be rebuilt.

Build Signatures

Modifying a source file will cause not only its direct target file to be rebuilt, but also the target file(s) that depend on that direct target file. In our example, changing the contents of the `hello.c` file causes the `hello.o` file to be rebuilt, which in turn causes the `hello` program to be rebuilt:

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% edit hello.c
    [CHANGE THE CONTENTS OF hello.c]
% scons -Q hello
```

```
cc -c -o hello.o hello.c
cc -o hello hello.o
```

What's not obvious, though, is that SCons internally handles the signature of the target file(s) (hello.o in the above example) differently from the signature of the source file (hello.c). By default, SCons tracks whether a target file must be rebuilt by using a build signature that consists of the combined signatures of all the files that go into making the target file. This is efficient because the accumulated signatures actually give SCons all of the information it needs to decide if the target file is out of date.

If you wish, you can specify this default behavior (build signatures) explicitly using the TargetSignatures function:

```
Program('hello.c')
TargetSignatures('build')
```

File Contents

Sometimes a source file can be changed in such a way that the contents of the rebuilt target file(s) will be exactly the same as the last time the file was built. If so, then any other target files that depend on such a built-but-not-changed target file actually need not be rebuilt. You can make SCons realize that it does not need to rebuild a dependent target file in this situation using the TargetSignatures function as follows:

```
Program('hello.c')
TargetSignatures('content')
```

So if, for example, a user were to only change a comment in a C file, then the rebuilt hello.o file would be exactly the same as the one previously built (assuming the compiler doesn't put any build-specific information in the object file). SCons would then realize that it would not need to rebuild the hello program as follows:

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% edit hello.c
  [CHANGE A COMMENT IN hello.c]
% scons -Q hello
cc -c -o hello.o hello.c
scons: `hello' is up to date.
```

In essence, SCons has "short-circuited" any dependent builds when it realizes that a target file has been rebuilt to exactly the same file as the last build. So configured, SCons does take some extra processing time to scan the contents of the target (hello.o) file, but this may save time if the rebuild that was avoided would have been very time-consuming and expensive.

Implicit Dependencies: The CPPPATH Construction Variable

Now suppose that our "Hello, World!" program actually has a #include line to include the hello.h file in the compilation:

```
#include <hello.h>
int
```

```
main()
{
    printf("Hello, %s!\n", string);
}
```

And, for completeness, the `hello.h` file looks like this:

```
#define string    "world"
```

In this case, we want `SCons` to recognize that, if the contents of the `hello.h` file change, the `hello` program must be recompiled. To do this, we need to modify the `SConstruct` file like so:

```
Program('hello.c', CPPPATH = '.')
```

The `CPPPATH` value tells `SCons` to look in the current directory (`'.'`) for any files included by C source files (`.c` or `.h` files). With this assignment in the `SConstruct` file:

```
% scons -Q hello
cc -I. -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q hello
scons: `hello' is up to date.
% edit hello.h
    [CHANGE THE CONTENTS OF hello.h]
% scons -Q hello
cc -I. -c -o hello.o hello.c
cc -o hello hello.o
```

First, notice that `SCons` added the `-I.` argument from the `CPPPATH` variable so that the compilation would find the `hello.h` file in the local directory.

Second, realize that `SCons` knows that the `hello` program must be rebuilt because it scans the contents of the `hello.c` file for the `#include` lines that indicate another file is being included in the compilation. `SCons` records these as *implicit dependencies* of the target file, Consequently, when the `hello.h` file changes, `SCons` realizes that the `hello.c` file includes it, and rebuilds the resulting `hello` program that depends on both the `hello.c` and `hello.h` files.

Like the `LIBPATH` variable, the `CPPPATH` variable may be a list of directories, or a string separated by the system-specific path separate character (':' on POSIX/Linux, ';' on Windows). Either way, `SCons` creates the right command-line options so that the following example:

```
Program('hello.c', CPPPATH = ['include', '/home/project/inc'])
```

Will look like this on POSIX or Linux:

```
% scons -Q hello
cc -Iinclude -I/home/project/inc -c -o hello.o hello.c
cc -o hello hello.o
```

And like this on Windows:

```
C:\>scons -Q hello.exe
cl /nologo /Iinclude /I\home\project\inc /c hello.c /Fohello.obj
link /nologo /OUT:hello.exe hello.obj
```

Caching Implicit Dependencies

Scanning each file for `#include` lines does take some extra processing time. When you're doing a full build of a large system, the scanning time is usually a very small percentage of the overall time spent on the build. You're most likely to notice the scanning time, however, when you *rebuild* all or part of a large system: `SCons` will likely take some extra time to "think about" what must be built before it issues the first build command (or decides that everything is up to date and nothing must be rebuilt).

In practice, having `SCons` scan files saves time relative to the amount of potential time lost to tracking down subtle problems introduced by incorrect dependencies. Nevertheless, the "waiting time" while `SCons` scans files can annoy individual developers waiting for their builds to finish. Consequently, `SCons` lets you cache the implicit dependencies that its scanners find, for use by later builds. You can do this by specifying the `--implicit-cache` option on the command line:

```
% scons -Q --implicit-cache hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q hello
scons: `hello' is up to date.
```

If you don't want to specify `--implicit-cache` on the command line each time, you can make it the default behavior for your build by setting the `implicit_cache` option in an `SConscript` file:

```
SetOption('implicit_cache', 1)
```

The `--implicit-deps-changed` Option

When using cached implicit dependencies, sometimes you want to "start fresh" and have `SCons` re-scan the files for which it previously cached the dependencies. For example, if you have recently installed a new version of external code that you use for compilation, the external header files will have changed and the previously-cached implicit dependencies will be out of date. You can update them by running `SCons` with the `--implicit-deps-changed` option:

```
% scons -Q --implicit-deps-changed hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q hello
scons: `hello' is up to date.
```

In this case, `SCons` will re-scan all of the implicit dependencies and cache updated copies of the information.

The `--implicit-deps-unchanged` Option

By default when caching dependencies, `SCons` notices when a file has been modified and re-scans the file for any updated implicit dependency information. Sometimes, however, you may want to force `SCons` to use the cached implicit dependencies, even if the source files changed. This can speed up a build for example, when you have changed your source files but know that you haven't changed any `#include` lines. In this case, you can use the `--implicit-deps-unchanged` option:

```
% scons -Q --implicit-deps-unchanged hello
cc -c -o hello.o hello.c
```

```
cc -o hello hello.o
% scons -Q hello
scons: 'hello' is up to date.
```

In this case, SCons will assume that the cached implicit dependencies are correct and will not bother to re-scan changed files. For typical builds after small, incremental changes to source files, the savings may not be very big, but sometimes every bit of improved performance counts.

Ignoring Dependencies: the Ignore Method

Sometimes it makes sense to not rebuild a program, even if a dependency file changes. In this case, you would tell SCons specifically to ignore a dependency as follows:

```
hello = Program('hello.c')
Ignore(hello, 'hello.h')
```

```
% scons -Q hello
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q hello
scons: 'hello' is up to date.
% edit hello.h
  [CHANGE THE CONTENTS OF hello.h]
% scons -Q hello
scons: 'hello' is up to date.
```

Now, the above example is a little contrived, because it's hard to imagine a real-world situation where you wouldn't to rebuild hello if the hello.h file changed. A more realistic example might be if the hello program is being built in a directory that is shared between multiple systems that have different copies of the stdio.h include file. In that case, SCons would notice the differences between the different systems' copies of stdio.h and would rebuild hello each time you change systems. You could avoid these rebuilds as follows:

```
hello = Program('hello.c')
Ignore(hello, '/usr/include/stdio.h')
```

Explicit Dependencies: the Depends Method

On the other hand, sometimes a file depends on another file that is not detected by an SCons scanner. For this situation, SCons allows you to specific explicitly that one file depends on another file, and must be rebuilt whenever that file changes. This is specified using the Depends method:

```
hello = Program('hello.c')
Depends(hello, 'other_file')
```

```
% scons -Q hello
cc -c hello.c -o hello.o
cc -o hello hello.o
% scons -Q hello
scons: 'hello' is up to date.
```

```
% edit other_file
    [CHANGE THE CONTENTS OF other_file]
% scons -Q hello
cc -c hello.c -o hello.o
cc -o hello hello.o
```

Chapter 7. Construction Environments

It is rare that all of the software in a large, complicated system needs to be built the same way. For example, different source files may need different options enabled on the command line, or different executable programs need to be linked with different libraries. SCons accomodates these different build requirements by allowing you to create and configure multiple construction environments that control how the software is built. Technically, a construction environment is an object that has a number of associated construction variables, each with a name and a value. (A construction environment also has an attached set of Builder methods, about which we'll learn more later.)

A construction environment is created by the Environment method:

```
env = Environment()
```

By default, SCons intializes every new construction environment with a set of construction variables based on the tools that it finds on your system, plus the default set of builder methods necessary for using those tools. The construction variables are initialized with values describing the C compiler, the Fortran compiler, the linker, etc., as well as the command lines to invoke them.

When you initialize a construction environment you can set the values of the environment's construction variables to control how a program is built. For example:

```
env = Environment(CC = 'gcc',
                  CCFLAGS = '-O2')

env.Program('foo.c')
```

The construction environment in this example is still initialized with the same default construction variable values, except that the user has explicitly specified use of the GNU C compiler gcc, and further specifies that the -O2 (optimization level two) flag should be used when compiling the object file. In other words, the explicit initializations of CC and CCFLAGS override the default values in the newly-created construction environment. So a run from this example would look like:

```
% scons -Q
gcc -O2 -c -o foo.o foo.c
gcc -o foo foo.o
```

Multiple Construction Environments

The real advantage of construction environments is that you can create as many different construction environments as you need, each tailored to a different way to build some piece of software or other file. If, for example, we need to build one program with the -O2 flag and another with the -g (debug) flag, we would do this like so:

```
opt = Environment(CCFLAGS = '-O2')
dbg = Environment(CCFLAGS = '-g')

opt.Program('foo', 'foo.c')

dbg.Program('bar', 'bar.c')
```

```
% scons -Q
cc -g -c -o bar.o bar.c
```

```
cc -o bar bar.o
cc -O2 -c -o foo.o foo.c
cc -o foo foo.o
```

We can even use multiple construction environments to build multiple versions of a single program. If you do this by simply trying to use the `Program` builder with both environments, though, like this:

```
opt = Environment(CCFLAGS = '-O2')
dbg = Environment(CCFLAGS = '-g')

opt.Program('foo', 'foo.c')

dbg.Program('foo', 'foo.c')
```

Then `SCons` generates the following error:

```
% scons -Q

scons: *** Two environments with different actions were specified for the same ta
File "SConstruct", line 6, in ?
```

This is because the two `Program` calls have each implicitly told `SCons` to generate an object file named `foo.o`, one with a `CCFLAGS` value of `-O2` and one with a `CCFLAGS` value of `-g`. `SCons` can't just decide that one of them should take precedence over the other, so it generates the error. To avoid this problem, we must explicitly specify that each environment compile `foo.c` to a separately-named object file using the `Object` call, like so:

```
opt = Environment(CCFLAGS = '-O2')
dbg = Environment(CCFLAGS = '-g')

o = opt.Object('foo-opt', 'foo.c')
opt.Program(o)

d = dbg.Object('foo-dbg', 'foo.c')
dbg.Program(d)
```

Notice that each call to the `Object` builder returns a value, an internal `SCons` object that represents the object file that will be built. We then use that object as input to the `Program` builder. This avoids having to specify explicitly the object file name in multiple places, and makes for a compact, readable `SConstruct` file. Our `SCons` output then looks like:

```
% scons -Q
cc -g -c -o foo-dbg.o foo.c
cc -o foo-dbg foo-dbg.o
cc -O2 -c -o foo-opt.o foo.c
cc -o foo-opt foo-opt.o
```

Copying `Construction Environments`

Sometimes you want more than one construction environment to share the same values for one or more variables. Rather than always having to repeat all of the common variables when you create each construction environment, you can use the `Copy` method to create a copy of a construction environment.

Like the `Environment` call that creates a construction environment, the `Copy` method takes `construction variable` assignments, which will override the values in the copied construction environment. For example, suppose we want to use `gcc` to create three versions of a program, one optimized, one debug, and one with neither. We could do this by creating a "base" construction environment that sets `CC` to `gcc`, and then creating two copies, one which sets `CCFLAGS` for optimization and the other which sets `CCFLAGS` for debugging:

```
env = Environment(CC = 'gcc')
opt = env.Copy(CCFLAGS = '-O2')
dbg = env.Copy(CCFLAGS = '-g')

env.Program('foo', 'foo.c')

o = opt.Object('foo-opt', 'foo.c')
opt.Program(o)

d = dbg.Object('foo-dbg', 'foo.c')
dbg.Program(d)
```

Then our output would look like:

```
% scons -Q
gcc -c -o foo.o foo.c
gcc -o foo foo.o
gcc -g -c -o foo-dbg.o foo.c
gcc -o foo-dbg foo-dbg.o
gcc -O2 -c -o foo-opt.o foo.c
gcc -o foo-opt foo-opt.o
```

Fetching Values From a `Construction Environment`

You can fetch individual construction variables using the normal syntax for accessing individual named items in a Python dictionary:

```
env = Environment()
print "CC is:", env['CC']
```

This example `SConstruct` file doesn't build anything, but because it's actually a Python script, it will print the value of `CC` for us:

```
% scons -Q
CC is: cc
scons: `.' is up to date.
```

A construction environment, however, is actually an object with associated methods, etc. If you want to have direct access to only the dictionary of construction variables, you can fetch this using the `Dictionary` method:

```
env = Environment(FOO = 'foo', BAR = 'bar')
dict = env.Dictionary()
for key in ['OBJSUFFIX', 'LIBSUFFIX', 'PROGSUFFIX']:
    print "key = %s, value = %s" % (key, dict[key])
```

This `SConstruct` file will print the specified dictionary items for us on POSIX systems as follows:

```
% scons -Q
key = OBJSUFFIX, value = .o
key = LIBSUFFIX, value = .a
key = PROGSUFFIX, value =
scons: `.' is up to date.
```

And on Win32:

```
C:\>scons -Q
key = OBJSUFFIX, value = .obj
key = LIBSUFFIX, value = .lib
key = PROGSUFFIX, value = .exe
scons: `.' is up to date.
```

If you want to loop through and print the values of all of the construction variables in a construction environment, the Python code to do that in sorted order might look something like:

```
env = Environment()
dict = env.Dictionary()
keys = dict.keys()
keys.sort()
for key in keys:
    print "construction variable = '%s', value = '%s'" % (key, dict[key])
```

Expanding Values From a `Construction Environment`

Another way to get information from a construction environment. is to use the `subst` method on a string containing $-expansions of construction variable names. As a simple example, the example from the previous section that used `env['CC']` to fetch the value of `CC` could also be written as:

```
env = Environment()
print "CC is:", env.subst('$CC')
```

The real advantage of using `subst` to expand strings is that construction variables in the result get re-expanded until there are no expansions left in the string. So a simple fetch of a value like `$CCCOM`:

```
env = Environment(CCFLAGS = '-DFOO')
print "CCCOM is:", env['CCCOM']
```

Will print the unexpanded value of `CCCOM`, showing us the construction variables that still need to be expanded:

```
% scons -Q
CCCOM is: $CC $CCFLAGS $CPPFLAGS $_CPPDEFFLAGS $_CPPINCFLAGS -c -o $TARGET $SOURCE
scons: `.' is up to date.
```

Calling the `subst` method on `$CCOM`, however:

```
env = Environment(CCFLAGS = '-DFOO')
print "CCCOM is:", env.subst('$CCCOM')
```

Will recursively expand all of the $-prefixed construction variables, showing us the final output:

```
% scons -Q
CCCOM is: gcc -DFOO -c -o
scons: `.' is up to date.
```

(Note that because we're not expanding this in the context of building something there are no target or source files for `$TARGET` and `$SOURCES` to expand.

Modifying a `Construction Environment`

`SCons` provides various methods that support modifying existing values in a construction environment.

Replacing Values in a `Construction Environment`

You can replace existing construction variable values using the `Replace` method:

```
env = Environment(CCFLAGS = '-DDEFINE1')
env.Replace(CCFLAGS = '-DDEFINE2')
env.Program('foo.c')
```

The replacing value (`-DDEFINE2` in the above example) completely replaces the value in the construction environment:

```
% scons -Q
cc -DDEFINE2 -c -o foo.o foo.c
cc -o foo foo.o
```

You can safely call `Replace` for construction variables that don't exist in the construction environment:

```
env = Environment()
env.Replace(NEW_VARIABLE = 'xyzzy')
print "NEW_VARIABLE =", env['NEW_VARIABLE']
```

In this case, the construction variable simply gets added to the construction environment:

```
% scons -Q
NEW_VARIABLE = xyzzy
scons: `.' is up to date.
```

Because the variables aren't expanded until the construction environment is actually used to build the targets, and because `SCons` function and method calls are order-independent, the last replacement "wins" and is used to build all targets, regardless of the order in which the calls to Replace() are interspersed with calls to builder methods:

```
env = Environment(CCFLAGS = '-DDEFINE1')
print "CCFLAGS =", env['CCFLAGS']
env.Program('foo.c')

env.Replace(CCFLAGS = '-DDEFINE2')
print "CCFLAGS =", env['CCFLAGS']
env.Program('bar.c')
```

The timing of when the replacement actually occurs relative to when the targets get built becomes apparent if we run `scons` without the `-Q` option:

```
% scons
scons: Reading SConscript files ...
CCFLAGS = -DDEFINE1
CCFLAGS = -DDEFINE2
scons: done reading SConscript files.
scons: Building targets ...
cc -DDEFINE2 -c -o bar.o bar.c
cc -o bar bar.o
cc -DDEFINE2 -c -o foo.o foo.c
cc -o foo foo.o
scons: done building targets.
```

Because the replacement occurs while the `SConscript` files are being read, the `$CCFLAGS` variable has already been set to `-DDEFINE2` by the time the `foo.o` target is built, even though the call to the `Replace` method does not occur until later in the `SConscript` file.

Appending to the End of Values in a `Construction Environment`

You can append a value to an existing construction variable using the `Append` method:

```
env = Environment(CCFLAGS = '-DMY_VALUE')
env.Append(CCFLAGS = ' -DLAST')
env.Program('foo.c')
```

`SCons` then supplies both the `-DMY_VALUE` and `-DLAST` flags when compiling the object file:

```
% scons -Q
cc -DMY_VALUE -DLAST -c -o foo.o foo.c
cc -o foo foo.o
```

If the construction variable doesn't already exist, the `Append` method will create it:

```
env = Environment()
env.Append(NEW_VARIABLE = 'added')
print "NEW_VARIABLE =", env['NEW_VARIABLE']
```

Which yields:

```
% scons -Q
NEW_VARIABLE = added
scons: `.' is up to date.
```

Appending to the Beginning of Values in a `Construction Environment`

You can append a value to the beginning an existing construction variable using the `Prepend` method:

```
env = Environment(CCFLAGS = '-DMY_VALUE')
```

```
env.Prepend(CCFLAGS = '-DFIRST ')
env.Program('foo.c')
```

SCons then supplies both the -DFIRST and -DMY_VALUE flags when compiling the object file:

```
% scons -Q
cc -DFIRST -DMY_VALUE -c -o foo.o foo.c
cc -o foo foo.o
```

If the construction variable doesn't already exist, the Prepend method will create it:

```
env = Environment()
env.Prepend(NEW_VARIABLE = 'added')
print "NEW_VARIABLE =", env['NEW_VARIABLE']
```

Which yields:

```
% scons -Q
NEW_VARIABLE = added
scons: `.' is up to date.
```

Chapter 8. Controlling the External Environment Used to Execute Build Commands

When SCons builds a target file, it does not execute the commands with the same external environment that you used to execute SCons. Instead, it uses the dictionary stored in the ENV construction variable as the external environment for executing commands.

The most important ramification of this behavior is that the PATH environment variable, which controls where the operating system will look for commands and utilities, is not the same as in the external environment from which you called SCons. This means that SCons will not, by default, necessarily find all of the tools that you can execute from the command line.

The default value of the PATH environment variable on a POSIX system is /usr/local/bin:/bin:/usr/bin. The default value of the PATH environment variable on a Win32 system comes from the Windows registry value for the command interpreter. If you want to execute any commands--compilers, linkers, etc.--that are not in these default locations, you need to set the PATH value in the ENV dictionary in your construction environment.

The simplest way to do this is to initialize explicitly the value when you create the construction environment; this is one way to do that:

```
path = ['/usr/local/bin', '/bin', '/usr/bin']
env = Environment(ENV = {'PATH' : path})
```

Assign a dictionary to the ENV construction variable in this way completely resets the external environment so that the only variable that will be set when external commands are executed will be the PATH value. If you want to use the rest of the values in ENV and only set the value of PATH, the most straightforward way is probably:

```
env['ENV']['PATH'] = ['/usr/local/bin', '/bin', '/usr/bin']
```

Note that SCons does allow you to define the directories in the PATH in a string, separated by the pathname-separator character for your system (':' on POSIX systems, ';' on Windows):

```
env['ENV']['PATH'] = '/usr/local/bin:/bin:/usr/bin'
```

But doing so makes your SConscript file less portable, (although in this case that may not be a huge concern since the directories you list are likley system-specific, anyway).

Propagating PATH From the External Environment

You may want to propagate the external PATH to the execution environment for commands. You do this by initializing the PATH variable with the PATH value from the os.environ dictionary, which is Python's way of letting you get at the external environment:

```
import os
env = Environment(ENV = {'PATH' : os.environ['PATH']})
```

Alternatively, you may find it easier to just propagate the entire external environment to the execution environment for commands. This is simpler to code than explicity selecting the PATH value:

```
import os
env = Environment(ENV = os.environ)
```

Either of these will guarantee that `SCons` will be able to execute any command that you can execute from the command line. The drawback is that the build can behave differently if it's run by people with different `PATH` values in their environment--for example, both the `/bin` and `/usr/local/bin` directories have different `cc` commands, then which one will be used to compile programs will depend on which directory is listed first in the user's `PATH` variable.

Chapter 9. Controlling a Build From the Command Line

SCons provides a number of ways that allow the writer of the SConscript files to give users a great deal of control over how to run the builds.

Not Having to Specify Command-Line Options Each Time: the SCONSFLAGS Environment Variable

Users may find themselves supplying the same command-line options every time they run SCons. For example, a user might find that it saves time to specify a value of -j 2 to run the builds in parallel. To avoid having to type -j 2 by hand every time, you can set the external environment variable SCONSFLAGS to a string containing command-line options that you want SCons to use.

If, for example, and you're using a POSIX shell that's compatible with the Bourne shell, and you always want SCons to use the -Q option, you can set the SCONSFLAGS environment as follows:

```
% scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
    ... [build output] ...
scons: done building targets.
% export SCONSFLAGS="-Q"
% scons
    ... [build output] ...
```

Users of csh-style shells on POSIX systems can set the SCONSFLAGS environment as follows:

```
$ setenv SCONSFLAGS "-Q"
```

Windows users may typically want to set this SCONSFLAGS in the appropriate tab of the System Properties window.

Getting at Command-Line Targets

SCons supports a COMMAND_LINE_TARGETS variable that lets you get at the list of targets that the user specified on the command line. You can use the targets to manipulate the build in any way you wish. As a simple example, suppose that you want to print a reminder to the user whenever a specific program is built. You can do this by checking for the target in the COMMAND_LINE_TARGETS list:

```
if 'bar' in COMMAND_LINE_TARGETS:
    print "Don't forget to copy 'bar' to the archive!"
Default(Program('foo.c'))
Program('bar.c')
```

Then, running SCons with the default target works as it always does, but explicity specifying the bar target on the command line generates the warning message:

```
% scons -Q
cc -c -o foo.o foo.c
cc -o foo foo.o
% scons -Q bar
Don't forget to copy 'bar' to the archive!
cc -c -o bar.o bar.c
```

```
cc -o bar bar.o
```

Another practical use for the COMMAND_LINE_TARGETS variable might be to speed up a build by only reading certain subsidiary SConscript files if a specific target is requested.

Controlling the Default Targets

One of the most basic things you can control is which targets SCons will build by default--that is, when there are no targets specified on the command line. As mentioned previously, SCons will normally build every target in or below the current directory by default--that is, when you don't explicitly specify one or more targets on the command line. Sometimes, however, you may want to specify explicitly that only certain programs, or programs in certain directories, should be built by default. You do this with the Default function:

```
env = Environment()
hello = env.Program('hello.c')
env.Program('goodbye.c')
Default(hello)
```

This SConstruct file knows how to build two programs, hello and goodbye, but only builds the hello program by default:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q
scons: `hello' is up to date.
% scons -Q goodbye
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
```

Note that, even when you use the Default function in your SConstruct file, you can still explicitly specify the current directory (.) on the command line to tell SCons to build everything in (or below) the current directory:

```
% scons -Q .
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
cc -c -o hello.o hello.c
cc -o hello hello.o
```

You can also call the Default function more than once, in which case each call adds to the list of targets to be built by default:

```
env = Environment()
prog1 = env.Program('prog1.c')
Default(prog1)
prog2 = env.Program('prog2.c')
prog3 = env.Program('prog3.c')
Default(prog3)
```

Or you can specify more than one target in a single call to the Default function:

```
env = Environment()
prog1 = env.Program('prog1.c')
```

```
prog2 = env.Program('prog2.c')
prog3 = env.Program('prog3.c')
Default(prog1, prog3)
```

Either of these last two examples will build only the `prog1` and `prog3` programs by default:

```
% scons -Q
cc -c -o prog1.o prog1.c
cc -o prog1 prog1.o
cc -c -o prog3.o prog3.c
cc -o prog3 prog3.o
% scons -Q .
cc -c -o prog2.o prog2.c
cc -o prog2 prog2.o
```

You can list a directory as an argument to `Default`:

```
env = Environment()
env.Program(['prog1/main.c', 'prog1/foo.c'])
env.Program(['prog2/main.c', 'prog2/bar.c'])
Default('prog1')
```

In which case only the target(s) in that directory will be built by default:

```
% scons -Q
cc -c -o prog1/foo.o prog1/foo.c
cc -c -o prog1/main.o prog1/main.c
cc -o prog1/main prog1/main.o prog1/foo.o
% scons -Q
scons: `prog1' is up to date.
% scons -Q .
cc -c -o prog2/bar.o prog2/bar.c
cc -c -o prog2/main.o prog2/main.c
cc -o prog2/main prog2/main.o prog2/bar.o
```

Lastly, if for some reason you don't want any targets built by default, you can use the Python `None` variable:

```
env = Environment()
prog1 = env.Program('prog1.c')
prog2 = env.Program('prog2.c')
Default(None)
```

Which would produce build output like:

```
% scons -Q
scons: *** No targets specified and no Default() targets found.  Stop.
% scons -Q .
cc -c -o prog1.o prog1.c
cc -o prog1 prog1.o
cc -c -o prog2.o prog2.c
cc -o prog2 prog2.o
```

Getting at the List of Default Targets

SCons supports a DEFAULT_TARGETS variable that lets you get at the current list of default targets. The DEFAULT_TARGETS variable has two important differences from the COMMAND_LINE_TARGETS variable. First, the DEFAULT_TARGETS variable is a list of internal SCons nodes, so you need to convert the list elements to strings if you want to print them or look for a specific target name. Fortunately, you can do this easily by using the Python map function to run the list through str:

```
prog1 = Program('prog1.c')
Default(prog1)
print "DEFAULT_TARGETS is", map(str, DEFAULT_TARGETS)
```

(Keep in mind that all of the manipulation of the DEFAULT_TARGETS list takes place during the first phase when SCons is reading up the SConscript files, which is obvious if we leave off the -Q flag when we run SCons:)

```
% scons
scons: Reading SConscript files ...
DEFAULT_TARGETS is ['prog1']
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o prog1.o prog1.c
cc -o prog1 prog1.o
scons: done building targets.
```

Second, the contents of the DEFAULT_TARGETS list change in response to calls to the Default: function, as you can see from the following SConstruct file:

```
prog1 = Program('prog1.c')
Default(prog1)
print "DEFAULT_TARGETS is now", map(str, DEFAULT_TARGETS)
prog2 = Program('prog2.c')
Default(prog2)
print "DEFAULT_TARGETS is now", map(str, DEFAULT_TARGETS)
```

Which yields the output:

```
% scons
scons: Reading SConscript files ...
DEFAULT_TARGETS is now ['prog1']
DEFAULT_TARGETS is now ['prog1', 'prog2']
scons: done reading SConscript files.
scons: Building targets ...
cc -c -o prog1.o prog1.c
cc -o prog1 prog1.o
cc -c -o prog2.o prog2.c
cc -o prog2 prog2.o
scons: done building targets.
```

In practice, this simply means that you need to pay attention to the order in which you call the Default function and refer to the DEFAULT_TARGETS list, to make sure that you don't examine the list before you've added the default targets you expect to find in it.

Getting at the List of Build Targets, Regardless of Origin

We've already been introduced to the COMMAND_LINE_TARGETS variable, which contains a list of targets specified on the command line, and the DEFAULT_TARGETS variable, which contains a list of targets specified via calls to the Default method or function. Sometimes, however, you want a list of whatever targets SCons will try to build, regardless of whether the targets came from the command line or a Default call. You could code this up by hand, as follows:

```
if COMMAND_LINE_TARGETS:
    targets = COMMAND_LINE_TARGETS
else:
    targets = DEFAULT_TARGETS
```

SCons, however, provides a convenient BUILD_TARGETS variable that eliminates the need for this by-hand manipulation. Essentially, the BUILD_TARGETS variable contains a list of the command-line targets, if any were specified, and if no command-line targets were specified, it contains a list of the targets specified via the Default method or function.

Because BUILD_TARGETS may contain a list of SCons nodes, you must convert the list elements to strings if you want to print them or look for a specific target name, just like the DEFAULT_TARGETS list:

```
prog1 = Program('prog1.c')
Program('prog2.c')
Default(prog1)
print "BUILD_TARGETS is", map(str, BUILD_TARGETS)
```

Notice how the value of BUILD_TARGETS changes depending on whether a target is specified on the command line:

```
% scons -Q
BUILD_TARGETS is ['prog1']
cc -c -o prog1.o prog1.c
cc -o prog1 prog1.o
% scons -Q prog2
BUILD_TARGETS is ['prog2']
cc -c -o prog2.o prog2.c
cc -o prog2 prog2.o
% scons -Q -c .
BUILD_TARGETS is ['.']
Removed prog1.o
Removed prog1
Removed prog2.o
Removed prog2
```

Command-Line variable=value Build Options

You may want to control various aspects of your build by allowing the user to specify variable=value values on the command line. For example, suppose you want users to be able to build a debug version of a program by running SCons as follows:

```
% scons -Q debug=1
```

SCons provides an ARGUMENTS dictionary that stores all of the variable=value assignments from the command line. This allows you to modify aspects of your build in response to specifications on the command line. (Note that unless you want to

require that users *always* specify an option, you probably want to use the Python ARGUMENTS.get() function, which allows you to specify a default value to be used if there is no specification on the command line.)

The following code sets the CCFLAGS construction variable in response to the debug flag being set in the ARGUMENTS dictionary:

```
env = Environment()
debug = ARGUMENTS.get('debug', 0)
if int(debug):
    env.Append(CCFLAGS = '-g')
env.Program('prog.c')
```

This results in the -g compiler option being used when debug=1 is used on the command line:

```
% scons -Q debug=0
cc -c -o prog.o prog.c
cc -o prog prog.o
% scons -Q debug=0
scons: `.' is up to date.
% scons -Q debug=1
cc -g -c -o prog.o prog.c
cc -o prog prog.o
% scons -Q debug=1
scons: `.' is up to date.
```

Notice that SCons keeps track of the last values used to build the object files, and as a result correctly rebuilds the object and executable files only when the value of the debug argument has changed.

Controlling Command-Line Build Options

Being able to use a command-line build option like debug=1 is handy, but it can be a chore to write specific Python code to recognize each such option and apply the values to a construction variable. To help with this, SCons supports a class to define such build options easily, and a mechanism to apply the build options to a construction environment. This allows you to control how the build options affect construction environments.

For example, suppose that you want users to set a RELEASE construction variable on the command line whenever the time comes to build a program for release, and that the value of this variable should be added to the command line with the appropriate -D option (or other command line option) to pass the value to the C compiler. Here's how you might do that by setting the appropriate value in a dictionary for the CPPDEFINES construction variable:

```
opts = Options()
opts.Add('RELEASE', 'Set to 1 to build for release', 0)
env = Environment(options = opts,
                  CPPDEFINES={'RELEASE_BUILD' : '${RELEASE}'})
env.Program(['foo.c', 'bar.c'])
```

This SConstruct file first creates an Options object (the opts = Options() call), and then uses the object's Add method to indicate that the RELEASE option can be set on the command line, and that it's default value will be 0 (the third argument to the Add method). The second argument is a line of help text; we'll learn how to use it in the next section.

We then pass the created `Options` object as an `options` keyword argument to the `Environment` call used to create the construction environment. This then allows a user to set the `RELEASE` build option on the command line and have the variable show up in the command line used to build each object from a C source file:

```
% scons -Q RELEASE=1
cc -DRELEASE_BUILD=1 -c -o bar.o bar.c
cc -DRELEASE_BUILD=1 -c -o foo.o foo.c
cc -o foo foo.o bar.o
```

Providing Help for Command-Line Build Options

To make command-line build options most useful, you ideally want to provide some help text that will describe the available options when the user runs `scons -h`. You could write this text by hand, but `SCons` provides an easier way. `Options` objects support a `GenerateHelpText` method that will, as its name indicates, generate text that describes the various options that have been added to it. You then pass the output from this method to the `Help` function:

```
opts = Options('custom.py')
opts.Add('RELEASE', 'Set to 1 to build for release', 0)
env = Environment(options = opts)
Help(opts.GenerateHelpText(env))
```

`SCons` will now display some useful text when the `-h` option is used:

```
% scons -Q -h

RELEASE: Set to 1 to build for release
    default: 0
    actual: 0

Use scons -H for help about command-line options.
```

Notice that the help output shows the default value, and the current actual value of the build option.

Reading Build Options From a File

Being able to use a command-line build option like `debug=1` is handy, but it can be a chore to write specific Python code to recognize each such option and apply the values to a construction variable. To help with this, `SCons` supports a class to define such build options easily and to read build option values from a file. This allows you to control how the build options affect construction environments. The way you do this is by specifying a file name when you call `Options`, like `custom.py` in the following example:

```
opts = Options('custom.py')
opts.Add('RELEASE', 'Set to 1 to build for release', 0)
env = Environment(options = opts,
                  CPPDEFINES={'RELEASE_BUILD' : '${RELEASE}'})
env.Program(['foo.c', 'bar.c'])
Help(opts.GenerateHelpText(env))
```

This then allows us to control the `RELEASE` variable by setting it in the `custom.py` file:

```
RELEASE = 1
```

Note that this file is actually executed like a Python script. Now when we run `SCons`:

```
% scons -Q
cc -DRELEASE_BUILD=1 -c -o bar.o bar.c
cc -DRELEASE_BUILD=1 -c -o foo.o foo.c
cc -o foo foo.o bar.o
```

And if we change the contents of `custom.py` to:

```
RELEASE = 0
```

The object files are rebuilt appropriately with the new option:

```
% scons -Q
cc -DRELEASE_BUILD=0 -c -o bar.o bar.c
cc -DRELEASE_BUILD=0 -c -o foo.o foo.c
cc -o foo foo.o bar.o
```

Canned Build Options

`SCons` provides a number of functions that provide ready-made behaviors for various types of command-line build options.

True/False Values: the `BoolOption` Build Option

It's often handy to be able to specify an option that controls a simple Boolean variable with a `true` or `false` value. It would be even more handy to accomodate users who have different preferences for how to represent `true` or `false` values. The `BoolOption` function makes it easy to accomodate a variety of common values that represent `true` or `false`.

The `BoolOption` function takes three arguments: the name of the build option, the default value of the build option, and the help string for the option. It then returns appropriate information for passing to the `Add` method of an `Options` object, like so:

```
opts = Options('custom.py')
opts.Add(BoolOption('RELEASE', 'Set to build for release', 0))
env = Environment(options = opts,
                  CPPDEFINES={'RELEASE_BUILD' : '${RELEASE}'})
env.Program('foo.c')
```

With this build option, the `RELEASE` variable can now be enabled by setting it to the value `yes` or `t`:

```
% scons -Q RELEASE=yes foo.o
cc -DRELEASE_BUILD=1 -c -o foo.o foo.c


% scons -Q RELEASE=t foo.o
cc -DRELEASE_BUILD=1 -c -o foo.o foo.c
```

Other values that equate to `true` include `y`, `1`, `on` and `all`.

Conversely, `RELEASE` may now be given a `false` value by setting it to `no` or `f`:

```
% scons -Q RELEASE=no foo.o
cc -DRELEASE_BUILD=0 -c -o foo.o foo.c


% scons -Q RELEASE=f foo.o
cc -DRELEASE_BUILD=0 -c -o foo.o foo.c
```

Other values that equate to `true` include `n`, `0`, `off` and `none`.

Lastly, if a user tries to specify any other value, `SCons` supplies an appropriate error message:

```
% scons -Q RELEASE=bad_value foo.o

scons: *** Error converting option: RELEASE
Invalid value for boolean option: bad_value
File "SConstruct", line 4, in ?
```

Single Value From a List: the `EnumOption` Build Option

Suppose that we want a user to be able to set a `COLOR` option that selects a background color to be displayed by an application, but that we want to restrict the choices to a specific set of allowed colors. This can be set up quite easily using the `EnumOption`, which takes a list of `allowed_values` in addition to the variable name, default value, and help text arguments:

```
opts = Options('custom.py')
opts.Add(EnumOption('COLOR', 'Set background color', 'red',
                    allowed_values=('red', 'green', 'blue')))
env = Environment(options = opts,
                  CPPDEFINES={'COLOR' : '"${COLOR}"'})
env.Program('foo.c')
```

The user can now explicity set the `COLOR` build option to any of the specified allowed values:

```
% scons -Q COLOR=red foo.o
cc -DCOLOR="red" -c -o foo.o foo.c
% scons -Q COLOR=blue foo.o
cc -DCOLOR="blue" -c -o foo.o foo.c
% scons -Q COLOR=green foo.o
cc -DCOLOR="green" -c -o foo.o foo.c
```

But, almost more importantly, an attempt to set `COLOR` to a value that's not in the list generates an error message:

```
% scons -Q COLOR=magenta foo.o

scons: *** Invalid value for option COLOR: magenta
File "SConstruct", line 5, in ?
```

The `EnumOption` function also supports a way to map alternate names to allowed values. Suppose, for example, that we want to allow the user to use the word `navy` as a synonym for `blue`. We do this by adding a `map` dictionary that will map its key values to the desired legal value:

```
opts = Options('custom.py')
opts.Add(EnumOption('COLOR', 'Set background color', 'red',
```

```
                    allowed_values=('red', 'green', 'blue'),
                    map={'navy':'blue'}))
env = Environment(options = opts,
                  CPPDEFINES={'COLOR' : '"${COLOR}"'})
env.Program('foo.c')
```

As desired, the user can then use `navy` on the command line, and `SCons` will translate it into `blue` when it comes time to use the `COLOR` option to build a target:

```
% scons -Q COLOR=navy foo.o
cc -DCOLOR="blue" -c -o foo.o foo.c
```

By default, when using the `EnumOption` function, arguments that differ from the legal values only in case are treated as illegal values:

```
% scons -Q COLOR=Red foo.o

scons: *** Invalid value for option COLOR: Red
File "SConstruct", line 5, in ?
% scons -Q COLOR=BLUE foo.o

scons: *** Invalid value for option COLOR: BLUE
File "SConstruct", line 5, in ?
% scons -Q COLOR=nAvY foo.o

scons: *** Invalid value for option COLOR: nAvY
File "SConstruct", line 5, in ?
```

The `EnumOption` function can take an additional `ignorecase` keyword argument that, when set to `1`, tells `SCons` to allow case differences when the values are specified:

```
opts = Options('custom.py')
opts.Add(EnumOption('COLOR', 'Set background color', 'red',
                    allowed_values=('red', 'green', 'blue'),
                    map={'navy':'blue'},
                    ignorecase=1))
env = Environment(options = opts,
                  CPPDEFINES={'COLOR' : '"${COLOR}"'})
env.Program('foo.c')
```

Which yields the output:

```
% scons -Q COLOR=Red foo.o
cc -DCOLOR="Red" -c -o foo.o foo.c
% scons -Q COLOR=BLUE foo.o
cc -DCOLOR="BLUE" -c -o foo.o foo.c
% scons -Q COLOR=nAvY foo.o
cc -DCOLOR="blue" -c -o foo.o foo.c
% scons -Q COLOR=green foo.o
cc -DCOLOR="green" -c -o foo.o foo.c
```

Notice that an `ignorecase` value of `1` preserves the case-spelling that the user supplied. If you want `SCons` to translate the names into lower-case, regardless of the case used by the user, specify an `ignorecase` value of `2`:

```
opts = Options('custom.py')
opts.Add(EnumOption('COLOR', 'Set background color', 'red',
                    allowed_values=('red', 'green', 'blue'),
                    map={'navy':'blue'},
```

```
                        ignorecase=2))
env = Environment(options = opts,
                  CPPDEFINES={'COLOR' : '"${COLOR}"'})
env.Program('foo.c')
```

Now SCons will use values of red, green or blue regardless of how the user spells those values on the command line:

```
% scons -Q COLOR=Red foo.o
cc -DCOLOR="red" -c -o foo.o foo.c
% scons -Q COLOR=nAvY foo.o
cc -DCOLOR="blue" -c -o foo.o foo.c
% scons -Q COLOR=GREEN foo.o
cc -DCOLOR="green" -c -o foo.o foo.c
```

Multiple Values From a List: the ListOption Build Option

Another way in which you might want to allow users to control build option is to specify a list of one or more legal values. SCons supports this through the ListOption function. If, for example, we want a user to be able to set a COLORS option to one or more of the legal list of values:

```
opts = Options('custom.py')
opts.Add(ListOption('COLORS', 'List of colors', 0,
                    ['red', 'green', 'blue']))
env = Environment(options = opts,
                  CPPDEFINES={'COLORS' : '"${COLORS}"'})
env.Program('foo.c')
```

A user can now specify a comma-separated list of legal values, which will get translated into a space-separated list for passing to the any build commands:

```
% scons -Q COLORS=red,blue foo.o
cc -DCOLORS="red blue" -c -o foo.o foo.c
% scons -Q COLORS=blue,green,red foo.o
cc -DCOLORS="blue green red" -c -o foo.o foo.c
```

In addition, the ListOption function allows the user to specify explicit keywords of all or none to select all of the legal values, or none of them, respectively:

```
% scons -Q COLORS=all foo.o
cc -DCOLORS="red green blue" -c -o foo.o foo.c
% scons -Q COLORS=none foo.o
cc -DCOLORS="" -c -o foo.o foo.c
```

And, of course, an illegal value still generates an error message:

```
% scons -Q COLORS=magenta foo.o

scons: *** Error converting option: COLORS
Invalid value(s) for option: magenta
File "SConstruct", line 5, in ?
```

Path Names: the `PathOption` Build Option

`SCons` supports a `PathOption` function to make it easy to create a build option to control an expected path name. If, for example, you need to define a variable in the preprocessor that control the location of a configuration file:

```
opts = Options('custom.py')
opts.Add(PathOption('CONFIG',
                    'Path to configuration file',
                    '/etc/my_config'))
env = Environment(options = opts,
                  CPPDEFINES={'CONFIG_FILE' : '"$CONFIG"'})
env.Program('foo.c')
```

This then allows the user to override the `CONFIG` build option on the command line as necessary:

```
% scons -Q foo.o
cc -DCONFIG_FILE="/etc/my_config" -c -o foo.o foo.c
% scons -Q CONFIG=/usr/local/etc/other_config foo.o
scons: `foo.o' is up to date.
```

Enabled/Disabled Path Names: the `PackageOption` Build Option

Sometimes you want to give users even more control over a path name variable, allowing them to explicitly enable or disable the path name by using `yes` or `no` keywords, in addition to allow them to supply an explicit path name. `SCons` supports the `PackageOption` function to support this:

```
opts = Options('custom.py')
opts.Add(PackageOption('PACKAGE',
                       'Location package',
                       '/opt/location'))
env = Environment(options = opts,
                  CPPDEFINES={'PACKAGE' : '"$PACKAGE"'})
env.Program('foo.c')
```

When the `SConscript` file uses the `PackageOption` funciton, user can now still use the default or supply an overriding path name, but can now explicitly set the specified variable to a value that indicates the package should be enabled (in which case the default should be used) or disabled:

```
% scons -Q foo.o
cc -DPACKAGE="/opt/location" -c -o foo.o foo.c
% scons -Q PACKAGE=/usr/local/location foo.o
cc -DPACKAGE="/usr/local/location" -c -o foo.o foo.c
% scons -Q PACKAGE=yes foo.o
cc -DPACKAGE="1" -c -o foo.o foo.c
% scons -Q PACKAGE=no foo.o
cc -DPACKAGE="0" -c -o foo.o foo.c
```

Adding Multiple Command-Line Build Options at Once

Lastly, `SCons` provides a way to add multiple build options to an `Options` object at once. Instead of having to call the `Add` method multiple times, you can call the `AddOptions` method with a list of build options to be added to the object. Each build option is specified as either a tuple of arguments, just like you'd pass to the `Add` method itself, or as a call to one of the canned functions for pre-packaged command-line build options. in any order:

```
opts = Options()
opts.AddOptions(
    ('RELEASE', 'Set to 1 to build for release', 0),
    ('CONFIG', 'Configuration file', '/etc/my_config'),
    BoolOption('warnings', 'compilation with -Wall and similiar', 1),
    EnumOption('debug', 'debug output and symbols', 'no',
               allowed_values=('yes', 'no', 'full'),
               map={}, ignorecase=0),  # case sensitive
    ListOption('shared',
               'libraries to build as shared libraries',
               'all',
               names = list_of_libs),
    PackageOption('x11',
                  'use X11 installed here (yes = search some places)',
                  'yes'),
    PathOption('qtdir', 'where the root of Qt is installed', qtdir),
)
```

Chapter 10. Providing Build Help: the `Help` Function

It's often very useful to be able to give users some help that describes the specific targets, build options, etc., that can be used for your build. `SCons` provides the `Help` function to allow you to specify this help text:

```
Help("""
Type: 'scons program' to build the production program,
      'scons debug' to build the debug version.
""")
```

(Note the above use of the Python triple-quote syntax, which comes in very handy for specifying multi-line strings like help text.)

When the `SConstruct` or `SConscript` files contain such a call to the `Help` function, the specified help text will be displayed in response to the `SCons -h` option:

```
% scons -h
scons: Reading SConscript files ...
scons: done reading SConscript files.

Type: 'scons program' to build the production program,
      'scons debug' to build the debug version.

Use scons -H for help about command-line options.
```

If there is no `Help` text in the `SConstruct` or `SConscript` files, `SCons` will revert to displaying its standard list that describes the `SCons` command-line options. This list is also always displayed whenever the `-H` option is used.

Chapter 11. Installing Files in Other Directories: the `Install` Builder

Once a program is built, it is often appropriate to install it in another directory for public use. You use the `Install` method to arrange for a program, or any other file, to be copied into a destination directory:

```
env = Environment()
hello = env.Program('hello.c')
env.Install('/usr/bin', hello)
```

Note, however, that installing a file is still considered a type of file "build." This is important when you remember that the default behavior of `SCons` is to build files in or below the current directory. If, as in the example above, you are installing files in a directory outside of the top-level `SConstruct` file's directory tree, you must specify that directory (or a higher directory, such as `/`) for it to install anything there:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q /usr/bin
Install file: "hello" as "/usr/bin/hello"
```

It can, however, be cumbersome to remember (and type) the specific destination directory in which the program (or any other file) should be installed. This is an area where the `Alias` function comes in handy, allowing you, for example, to create a pseudo-target named `install` that can expand to the specified destination directory:

```
env = Environment()
hello = env.Program('hello.c')
env.Install('/usr/bin', hello)
env.Alias('install', '/usr/bin')
```

This then yields the more natural ability to install the program in its destination as follows:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q install
Install file: "hello" as "/usr/bin/hello"
```

Installing Multiple Files in a Directory

You can install multiple files into a directory simply by calling the `Install` function multiple times:

```
env = Environment()
hello = env.Program('hello.c')
goodbye = env.Program('goodbye.c')
env.Install('/usr/bin', hello)
env.Install('/usr/bin', goodbye)
env.Alias('install', '/usr/bin')
```

Or, more succinctly, listing the multiple input files in a list (just like you can do with any other builder):

```
env = Environment()
hello = env.Program('hello.c')
goodbye = env.Program('goodbye.c')
env.Install('/usr/bin', [hello, goodbye])
env.Alias('install', '/usr/bin')
```

Either of these two examples yields:

```
% scons -Q install
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
Install file: "goodbye" as "/usr/bin/goodbye"
cc -c -o hello.o hello.c
cc -o hello hello.o
Install file: "hello" as "/usr/bin/hello"
```

Installing a File Under a Different Name

The Install method preserves the name of the file when it is copied into the destination directory. If you need to change the name of the file when you copy it, use the InstallAs function:

```
env = Environment()
hello = env.Program('hello.c')
env.InstallAs('/usr/bin/hello-new', hello)
env.Alias('install', '/usr/bin')
```

This installs the hello program with the name hello-new as follows:

```
% scons -Q install
cc -c -o hello.o hello.c
cc -o hello hello.o
Install file: "hello" as "/usr/bin/hello-new"
```

Installing Multiple Files Under Different Names

Lastly, if you have multiple files that all need to be installed with different file names, you can either call the InstallAs function multiple times, or as a shorthand, you can supply same-length lists for the both the target and source arguments:

```
env = Environment()
hello = env.Program('hello.c')
goodbye = env.Program('goodbye.c')
env.InstallAs(['/usr/bin/hello-new',
               '/usr/bin/goodbye-new'],
              [hello, goodbye])
env.Alias('install', '/usr/bin')
```

In this case, the InstallAs function loops through both lists simultaneously, and copies each source file into its corresponding target file name:

```
% scons -Q install
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
Install file: "goodbye" as "/usr/bin/goodbye-new"
cc -c -o hello.o hello.c
```

```
cc -o hello hello.o
Install file: "hello" as "/usr/bin/hello-new"
```

Chapter 12. Preventing Removal of Targets: the `Precious` Function

By default, `SCons` removes targets before building them. Sometimes, however, this is not what you want. For example, you may want to update a library incrementally, not by having it deleted and then rebuilt from all of the constituent object files. In such cases, you can use the `Precious` method to prevent `SCons` from removing the target before it is built:

```
env = Environment()
lib = env.Library('foo', ['f1.c', 'f2.c', 'f3.c'])
env.Precious(lib)
```

Although the output doesn't look any different, `SCons` does not, in fact, delete the target library before rebuilding it:

```
% scons -Q
cc -c -o f1.o f1.c
cc -c -o f2.o f2.c
cc -c -o f3.o f3.c
ar r libfoo.a f1.o f2.o f3.o
ranlib libfoo.a
```

`SCons` will, however, still delete files marked as `Precious` when the `-c` option is used.

Chapter 13. Hierarchical Builds

The source code for large software projects rarely stays in a single directory, but is nearly always divided into a hierarchy of directories. Organizing a large software build using `SCons` involves creating a hierarchy of build scripts using the `SConscript` function.

`SConscript` Files

As we've already seen, the build script at the top of the tree is called `SConstruct`. The top-level `SConstruct` file can use the `SConscript` function to include other subsidiary scripts in the build. These subsidiary scripts can, in turn, use the `SConscript` function to include still other scripts in the build. By convention, these subsidiary scripts are usually named `SConscript`. For example, a top-level `SConstruct` file might arrange for four subsidiary scripts to be included in the build as follows:

```
SConscript(['drivers/display/SConscript',
            'drivers/mouse/SConscript',
            'parser/SConscript',
            'utilities/SConscript'])
```

In this case, the `SConstruct` file lists all of the `SConscript` files in the build explicitly. (Note, however, that not every directory in the tree necessarily has an `SConscript` file.) Alternatively, the `drivers` subdirectory might contain an intermediate `SConscript` file, in which case the `SConscript` call in the top-level `SConstruct` file would look like:

```
SConscript(['drivers/SConscript',
            'parser/SConscript',
            'utilities/SConscript'])
```

And the subsidiary `SConscript` file in the `drivers` subdirectory would look like:

```
SConscript(['display/SConscript',
            'mouse/SConscript'])
```

Whether you list all of the `SConscript` files in the top-level `SConstruct` file, or place a subsidiary `SConscript` file in intervening directories, or use some mix of the two schemes, is up to you and the needs of your software.

Path Names Are Relative to the `SConscript` Directory

Subsidiary `SConscript` files make it easy to create a build hierarchy because all of the file and directory names in a subsidiary `SConscript` files are interpreted relative to the directory in which the `SConscript` file lives. Typically, this allows the `SConscript` file containing the instructions to build a target file to live in the same directory as the source files from which the target will be built, making it easy to update how the software is built whenever files are added or deleted (or other changes are made).

For example, suppose we want to build two programs `prog1` and `prog2` in two separate directories with the same names as the programs. One typical way to do this would be with a top-level `SConstruct` file like this:

```
SConscript(['prog1/SConscript',
            'prog2/SConscript'])
```

And subsidiary SConscript files that look like this:

```
env = Environment()
env.Program('prog1', ['main.c', 'foo1.c', 'foo2.c'])
```

And this:

```
env = Environment()
env.Program('prog2', ['main.c', 'bar1.c', 'bar2.c'])
```

Then, when we run SCons in the top-level directory, our build looks like:

```
% scons -Q
cc -c -o prog1/foo1.o prog1/foo1.c
cc -c -o prog1/foo2.o prog1/foo2.c
cc -c -o prog1/main.o prog1/main.c
cc -o prog1/prog1 prog1/main.o prog1/foo1.o prog1/foo2.o
cc -c -o prog2/bar1.o prog2/bar1.c
cc -c -o prog2/bar2.o prog2/bar2.c
cc -c -o prog2/main.o prog2/main.c
cc -o prog2/prog2 prog2/main.o prog2/bar1.o prog2/bar2.o
```

Notice the following: First, you can have files with the same names in multiple directories, like main.c in the above example. Second, unlike standard recursive use of Make, SCons stays in the top-level directory (where the SConstruct file lives) and issues commands that use the path names from the top-level directory to the target and source files within the hierarchy.

Top-Level Path Names in Subsidiary SConscript Files

If you need to use a file from another directory, it's sometimes more convenient to specify the path to a file in another directory from the top-level SConstruct directory, even when you're using that file in a subsidiary SConscript file in a subdirectory. You can tell SCons to interpret a path name as relative to the top-level SConstruct directory, not the local directory of the SConscript file, by appending a # (hash mark) to the beginning of the path name:

```
env = Environment()
env.Program('prog', ['main.c', '#lib/foo1.c', 'foo2.c'])
```

In this example, the lib directory is directly underneath the top-level SConstruct directory. If the above SConscript file is in a subdirectory named src/prog, the output would look like:

```
% scons -Q
cc -c -o lib/foo1.o lib/foo1.c
cc -c -o src/prog/foo2.o src/prog/foo2.c
cc -c -o src/prog/main.o src/prog/main.c
cc -o src/prog/prog src/prog/main.o lib/foo1.o src/prog/foo2.o
```

(Notice that the lib/foo1.o object file is built in the same directory as its source file. See Chapter 14, below, for information about how to build the object file in a different subdirectory.)

Absolute Path Names

Of course, you can always specify an absolute path name for a file--for example:

```
env = Environment()
env.Program('prog', ['main.c', '/usr/joe/lib/foo1.c', 'foo2.c'])
```

Which, when executed, would yield:

```
% scons -Q
cc -c -o src/prog/foo2.o src/prog/foo2.c
cc -c -o src/prog/main.o src/prog/main.c
cc -c -o /usr/joe/lib/foo1.o /usr/joe/lib/foo1.c
cc -o src/prog/prog src/prog/main.o /usr/joe/lib/foo1.o src/prog/foo2.o
```

(As was the case with top-relative path names, notice that the `/usr/joe/lib/foo1.o` object file is built in the same directory as its source file. See Chapter 14, below, for information about how to build the object file in a different subdirectory.)

Sharing Environments (and Other Variables) Between `SConscript` Files

In the previous example, each of the subsidiary `SConscript` files created its own construction environment by calling `Environment` separately. This obviously works fine, but if each program must be built with the same construction variables, it's cumbersome and error-prone to initialize separate construction environments in the same way over and over in each subsidiary `SConscript` file.

`SCons` supports the ability to *export* variables from a parent `SConscript` file to its subsidiary `SConscript` files, which allows you to share common initialized values throughout your build hierarchy.

Exporting Variables

There are two ways to export a variable, such as a construction environment, from an `SConscript` file, so that it may be used by other `SConscript` files. First, you can call the `Export` function with a list of variables, or a string white-space separated variable names. Each call to `Export` adds one or more variables to a global list of variables that are available for import by other `SConscript` files.

```
env = Environment()
Export('env')
```

You may export more than one variable name at a time:

```
env = Environment()
debug = ARGUMENTS['debug']
Export('env', 'debug')
```

Because white space is not legal in Python variable names, the `Export` function will even automatically split a string into separate names for you:

```
Export('env debug')
```

Second, you can specify a list of variables to export as a second argument to the `SConscript` function call:

```
SConscript('src/SConscript', 'env')
```

Or as the `exports` keyword argument:

```
SConscript('src/SConscript', exports='env')
```

These calls export the specified variables to only the listed `SConscript` files. You may, however, specify more than one `SConscript` file in a list:

```
SConscript(['src1/SConscript',
            'src2/SConscript'], exports='env')
```

This is functionally equivalent to calling the `SConscript` function multiple times with the same `exports` argument, one per `SConscript` file.

Importing Variables

Once a variable has been exported from a calling `SConscript` file, it may be used in other `SConscript` files by calling the `Import` function:

```
Import('env')
env.Program('prog', ['prog.c'])
```

The `Import` call makes the `env` construction environment available to the `SConscript` file, after which the variable can be used to build programs, libraries, etc.

Like the `Export` function, the `Import` function can be used with multiple variable names:

```
Import('env', 'debug')
env = env.Copy(DEBUG = debug)
env.Program('prog', ['prog.c'])
```

And the `Import` function will similarly split a string along white-space into separate variable names:

```
Import('env debug')
env = env.Copy(DEBUG = debug)
env.Program('prog', ['prog.c'])
```

Lastly, as a special case, you may import all of the variables that have been exported by supplying an asterisk to the `Import` function:

```
Import('*')
env = env.Copy(DEBUG = debug)
env.Program('prog', ['prog.c'])
```

If you're dealing with a lot of `SConscript` files, this can be a lot simpler than keeping arbitrary lists of imported variables in each file.

Returning Values From an `SConscript` File

Sometimes, you would like to be able to use information from a subsidiary `SConscript` file in some way. For example, suppose that you want to create one library from source files scattered throughout a number of subsidiary `SConscript` files. You can do this by using the `Return` function to return values from the subsidiary `SConscript` files to the calling file.

If, for example, we have two subdirectories `foo` and `bar` that should each contribute a source file to a Library, what we'd like to be able to do is collect the object files from the subsidiary `SConscript` calls like this:

```
env = Environment()
Export('env')
objs = []
for subdir in ['foo', 'bar']:
    o = SConscript('%s/SConscript' % subdir)
    objs.append(o)
env.Library('prog', objs)
```

We can do this by using the `Return` function in the `foo/SConscript` file like this:

```
Import('env')
obj = env.Object('foo.c')
Return('obj')
```

(The corresponding `bar/SConscript` file should be pretty obvious.) Then when we run `SCons`, the object files from the subsidiary subdirectories are all correctly archived in the desired library:

```
% scons -Q
cc -c -o bar/bar.o bar/bar.c
cc -c -o foo/foo.o foo/foo.c
ar r libprog.a foo/foo.o bar/bar.o
ranlib libprog.a
```

Chapter 14. Separating Source and Build Directories

It's often useful to keep any built files completely separate from the source files. This is usually done by creating one or more separate *build directories* that are used to hold the built objects files, libraries, and executable programs, etc. for a specific flavor of build. SCons provides two ways to do this, one through the SConscript function that we've already seen, and the second through a more flexible BuildDir function.

Specifying a Build Directory as Part of an SConscript Call

The most straightforward way to establish a build directory uses the fact that the usual way to set up a build hierarchy is to have an SConscript file in the source subdirectory. If you then pass a build_dir argument to the SConscript function call:

```
SConscript('src/SConscript', build_dir='build')
```

SCons will then build all of the files in the build subdirectory:

```
% ls src
SConscript  hello.c
% scons -Q
cc -c -o build/hello.o build/hello.c
cc -o build/hello build/hello.o
% ls build
SConscript  hello  hello.c  hello.o
```

But wait a minute--what's going on here? SCons created the object file build/hello.o in the build subdirectory, as expected. But even though our hello.c file lives in the src subdirectory, SCons has actually compiled a build/hello.c file to create the object file.

What's happened is that SCons has *duplicated* the hello.c file from the src subdirectory to the build subdirectory, and built the program from there. The next section explains why SCons does this.

Why SCons Duplicates Source Files in a Build Directory

SCons duplicates source files in build directories because it's the most straightforward way to guarantee a correct build *regardless of include-file directory paths, relative references between files, or tool support for putting files in different locations*, and the SCons philosophy is to, by default, guarantee a correct build in all cases.

The most direct reason to duplicate source files in build directories is simply that some tools (mostly older vesions) are written to only build their output files in the same directory as the source files. In this case, the choices are either to build the output file in the source directory and move it to the build directory, or to duplicate the source files in the build directory.

Additionally, relative references between files can cause problems if we don't just duplicate the hierarchy of source files in the build directory. You can see this at work in use of the C preprocessor #include mechanism with double quotes, not angle brackets:

```
#include "file.h"
```

The *de facto* standard behavior for most C compilers in this case is to first look in the same directory as the source file that contains the #include line, then to look in the

directories in the preprocessor search path. Add to this that the SCons implementation of support for code repositories (described below) means not all of the files will be found in the same directory hierarchy, and the simplest way to make sure that the right include file is found is to duplicate the source files into the build directory, which provides a correct build regardless of the original location(s) of the source files.

Although source-file duplication guarantees a correct build even in these end-cases, it *can* usually be safely disabled. The next section describes how you can disable the duplication of source files in the build directory.

Telling SCons to Not Duplicate Source Files in the Build Directory

In most cases and with most tool sets, SCons can place its target files in a build subdirectory *without* duplicating the source files and everything will work just fine. You can disable the default SCons behavior by specifying duplicate=0 when you call the SConscript function:

```
SConscript('src/SConscript', build_dir='build', duplicate=0)
```

When this flag is specified, SCons uses the build directory like most people expect--that is, the output files are placed in the build directory while the source files stay in the source directory:

```
% ls src
SConscript
hello.c
% scons -Q
cc -c src/hello.c -o build/hello.o
cc -o build/hello build/hello.o
% ls build
hello
hello.o
```

The BuildDir Function

Use the BuildDir function to establish that target files should be built in a separate directory from the source files:

```
BuildDir('build', 'src')
env = Environment()
env.Program('build/hello.c')
```

Note that when you're not using an SConscript file in the src subdirectory, you must actually specify that the program must be built from the build/hello.c file that SCons will duplicate in the build subdirectory.

When using the BuildDir function directly, SCons still duplicates the source files in the build directory by default:

```
% ls src
hello.c
% scons -Q
cc -c -o build/hello.o build/hello.c
cc -o build/hello build/hello.o
% ls build
hello  hello.c  hello.o
```

You can specify the same `duplicate=0` argument that you can specify for an `SConscript` call:

```
BuildDir('build', 'src', duplicate=0)
env = Environment()
env.Program('build/hello.c')
```

In which case `SCons` will disable duplication of the source files:

```
% ls src
hello.c
% scons -Q
cc -c -o build/hello.o src/hello.c
cc -o build/hello build/hello.o
% ls build
hello  hello.o
```

Using `BuildDir` With an `SConscript` File

Even when using the `BuildDir` function, it's much more natural to use it with a subsidiary `SConscript` file. For example, if the `src/SConscript` looks like this:

```
env = Environment()
env.Program('hello.c')
```

Then our `SConstruct` file could look like:

```
BuildDir('build', 'src')
SConscript('build/SConscript')
```

Yielding the following output:

```
% ls src
SConscript  hello.c
% scons -Q
cc -c -o build/hello.o build/hello.c
cc -o build/hello build/hello.o
% ls build
SConscript  hello  hello.c  hello.o
```

Notice that this is completely equivalent to the use of `SConscript` that we learned about in the previous section.

Chapter 15. Variant Builds

The `BuildDir` function now gives us everything we need to show how easy it is to create variant builds using `SCons`. Suppose, for example, that we want to build a program for both Windows and Linux platforms, but that we want to build it in a shared directory with separate side-by-side build directories for the Windows and Linux versions of the program.

```
platform = ARGUMENTS.get('OS', Platform())

include = "#export/$PLATFORM/include"
lib = "#export/$PLATFORM/lib"
bin = "#export/$PLATFORM/bin"

env = Environment(PLATFORM = platform,
                  BINDIR = bin,
                  INCDIR = include,
                  LIBDIR = lib,
                  CPPPATH = [include],
                  LIBPATH = [lib],
                  LIBS = 'world')

Export('env')

env.SConscript('src/SConscript', build_dir='build/$PLATFORM')

#
#BuildDir("#build/$PLATFORM", 'src')
#SConscript("build/$PLATFORM/hello/SConscript")
#SConscript("build/$PLATFORM/world/SConscript")
```

This SConstruct file, when run on a Linux system, yields:

```
% scons -Q OS=linux
Install file: "build/linux/world/world.h" as "export/linux/include/world.h"
cc -Iexport/linux/include -c -o build/linux/hello/hello.o build/linux/hello/hello.c
cc -Iexport/linux/include -c -o build/linux/world/world.o build/linux/world/world.c
ar r build/linux/world/libworld.a build/linux/world/world.o
ranlib build/linux/world/libworld.a
Install file: "build/linux/world/libworld.a" as "export/linux/lib/libworld.a"
cc -o build/linux/hello/hello build/linux/hello/hello.o -Lexport/linux/lib -lworld
Install file: "build/linux/hello/hello" as "export/linux/bin/hello"
```

The same SConstruct file on Windows would build:

```
C:\>scons -Q OS=windows
Install file: "build/windows/world/world.h" as "export/windows/include/world.h"
cl /nologo /Iexport\windows\include /c build\windows\hello\hello.c /Fobuild\windows
cl /nologo /Iexport\windows\include /c build\windows\world\world.c /Fobuild\windows
lib /nologo /OUT:build\windows\world\world.lib build\windows\world\world.obj
Install file: "build/windows/world/world.lib" as "export/windows/lib/world.lib"
link /nologo /OUT:build\windows\hello\hello.exe /LIBPATH:export\windows\lib world.l
Install file: "build/windows/hello/hello.exe" as "export/windows/bin/hello.exe"
```

Chapter 16. Writing Your Own Builders

Although SCons provides many useful methods for building common software products: programs, libraries, documents. you frequently want to be able to build some other type of file not supported directly by SCons Fortunately, SCons makes it very easy to define your own Builder objects for any custom file types you want to build. (In fact, the SCons interfaces for creating Builder objects are flexible enough and easy enough to use that all of the the SCons built-in Builder objects are created the mechanisms described in this section.)

Writing Builders That Execute External Commands

The simplest Builder to create is one that executes an external command. For example, if we want to build an output file by running the contents of the input file through a command named foobuild, creating that Builder might look like:

```
bld = Builder(action = 'foobuild < $SOURCE > $TARGET')
```

All the above line does is create a free-standing Builder object. The next section will show us how to actually use it.

Attaching a Builder to a `Construction Environment`

A Builder object isn't useful until it's attached to a construction environment so that we can call it to arrange for files to be built. This is done through the BUILDERS construction variable in an environment. The BUILDERS variable is a Python dictionary that maps the names by which you want to call various Builder objects to the objects themselves. For example, if we want to call the Builder we just defined by the name Foo, our SConstruct file might look like:

```
bld = Builder(action = 'foobuild < $SOURCE > $TARGET')
env = Environment(BUILDERS = {'Foo' : bld})
```

With the Builder so attached to our construction environment we can now actually call it like so:

```
env.Foo('file.foo', 'file.input')
```

Then when we run SCons it looks like:

```
% scons -Q
foobuild < file.input > file.foo
```

Note, however, that the default BUILDERS variable in a construction environment comes with a default set of Builder objects already defined: Program, Library, etc. And when we explicitly set the BUILDERS variable when we create the construction environment, the default Builders are no longer part of the environment:

```
bld = Builder(action = 'foobuild < $SOURCE > $TARGET')
env = Environment(BUILDERS = {'Foo' : bld})
env.Foo('file.foo', 'file.input')
env.Program('hello.c')
```

```
% scons -Q
AttributeError: SConsEnvironment instance has no attribute 'Program':
```

```
File "SConstruct", line 4:
  env.Program('hello.c')
```

To be able use both our own defined `Builder` objects and the default `Builder` objects in the same `construction environment`, you can either add to the `BUILDERS` variable using the `Append` function:

```
env = Environment()
bld = Builder(action = 'foobuild < $SOURCE > $TARGET')
env.Append(BUILDERS = {'Foo' : bld})
env.Foo('file.foo', 'file.input')
env.Program('hello.c')
```

Or you can explicitly set the appropriately-named key in the `BUILDERS` dictionary:

```
env = Environment()
bld = Builder(action = 'foobuild < $SOURCE > $TARGET')
env['BUILDERS']['Foo'] = bld
env.Foo('file.foo', 'file.input')
env.Program('hello.c')
```

Either way, the same `construction environment` can then use both the newly-defined `Foo Builder` and the default `Program Builder`:

```
% scons -Q
foobuild < file.input > file.foo
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Letting `SCons` Handle The File Suffixes

By supplying additional information when you create a `Builder`, you can let `SCons` add appropriate file suffixes to the target and/or the source file. For example, rather than having to specify explicitly that you want the `Foo Builder` to build the `file.foo` target file from the `file.input` source file, you can give the `.foo` and `.input` suffixes to the `Builder`, making for more compact and readable calls to the `Foo Builder`:

```
bld = Builder(action = 'foobuild < $SOURCE > $TARGET',
              suffix = '.foo',
              src_suffix = '.input')
env = Environment(BUILDERS = {'Foo' : bld})
env.Foo('file1')
env.Foo('file2')
```

```
% scons -Q
foobuild < file1.input > file1.foo
foobuild < file2.input > file2.foo
```

You can also supply a `prefix` keyword argument if it's appropriate to have `SCons` append a prefix to the beginning of target file names.

Builders That Execute Python Functions

In SCons, you don't have to call an external command to build a file. You can, instead, define a Python function that a Builder object can invoke to build your target file (or files). Such a builder function definition looks like:

```
def build_function(target, source, env):
    # Code to build "target" from "source"
    return None
```

The arguments of a builder function are:

target

A list of Node objects representing the target or targets to be built by this builder function. The file names of these target(s) may be extracted using the Python str function.

source

A list of Node objects representing the sources to be used by this builder function to build the targets. The file names of these source(s) may be extracted using the Python str function.

env

The construction environment used for building the target(s). The builder function may use any of the environment's construction variables in any way to affect how it builds the targets.

The builder function must return a 0 or None value if the target(s) are built successfully. The builder function may raise an exception or return any non-zero value to indicate that the build is unsuccessful,

Once you've defined the Python function that will build your target file, defining a Builder object for it is as simple as specifying the name of the function, instead of an external command, as the Builder's action argument:

```
def build_function(target, source, env):
    # Code to build "target" from "source"
    return None
bld = Builder(action = build_function,
              suffix = '.foo',
              src_suffix = '.input')
env = Environment(BUILDERS = {'Foo' : bld})
env.Foo('file')
```

And notice that the output changes slightly, reflecting the fact that a Python function, not an external command, is now called to build the target file:

```
% scons -Q
build_function(["file.foo"], ["file.input"])
```

Builders That Create Actions Using a Generator

SCons Builder objects can create an action "on the fly" by using a function called a generator. This provides a great deal of flexibility to construct just the right list of commands to build your target. A generator looks like:

```
def generate_actions(source, target, env, for_signature):
```

```
        return 'foobuild < %s > %s' % (target[0], source[0])
```

The arguments of a `generator` are:

source

A list of Node objects representing the sources to be built by the command or other action generated by this function. The file names of these source(s) may be extracted using the Python `str` function.

target

A list of Node objects representing the target or targets to be built by the command or other action generated by this function. The file names of these target(s) may be extracted using the Python `str` function.

env

The `construction environment` used for building the target(s). The generator may use any of the environment's construction variables in any way to determine what command or other action to return.

for_signature

A flag that specifies whether the generator is being called to contribute to a build signature, as opposed to actually executing the command.

The `generator` must return a command string or other action that will be used to build the specified target(s) from the specified source(s).

Once you've defined a `generator`, you create a `Builder` to use it by specifying the generator keyword argument instead of `action`.

```
def generate_actions(source, target, env, for_signature):
    return 'foobuild < %s > %s' % (source[0], target[0])
bld = Builder(generator = generate_actions,
              suffix = '.foo',
              src_suffix = '.input')
env = Environment(BUILDERS = {'Foo' : bld})
env.Foo('file')
```

```
% scons -Q
foobuild < file.input > file.foo
```

Note that it's illegal to specify both an `action` and a `generator` for a `Builder`.

Builders That Modify the Target or Source Lists Using an `Emitter`

`SCons` supports the ability for a Builder to modify the lists of target(s) from the specified source(s).

```
def modify_targets(target, source, env):
    target.append('new_target')
    source.append('new_source')
    return target, source
bld = Builder(action = 'foobuild $TARGETS - $SOURCES',
              suffix = '.foo',
              src_suffix = '.input',
              emitter = modify_targets)
env = Environment(BUILDERS = {'Foo' : bld})
env.Foo('file')
```

```
% scons -Q
foobuild file.foo new_target - file.input new_source
```

```
bld = Builder(action = 'XXX',
              suffix = '.foo',
              src_suffix = '.input',
              emitter = 'MY_EMITTER')
def modify1(target, source, env):
    return target, source
def modify2(target, source, env):
    return target, source
env1 = Environment(BUILDERS = {'Foo' : bld},
                   MY_EMITTER = modify1)
env2 = Environment(BUILDERS = {'Foo' : bld},
                   MY_EMITTER = modify2)
env1.Foo('file1')
env2.Foo('file2')
```

Chapter 17. Not Writing a Builder: the `Command` Builder

Creating a `Builder` and attaching it to a `construction environment` allows for a lot of flexibility when you want to re-use actions to build multiple files of the same type. This can, however, be cumbersome if you only need to execute one specific command to build a single file (or group of files). For these situations, `SCons` supports a `Command Builder` that arranges for a specific action to be executed to build a specific file or files. This looks a lot like the other builders (like `Program`, `Object`, etc.), but takes as an additional argument the command to be executed to build the file:

```
env = Environment()
env.Command('foo.out', 'foo.in', "sed 's/x/y/' < $SOURCE > $TARGET")
```

```
% scons -Q
sed 's/x/y/' < foo.in > foo.out
```

This is often more convenient than creating a `Builder` object and adding it to the `BUILDERS` variable of a `construction environment`

Note that the action you

```
env = Environment()
def build(target, source, env):
    # Whatever it takes to build
    return None
env.Command('foo.out', 'foo.in', build)
```

```
% scons -Q
build(["foo.out"], ["foo.in"])
```

Chapter 18. Writing Scanners

SCons has built-in scanners that know how to look in C, Fortran and IDL source files for information about other files that targets built from those files depend on--for example, in the case of files that use the C preprocessor, the .h files that are specified using #include lines in the source. You can use the same mechanisms that SCons uses to create its built-in scanners to write scanners of your own for file types that SCons does not know how to scan "out of the box."

A Simple Scanner Example

Suppose, for example, that we want to create a simple scanner for .foo files. A .foo file contains some text that will be processed, and can include other files on lines that begin with include followed by a file name:

```
include filename.foo
```

Scanning a file will be handled by a Python function that you must supply. Here is a function that will use the Python re module to scan for the include lines in our example:

```
import re

include_re = re.compile(r'^include\\s+(\\S+)$', re.M)

def kfile_scan(node, env, path, arg):
    contents = node.get_contents()
    return include_re.findall(contents)
```

The scanner function must accept the four specified arguments and return a list of implicit dependencies. Presumably, these would be dependencies found from examining the contents of the file, although the function can perform any manipulation at all to generate the list of dependencies.

node

An SCons node object representing the file being scanned. The path name to the file can be used by converting the node to a string using the str() function, or an internal SCons get_contents() object method can be used to fetch the contents.

env

The construction environment in effect for this scan. The scanner function may choose to use construction variables from this environment to affect its behavior.

path

A list of directories that form the search path for included files for this scanner. This is how SCons handles the CPPPATH and LIBPATH variables.

arg

An optional argument that you can choose to have passed to this scanner function by various scanner instances.

A Scanner object is created using the Scanner function, which typically takes an skeys argument to associate the type of file suffix with this scanner. The Scanner object must then be associated with the SCANNERS construction variable of a construction environment, typically by using the Append method:

```
kscan = Scanner(function = kfile_scan,
```

```
                skeys = ['.k'])
env.Append(SCANNERS = kscan)
```

When we put it all together, it looks like:

```
import re

include_re = re.compile(r'^include\\s+(\\S+)$', re.M)

def kfile_scan(node, env, path):
    contents = node.get_contents()
    includes = include_re.findall(contents)
    return includes

kscan = Scanner(function = kfile_scan,
                skeys = ['.k'])

env = Environment(ENV = {'PATH' : '/usr/local/bin'})
env.Append(SCANNERS = kscan)

env.Command('foo', 'foo.k', 'kprocess < $SOURCES > $TARGET')
```

Chapter 19. Building From Code Repositories

Often, a software project will have one or more central repositories, directory trees that contain source code, or derived files, or both. You can eliminate additional unnecessary rebuilds of files by having SCons use files from one or more code repositories to build files in your local build tree.

The Repository Method

It's often useful to allow multiple programmers working on a project to build software from source files and/or derived files that are stored in a centrally-accessible repository, a directory copy of the source code tree. (Note that this is not the sort of repository maintained by a source code management system like BitKeeper, CVS, or Subversion. For information about using SCons with these systems, see the section, "Fetching Files From Source Code Management Systems," below.) You use the Repository method to tell SCons to search one or more central code repositories (in order) for any source files and derived files that are not present in the local build tree:

```
env = Environment()
env.Program('hello.c')
Repository('/usr/repository1', '/usr/repository2')
```

Multiple calls to the Repository method will simply add repositories to the global list that SCons maintains, with the exception that SCons will automatically eliminate the current directory and any non-existent directories from the list.

Finding source files in repositories

The above example specifies that SCons will first search for files under the /usr/repository1 tree and next under the /usr/repository2 tree. SCons expects that any files it searches for will be found in the same position relative to the top-level directory. In the above example, if the hello.c file is not found in the local build tree, SCons will search first for a /usr/repository1/hello.c file and then for a /usr/repository1/hello.c file to use in its place.

So given the SConstruct file above, if the hello.c file exists in the local build directory, SCons will rebuild the hello program as normal:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
```

If, however, there is no local hello.c file, but one exists in /usr/repository1, SCons will recompile the hello program from the source file it finds in the repository:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
gcc -c /usr/repository1/hello.c -o hello.o
gcc -o hello hello.o
```

And similarly, if there is no local hello.c file and no /usr/repository1/hello.c, but one exists in /usr/repository2:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Finding the SConstruct file in repositories

SCons will also search in repositories for the SConstruct file and any specified SConscript files. This poses a problem, though: how can SCons search a repository tree for an SConstruct file if the SConstruct file itself contains the information about the pathname of the repository? To solve this problem, SCons allows you to specify repository directories on the command line using the -Y option:

```
% scons -Q -Y /usr/repository1 -Y /usr/repository2
```

When looking for source or derived files, SCons will first search the repositories specified on the command line, and then search the repositories specified in the SConstruct or SConscript files.

Finding derived files in repositories

If a repository contains not only source files, but also derived files (such as object files, libraries, or executables), SCons will perform its normal MD5 signature calculation to decide if a derived file in a repository is up-to-date, or the derived file must be rebuilt in the local build directory. For the SCons signature calculation to work correctly, a repository tree must contain the .sconsign files that SCons uses to keep track of signature information.

Usually, this would be done by a build integrator who would run SCons in the repository to create all of its derived files and .sconsign files, or who would SCons in a separate build directory and copying the resulting tree to the desired repository:

```
% cd /usr/repository1
% scons -Q
cc -c -o file1.o file1.c
cc -c -o file2.o file2.c
cc -c -o hello.o hello.c
cc -o hello hello.o file1.o file2.o
```

(Note that this is safe even if the SConstruct file lists /usr/repository1 as a repository, because SCons will remove the current build directory from its repository list for that invocation.)

Now, with the repository populated, we only need to create the one local source file we're interested in working with at the moment, and use the -Y option to tell SCons to fetch any other files it needs from the repository:

```
% cd $HOME/build
% edit hello.c
% scons -Q -Y /usr/repository1
cc -c -o hello.o hello.c
cc -o hello hello.o /usr/repository1/file1.o /usr/repository1/file2.o
```

Notice that SCons realizes that it does not need to rebuild local copies file1.o and file2.o files, but instead uses the already-compiled files from the repository.

Guaranteeing local copies of files

If the repository tree contains the complete results of a build, and we try to build from the repository without any files in our local tree, something moderately surprising happens:

```
% mkdir $HOME/build2
% cd $HOME/build2
% scons -Q -Y /usr/all/repository hello
scons: 'hello' is up-to-date.
```

Why does SCons say that the hello program is up-to-date when there is no hello program in the local build directory? Because the repository (not the local directory) contains the up-to-date hello program, and SCons correctly determines that nothing needs to be done to rebuild that up-to-date copy of the file.

There are, however, many times when you want to ensure that a local copy of a file always exists. A packaging or testing script, for example, may assume that certain generated files exist locally. To tell SCons to make a copy of any up-to-date repository file in the local build directory, use the Local function:

```
env = Environment()
hello = env.Program('hello.c')
Local(hello)
```

If we then run the same command, SCons will make a local copy of the program from the repository copy, and tell you that it is doing so:

```
% scons -Y /usr/all/repository hello
Local copy of hello from /usr/all/repository/hello
scons: 'hello' is up-to-date.
```

(Notice that, because the act of making the local copy is not considered a "build" of the hello file, SCons still reports that it is up-to-date.)

Chapter 20. Multi-Platform Configuration (`Autoconf` Functionality)

SCons has integrated support for multi-platform build configuration similar to that offered by GNU Autoconf, such as figuring out what libraries or header files are available on the local system. This section describes how to use this SCons feature.

> **Note:** This chapter is still under development, so not everything is explained as well as it should be. See the SCons man page for additional information.

Configure Contexts

The basic framework for multi-platform build configuration in SCons is to attach a configure context to a construction environment by calling the Configure function, perform a number of checks for libraries, functions, header files, etc., and to then call the configure context's Finish method to finish off the configuration:

```
env = Environment()
conf = Configure(env)
# Checks for libraries, header files, etc. go here!
env = conf.Finish()
```

The next sections describe the basic checks that SCons supports, as well as how to add your own custom checks.

Checking for the Existence of Header Files

Testing the existence of a header file requires knowing what language the header file is. A configure context has a CheckCHeader method that checks for the existence of a C header file:

```
env = Environment()
conf = Configure(env)
if not conf.CheckCHeader('math.h'):
    print 'Math.h must be installed!'
    Exit(1)
if conf.CheckCHeader('foo.h'):
    conf.env.Append('-DHAS_FOO_H')
env = conf.Finish()
```

Note that you can choose to terminate the build if a given header file doesn't exist, or you can modify the contstruction environment based on the existence of a header file.

If you need to check for the existence a C++ header file, use the CheckCXXHeader method:

```
env = Environment()
conf = Configure(env)
if not conf.CheckCXXHeader('vector.h'):
    print 'vector.h must be installed!'
    Exit(1)
env = conf.Finish()
```

Checking for the Availability of a Function

Check for the availability of a specific function using the CheckFunc method:

```
env = Environment()
conf = Configure(env)
if not conf.CheckFunc('strcpy'):
    print 'Did not find strcpy(), using local version'
    conf.env.Append('-Dstrcpy=my_local_strcpy')
env = conf.Finish()
```

Checking for the Availability of a Library

Check for the availability of a library using the CheckLib method. You only specify the basename of the library, you don't need to add a lib prefix or a .a or .lib suffix:

```
env = Environment()
conf = Configure(env)
if not conf.CheckLib('m'):
    print 'Did not find libm.a or m.lib, exiting!'
    Exit(1)
env = conf.Finish()
```

Because the ability to use a library successfully often depends on having access to a header file that describes the library's interface, you can check for a library *and* a header file at the same time by using the CheckLibWithHeader method:

```
env = Environment()
conf = Configure(env)
if not conf.CheckLibWithHeader('m', 'math.h'):
    print 'Did not find libm.a or m.lib, exiting!'
    Exit(1)
env = conf.Finish()
```

This is essentially shorthand for separate calls to the CheckHeader and CheckLib functions.

Checking for the Availability of a `typedef`

Check for the availability of a typedef by using the CheckType method:

```
env = Environment()
conf = Configure(env)
if not conf.CheckType('off_t'):
    print 'Did not find off_t typedef, assuming int'
    conf.env.Append(CCFLAGS = '-Doff_t=int')
env = conf.Finish()
```

You can also add a string that will be placed at the beginning of the test file that will be used to check for the typedef. This provide a way to specify files that must be included to find the typedef:

```
env = Environment()
conf = Configure(env)
if not conf.CheckType('off_t', '#include <sys/types.h>\n'):
    print 'Did not find off_t typedef, assuming int'
    conf.env.Append(CCFLAGS = '-Doff_t=int')
```

```
env = conf.Finish()
```

Adding Your Own Custom Checks

A custom check is a Python function that checks for a certain condition to exist on the running system, usually using methods that SCons supplies to take care of the details of checking whether a compilation succeeds, a link succeeds, a program is runnable, etc. A simple custom check for the existence of a specific library might look as follows:

```
mylib_test_source_file = """
#include <mylib.h>
int main(int argc, char **argv)
{
    MyLibrary mylib(argc, argv);
    return 0;
}
"""

def CheckMyLibrary(context):
    context.Message('Checking for MyLibrary...')
    result = context.TryLink(mylib_test_source_file, '.c')
    context.Result(result)
    return result
```

The Message and Result methods should typically begin and end a custom check to let the user know what's going on: the Message call prints the specified message (with no trailing newline) and the Result call prints ok if the check succeeds and failed if it doesn't. The TryLink method actually tests for whether the specified program text will successfully link.

(Note that a custom check can modify its check based on any arguments you choose to pass it, or by using or modifying the configure context environment in the context.env attribute.)

This custom check function is then attached to the configure context by passing a dictionary to the Configure call that maps a name of the check to the underlying function:

```
env = Environment()
conf = Configure(env, custom_tests = {'CheckMyLibrary' : CheckMyLibrary})
```

You'll typically want to make the check and the function name the same, as we've done here, to avoid potential confusion.

We can then put these pieces together and actually call the CheckMyLibrary check as follows:

```
mylib_test_source_file = """
#include <mylib.h>
int main(int argc, char **argv)
{
    MyLibrary mylib(argc, argv);
    return 0;
}
"""

def CheckMyLibrary(context):
    context.Message('Checking for MyLibrary... ')
    result = context.TryLink(mylib_test_source_file, '.c')
```

```
        context.Result(result)
        return result

env = Environment()
conf = Configure(env, custom_tests = {'CheckMyLibrary' : CheckMyLibrary})
if not conf.CheckMyLibrary():
    print 'MyLibrary is not installed!'
    Exit(1)
env = conf.Finish()

# We would then add actual calls like Program() to build
# something using the "env" construction environment.
```

If MyLibrary is not installed on the system, the output will look like:

```
% scons
scons: Reading SConscript file ...
Checking for MyLibrary... failed
MyLibrary is not installed!
```

If MyLibrary is installed, the output will look like:

```
% scons
scons: Reading SConscript file ...
Checking for MyLibrary... failed
scons: done reading SConscript
scons: Building targets ...
    .
    .
    .
```

Chapter 21. Caching Built Files

On multi-developer software projects, you can sometimes speed up every developer's builds a lot by allowing them to share the derived files that they build. SCons makes this easy, as well as reliable.

Specifying the Shared Cache Directory

To enable sharing of derived files, use the CacheDir function in any SConscript file:

```
CacheDir('/usr/local/build_cache')
```

Note that the directory you specify must already exist and be readable and writable by all developers who will be sharing derived files. It should also be in some central location that all builds will be able to access. In environments where developers are using separate systems (like individual workstations) for builds, this directory would typically be on a shared or NFS-mounted file system.

Here's what happens: When a build has a CacheDir specified, every time a file is built, it is stored in the shared cache directory along with its MD5 build signature. On subsequent builds, before an action is invoked to build a file, SCons will check the shared cache directory to see if a file with the exact same build signature already exists. If so, the derived file will not be built locally, but will be copied into the local build directory from the shared cache directory, like so:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q
Retrieved `hello.o' from cache
Retrieved `hello' from cache
```

Keeping Build Output Consistent

One potential drawback to using a shared cache is that your build output can be inconsistent from invocation to invocation, because any given file may be rebuilt one time and retrieved from the shared cache the next time. This can make analyzing build output more difficult, especially for automated scripts that expect consistent output each time.

If, however, you use the --cache-show option, SCons will print the command line that it *would* have executed to build the file, even when it is retrieving the file from the shared cache. This makes the build output consistent every time the build is run:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q --cache-show
cc -c -o hello.o hello.c
cc -o hello hello.o
```

The trade-off, of course, is that you no longer know whether or not SCons has retrieved a derived file from cache or has rebuilt it locally.

Not Retrieving Files From a Shared Cache

Retrieving an already-built file from the shared cache is usually a significant time-savings over rebuilding the file, but how much of a savings (or even whether it saves time at all) can depend a great deal on your system or network configuration. For example, retrieving cached files from a busy server over a busy network might end up being slower than rebuilding the files locally.

In these cases, you can specify the --cache-disable command-line option to tell SCons to not retrieve already-built files from the shared cache directory:

```
% scons -Q
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q
Retrieved `hello.o' from cache
Retrieved `hello' from cache
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q --cache-disable
cc -c -o hello.o hello.c
cc -o hello hello.o
```

Populating a Shared Cache With Already-Built Files

Sometimes, you may have one or more derived files already built in your local build tree that you wish to make available to other people doing builds. For example, you may find it more effective to perform integration builds with the cache disabled (per the previous section) and only populate the shared cache directory with the built files after the integration build has completed successfully. This way, the cache will only get filled up with derived files that are part of a complete, successful build not with files that might be later overwritten while you debug integration problems.

In this case, you can use the the --cache-force option to tell SCons to put all derived files in the cache, even if the files had already been built by a previous invocation:

```
% scons -Q --cache-disable
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q --cache-disable
cc -c -o hello.o hello.c
cc -o hello hello.o
% scons -Q --cache-force
scons: `.' is up to date.
% scons -Q -c
Removed hello.o
Removed hello
% scons -Q
Retrieved `hello.o' from cache
Retrieved `hello' from cache
```

Notice how the above sample run demonstrates that the `--cache-disable` option avoids putting the built `hello.o` and `hello` files in the cache, but after using the `--cache-force` option, the files have been put in the cache for the next invocation to retrieve.

Chapter 22. Alias Targets

We've already seen how you can use the `Alias` function to create a target named `install`:

```
env = Environment()
hello = env.Program('hello.c')
env.Install('/usr/bin', hello)
env.Alias('install', '/usr/bin')
```

You can then use this alias on the command line to tell `SCons` more naturally that you want to install files:

```
% scons -Q install
cc -c -o hello.o hello.c
cc -o hello hello.o
Install file: "hello" as "/usr/bin/hello"
```

Like other `Builder` methods, though, the `Alias` method returns an object representing the alias being built. You can then use this object as input to anothother `Builder`. This is especially useful if you use such an object as input to another call to the `Alias Builder`, allowing you to create a hierarchy of nested aliases:

```
env = Environment()
p = env.Program('foo.c')
l = env.Library('bar.c')
env.Install('/usr/bin', p)
env.Install('/usr/lib', l)
ib = env.Alias('install-bin', '/usr/bin')
il = env.Alias('install-lib', '/usr/lib')
env.Alias('install', [ib, il])
```

This example defines separate `install`, `install-bin`, and `install-lib` aliases, allowing you finer control over what gets installed:

```
% scons -Q install-bin
cc -c -o foo.o foo.c
cc -o foo foo.o
Install file: "foo" as "/usr/bin/foo"
% scons -Q install-lib
cc -c -o bar.o bar.c
ar r libbar.a bar.o
ranlib libbar.a
Install file: "libbar.a" as "/usr/lib/libbar.a"
% scons -Q -c /
Removed foo.o
Removed foo
Removed /usr/bin/foo
Removed bar.o
Removed libbar.a
Removed /usr/lib/libbar.a
% scons -Q install
cc -c -o foo.o foo.c
cc -o foo foo.o
Install file: "foo" as "/usr/bin/foo"
cc -c -o bar.o bar.c
ar r libbar.a bar.o
ranlib libbar.a
Install file: "libbar.a" as "/usr/lib/libbar.a"
```

Chapter 23. Java Builds

So far, we've been using examples of building C and C++ programs to demonstrate the features of SCons. SCons also supports building Java programs, but Java builds are handled slightly differently, which reflects the ways in which the Java compiler and tools build programs differently than other languages' tool chains.

Building Java Class Files: the Java Builder

The basic activity when programming in Java, of course, is to take one or more .java files containing Java source code and to call the Java compiler to turn them into one or more .class files. In SCons, you do this by giving the Java Builder a target directory in which to put the .class files, and a source directory that contains the .java files:

```
Java('classes', 'src')
```

If the src directory contains three .java source files, then running SCons might look like this:

```
% scons -Q
javac -d classes -sourcepath src src/Example1.java src/Example2.java src/Example3
```

SCons will actually search the src directory tree for all of the .java files. The Java compiler will then create the necessary class files in the classes subdirectory, based on the class names found in the .java files.

How SCons Handles Java Dependencies

In addition to searching the source directory for .java files, SCons actually runs the .java files through a stripped-down Java parser that figures out what classes are defined. In other words, SCons knows, without you having to tell it, what .class files will be produced by the javac call. So our one-liner example from the preceding section:

```
Java('classes', 'src')
```

Will not only tell you reliably that the .class files in the classes subdirectory are up-to-date:

```
% scons -Q
javac -d classes -sourcepath src src/Example1.java src/Example2.java src/Example3
% scons -Q classes
scons: `classes' is up to date.
```

But it will also remove all of the generated .class files, even for inner classes, without you having to specify them manually. For example, if our Example1.java and Example3.java files both define additional classes, and the class defined in Example2.java has an inner class, running **scons -c** will clean up all of those .class files as well:

```
% scons -Q
javac -d classes -sourcepath src src/Example1.java src/Example2.java src/Example3
% scons -Q -c classes
Removed classes/Example1.class
Removed classes/AdditionalClass1.class
Removed classes/Example2$Inner2.class
```

```
Removed classes/Example2.class
Removed classes/Example3.class
Removed classes/AdditionalClass3.class
```

Building Java Archive (`.jar`) Files: the `Jar` Builder

After building the class files, it's common to collect them into a Java archive (`.jar`) file, which you do by calling the `Jar` Builder method. If you want to just collect all of the class files within a subdirectory, you can just specify that subdirectory as the `Jar` source:

```
Java(target = 'classes', source = 'src')
Jar(target = 'test.jar', source = 'classes')
```

`SCons` will then pass that directory to the `jar` command, which will collect all of the underlying `.class` files:

```
% scons -Q
javac -d classes -sourcepath src src/Example1.java src/Example2.java src/Example3
jar cf test.jar classes
```

If you want to keep all of the `.class` files for multiple programs in one location, and only archive some of them in each `.jar` file, you can pass the `Jar` builder a list of files as its source. It's extremely simple to create multiple `.jar` files this way, using the lists of target class files created by calls to the `Java` builder as sources to the various `Jar` calls:

```
prog1_class_files = Java(target = 'classes', source = 'prog1')
prog2_class_files = Java(target = 'classes', source = 'prog2')
Jar(target = 'prog1.jar', source = prog1_class_files)
Jar(target = 'prog2.jar', source = prog2_class_files)
```

This will then create `prog1.jar` and `prog2.jar` next to the subdirectories that contain their `.java` files:

```
% scons -Q
javac -d classes -sourcepath prog1 prog1/Example1.java prog1/Example2.java
javac -d classes -sourcepath prog2 prog2/Example3.java prog2/Example4.java
jar cf prog1.jar classes/Example1.class classes/Example2.class
jar cf prog2.jar classes/Example3.class classes/Example4.class
```

Building C Header and Stub Files: the `JavaH` Builder

You can generate C header and source files for implementing native methods, by using the `JavaH` Builder. There are several ways of using the `JavaH` Builder. One typical invocation might look like:

```
classes = Java(target = 'classes', source = 'src/pkg/sub')
JavaH(target = 'native', source = classes)
```

The source is a list of class files generated by the call to the `Java` Builder, and the target is the output directory in which we want the C header files placed. The target gets converted into the `-d` when `SCons` runs `javah`:

```
% scons -Q
javac -d classes -sourcepath src/pkg/sub src/pkg/sub/Example1.java src/pkg/sub/Ex
javah -d native -classpath classes pkg.sub.Example1 pkg.sub.Example2 pkg.sub.Exam
```

In this case, the call to `javah` will generate the header files `native/pkg_sub_Example1.h`, `native/pkg_sub_Example2.h` and `native/pkg_sub_Example3.h`. Notice that `SCons` remembered that the class files were generated with a target directory of `classes`, and that it then specified that target directory as the `-classpath` option to the call to `javah`.

Although it's more convenient to use the list of class files returned by the `Java` Builder as the source of a call to the `JavaH` Builder, you *can* specify the list of class files by hand, if you prefer. If you do, you need to set the `JAVACLASSDIR` construction variable when calling `JavaH`:

```
Java(target = 'classes', source = 'src/pkg/sub')
class_file_list = ['classes/pkg/sub/Example1.class',
                   'classes/pkg/sub/Example2.class',
                   'classes/pkg/sub/Example3.class']
JavaH(target = 'native', source = class_file_list, JAVACLASSDIR = 'classes')
```

The `JAVACLASSDIR` value then gets converted into the `-classpath` when `SCons` runs `javah`:

```
% scons -Q
javac -d classes -sourcepath src/pkg/sub src/pkg/sub/Example1.java src/pkg/sub/Ex
javah -d native -classpath classes pkg.sub.Example1 pkg.sub.Example2 pkg.sub.Exam
```

Lastly, if you don't want a separate header file generated for each source file, you can specify an explicit File Node as the target of the `JavaH` Builder:

```
classes = Java(target = 'classes', source = 'src/pkg/sub')
JavaH(target = File('native.h'), source = classes)
```

Because `SCons` assumes by default that the target of the `JavaH` builder is a directory, you need to use the `File` function to make sure that `SCons` doesn't create a directory named `native.h`. When a file is used, though, `SCons` correctly converts the file name into the `javah -o` option:

```
% scons -Q
javac -d classes -sourcepath src/pkg/sub src/pkg/sub/Example1.java src/pkg/sub/Ex
javah -o native.h -classpath classes pkg.sub.Example1 pkg.sub.Example2 pkg.sub.Ex
```

Building RMI Stub and Skeleton Class Files: the `RMIC` Builder

You can generate Remote Method Invocation stubs by using the `RMIC` Builder. The source is a list of directories, typically returned by a call to the `Java` Builder, and the target is an output directory where the `_Stub.class` and `_Skel.class` files will be placed:

```
classes = Java(target = 'classes', source = 'src/pkg/sub')
RMIC(target = 'outdir', source = classes)
```

As it did with the `JavaH` Builder, `SCons` remembers the class directory and passes it as the `-classpath` option to `rmic`:

```
% scons -Q
javac -d classes -sourcepath src/pkg/sub src/pkg/sub/Example1.java src/pkg/sub/Ex
rmic -d outdir -classpath classes pkg.sub.Example1 pkg.sub.Example2
```

This example would generate the files `outdir/pkg/sub/Example1_Skel.class`, `outdir/pkg/sub/Example1_Stub.class`,`outdir/pkg/sub/Example2_Skel.class` and `outdir/pkg/sub/Example2_Stub.class`.

Chapter 24. Troubleshooting

The experience of configuring any software build tool to build a large code base usually, at some point, involves trying to figure out why the tool is behaving a certain way, and how to get it to behave the way you want. SCons is no different.

Why is That Target Being Rebuilt? the --debug=explain Option

Let's take a simple example of a misconfigured build that causes a target to be rebuilt every time SCons is run:

```
# Intentionally misspell the output file name in the
# command used to create the file:
Command('file.out', 'file.in', 'cp $SOURCE file.oout')
```

(Note to Windows users: The POSIX cp command copies the first file named on the command line to the second file. In our example, it copies the file.in file to the file.out file.)

Now if we run SCons multiple on this example, we see that it re-runs the cp command every time:

```
% scons -Q
cp file.in file.oout
% scons -Q
cp file.in file.oout
% scons -Q
cp file.in file.oout
```

In this example, the underlying cause is obvious: we've intentionally misspelled the output file name in the cp command, so the command doesn't actually build the file.out file that we've told SCons to expect. But if the problem weren't obvious, it would be helpful to specify the --debug=explain option on the command line to have SCons tell us very specifically why it's decided to rebuild the target:

```
% scons -Q --debug=explain
scons: building 'file.out' because it doesn't exist
cp file.in file.oout
```

If this had been a more complicated example involving a lot of build output, having SCons tell us that it's trying to rebuild the target file because it doesn't exist would be an important clue that something was wrong with the command that we invoked to build it.

The --debug=explain option also comes in handy to help figure out what input file changed. Given a simple configuration that builds a program from three source files, changing one of the source files and rebuilding with the --debug=explain option shows very specifically why SCons rebuilds the files that it does:

```
% scons -Q
cc -c -o file1.o file1.c
cc -c -o file2.o file2.c
cc -c -o file3.o file3.c
cc -o prog file1.o file2.o file3.o
% edit file2.c
    [CHANGE THE CONTENTS OF file2.c]
% scons -Q --debug=explain
scons: rebuilding 'file2.o' because 'file2.c' changed
cc -c -o file2.o file2.c
scons: rebuilding 'prog' because 'file2.o' changed
```

```
cc -o prog file1.o file2.o file3.o
```

This becomes even more helpful in identifying when a file is rebuilt due to a change in an implicit dependency, such as an incuded `.h` file. If the `file1.c` and `file3.c` files in our example both included a `hello.h` file, then changing that included file and re-running `SCons` with the `--debug=explain` option will pinpoint that it's the change to the included file that starts the chain of rebuilds:

```
% scons -Q
cc -I. -c -o file1.o file1.c
cc -I. -c -o file2.o file2.c
cc -I. -c -o file3.o file3.c
cc -o prog file1.o file2.o file3.o
% edit hello.h
    [CHANGE THE CONTENTS OF hello.h]
% scons -Q --debug=explain
scons: rebuilding 'file1.o' because 'hello.h' changed
cc -I. -c -o file1.o file1.c
scons: rebuilding 'file3.o' because 'hello.h' changed
cc -I. -c -o file3.o file3.c
scons: rebuilding 'prog' because:
           'file1.o' changed
           'file3.o' changed
cc -o prog file1.o file2.o file3.o
```

Appendix A. Handling Common Tasks

There is a common set of simple tasks that many build configurations rely on as they become more complex. Most build tools have special purpose constructs for performing these tasks, but since `SConscript` files are `Python` scripts, you can use more flexible built-in `Python` services to perform these tasks. This appendix lists a number of these tasks and how to implement them in `Python`.

Example A-1. Wildcard globbing to create a list of filenames

```
import glob
files = glob.glob(wildcard)
```

Example A-2. Filename extension substitution

```
import os.path
filename = os.path.splitext(filename)[0]+extension
```

Example A-3. Appending a path prefix to a list of filenames

```
import os.path
filenames = [os.path.join(prefix, x) for x in filenames]
```

or in Python 1.5.2:

```
import os.path
new_filenames = []
for x in filenames:
    new_filenames.append(os.path.join(prefix, x))
```

Example A-4. Substituting a path prefix with another one

```
if filename.find(old_prefix) == 0:
    filename = filename.replace(old_prefix, new_prefix)
```

or in Python 1.5.2:

```
import string
if string.find(filename, old_prefix) == 0:
    filename = string.replace(filename, old_prefix, new_prefix)
```

Example A-5. Filtering a filename list to exclude/retain only a specific set of extensions

```
import os.path
filenames = [x for x in filenames if os.path.splitext(x)[1] in extensions]
```

or in Python 1.5.2:

```
import os.path
new_filenames = []
for x in filenames:
    if os.path.splitext(x)[1] in extensions:
        new_filenames.append(x)
```

Example A-6. The "backtick function": run a shell command and capture the output

```
import os
output = os.popen(command).read()
```