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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.
Preface
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:

```bash
$ 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:

```bash
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 program 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/.
Chapter 1. Building and Installing SCons

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 gnrpm. See your package manager application’s documentation 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:

```bash
# 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:

```bash
# 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

2. http://www.rpmfind.net/
3. http://rpm.pbone.net/
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 different programming languages on different types of systems.

Building Simple C / C++ Programs

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

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

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

```python
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 ...
c1 /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.
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
c -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 ...
c /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:
Chapter 2. Simple Builds

# 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. 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:

```python
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.
Chapter 2. Simple Builds

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:

```bash
C:\>scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
c/ /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`:

```bash
C:\>scons -Q
c/ /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
```
Chapter 3. Less Simple Things to Do With Builds

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:

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

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

```sh
% 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:

```sh
C:\>scons -Q
cl /nologo /c file1.c /Fo:file1.obj
cl /nologo /c file2.c /Fo:file2.obj
cl /nologo /c main.c /Fo:main.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:

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

And one with a single file:

```python
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:

```python
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:

```python
# 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:

```python
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:

```python
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:

```python
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:

```python
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.)
Chapter 3. Less Simple Things to Do With Builds

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:

```python
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:

```python
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:

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

SCons would then build the programs as follows:

```bash
% 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:

```python
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:

```python
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 3. Less Simple Things to Do With Builds
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:
Chapter 4. Building and Linking with Libraries

% 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 4. Building and Linking with Libraries
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:

```python
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:

```python
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:

```python
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 -DGGOODBYE -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 -DGGOODBYE /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.
Chapter 5. Node Objects

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, respectively, return a file or directory Node:

```python
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.

```python
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:

```python
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:

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

And the following file names on a Windows system:

```cmd
C:\>scons -Q
The object file is: hello.obj
The program file is: hello.exe
c1 /nologo /c hello.c /Fohello.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 built-in 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:

```python
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 by re-invoking SCons after building our simple hello example:

```
% scons -Q
cc -c -o hello.o hello.c
c -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
c -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
c -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
```
Chapter 6. Dependencies

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
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:

```python
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:

```python
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
c -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:

```python
#include <hello.h>
int
```
Chapter 6. Dependencies

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

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

```c
#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:

```python
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:

```bash
% 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:

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

Will look like this on POSIX or Linux:

```bash
% 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:

```bash
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
```
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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:

```python
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:

```python
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 specify explicitly that one file depends on another file, and must be rebuilt whenever that file changes. This is specified using the Depends method:

```python
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
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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 accommodates 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:

```python
env = Environment()
```

By default, SCons initializes 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:

```python
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:

```bash
% 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:

```python
opt = Environment(CCFLAGS = '-O2')
dbg = Environment(CCFLAGS = '-g')
opt.Program('foo', 'foo.c')
dbg.Program('bar', 'bar.c')
```

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

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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:

```python
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 target: foo.o
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:

```python
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:

```python
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:

```bash
% 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:

```python
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:

```bash
% 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:

```python
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:
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\%
\% scons -Q
key = OBJSUFX, value = .o
key = LIBSUFX, value = .a
key = PROGSUFX, value = .scons: "." is up to date.

And on Win32:

\%
\% scons -Q
key = OBJSUFX, value = .obj
key = LIBSUFX, value = .lib
key = PROGSUFX, 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 $CCOM:

```
env = Environment(CCFLAGS = ‘-DFOO’)  
print "CCOM is:”, env[‘CCOM’]
```

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

\%
\% scons -Q
CCOM 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 "CCOM is:”, env.subst(‘$CCOM’)  
```
Chapter 7. Construction Environments

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')
```
Chapter 7. Construction Environments

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:

```python
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:

```python
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:

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

```python
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:

```python
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):

```python
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 likely 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:

```python
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 explicitly 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:

```python
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 explicitly 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
Chapter 9. Controlling a Build From the Command Line

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:

```python
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:

```python
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:

```python
env = Environment()
prog1 = env.Program('prog1.c')
```
Chapter 9. Controlling a Build From the Command Line

```python
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`:

```python
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:

```python
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
```

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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`:

```python
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`):

```bash%
% 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:

```python
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:

```bash%
% 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:

```python
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:

```python
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 .
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:

```python
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 com-
mand 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 val-
ues 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 appropri-
ate -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:

```python
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:

```bash
% 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:

```python
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:

```bash
% 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:

```python
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:
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RELEASE = 1

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

```bash
% 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:

```python
RELEASE = 0
```

The object files are rebuilt appropriately with the new option:

```bash
% 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 accommodate users who have different preferences for how to represent true or false values. The `BoolOption` function makes it easy to accommodate 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:

```python
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:

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

```bash
% 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:

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

```bash
% scons -Q RELEASE=f foo.o
cc -DRELEASE_BUILD=0 -c -o foo.o foo.c
```
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```
% 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 explicitly 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',
map={'navy': 'blue'}))
env = Environment(options = opts,
CPPDEFINES={'COLOR' : '"${COLOR}"'})
env.Program('foo.c')
```
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```python
allowed_values=('red', 'green', 'blue'),
    map={'navy': 'blue'})
env = Environment(options=opts,
    CPPDEFINES={'COLOR': '${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:

```python
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:

```python
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')
```
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```python
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:

```python
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 ?
```

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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 controls the location of a configuration file:

```python
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
c -DCONFIG_FILE="/etc/my_config" -c -o foo.o foo.c
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:

```python
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 function, 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/etc/other_config" foo.o
scons: 'foo.o' is up to date.
% scons -Q PACKAGE=yes foo.o
cc -DPACKAGE="/opt/location" -c -o foo.o foo.c
% scons -Q PACKAGE=no foo.o
cc -DPACKAGE="/usr/local/etc/other_config" -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:

```python
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 similar', 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 9. Controlling a Build From the Command Line
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):
Chapter 11. Installing Files in Other Directories: the Install Builder

```python
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:

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

```python
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:

```bash
% 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:

```python
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:

```bash
% scons -Q install
cc -c -o goodbye.o goodbye.c
cc -o goodbye goodbye.o
Install file: "goodbye" as "/usr/bin/goodbye-new"
c
cc -c -o hello.o hello.c
```
Chapter 11. Installing Files in Other Directories: the Install Builder

cc -o hello hello.o
Install file: "hello" as "/usr/bin/hello-new"
Chapter 11. Installing Files in Other Directories: the Install Builder
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:

```python
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:

```bash
% scons -Q
cc -c -o f1.o f1.c
c -c -o f2.o f2.c
c -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:

\[
\text{SConstruct}([\text{'drivers/display/SConscript'},
\text{'drivers/mouse/SConscript'},
\text{'parser/SConscript'},
\text{'utilities/SConscript']})
\]

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:

\[
\text{SConstruct}([\text{'drivers/SConscript'},
\text{'parser/SConscript'},
\text{'utilities/SConscript']})
\]

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

\[
\text{SConscript}([\text{'display/SConscript'},
\text{'mouse/SConscript']})
\]

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:

\[
\text{SConstruct}([\text{'prog1/SConscript'},
\text{'prog2/SConscript']})
\]
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.)
Chapter 13. Hierarchical Builds

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', 'debug')
```

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

```
env = Environment()
deploy = ARGUMENTS['deploy']
env.Program('deploy', ['do1.c', 'do2.c'])
Export('env', 'deploy')
```

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:
Chapter 13. Hierarchical Builds

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:

```python
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:

```python
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:

```bash
% 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:

```python
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 versions) 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:

```c
#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:

```python
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:

```python
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:

```python
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:

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

Then our `SConstruct` file could look like:

```python
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.

```python
platform = ARGUMENTS.get('OS', Platform())
include = '#export/$PLATFORM/include'
lib = '#export/$PLATFORM/lib'
bin = '#export/$PLATFORM/bin'

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

Export('directory')

directory.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
cp -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/world.lib"
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"
cp /nologo /Iexport\windows\include /c build\windows\hello\hello.c /Fobuild\windows\hello\hello.obj
cc /nologo /Iexport\windows\include /c build\windows\world\world.c /Fobuild\windows\world\world.obj
lib /nologo /OUT:build\windows\world\libworld.a 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.lib
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:

```python
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:

```python
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:

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

Then when we run SCons it looks like:

```
% scons -Q
foo build < 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:

```python
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':
```
Chapter 16. Writing Your Own Builders

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:

```python
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:

```python
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:

```bash
% 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:

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

```bash
% 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.
Chapter 16. Writing Your Own Builders

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:

```python
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:

```python
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:

```python
def generate_actions(source, target, env, for_signature):
```
Chapter 16. Writing Your Own Builders

```python
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`.

```python
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).

```python
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')
```

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Chapter 16. Writing Your Own Builders

```python
\% 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 16. Writing Your Own Builders
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:

```python
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

```python
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'])
```

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Chapter 17. Not Writing a Builder: the *Command Builder*
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,
```
When we put it all together, it looks like:

```python
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')
```

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:

```python
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:

```python
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:

```python
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:

```python
env = Environment()
conf = Configure(env)
if not conf.CheckCHeader('math.h'):
    print 'Math.h must be installed!'
    Exit(1)
if conf.CheckCXXHeader('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 construction 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:

```python
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:

```python
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:

```python
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:

```python
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:

```python
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:

```python
env = Environment()
conf = Configure(env)
if not conf.CheckType('off_t', '#include <sys/types.h>
'): 
    print 'Did not find off_t typedef, assuming int'
    conf.env.Append(CCFLAGS = '-Doff_t=int')
```
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:

```python
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:

```python
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:

```python
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
```
Chapter 21. Caching Built Files

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:

```bash
% scons -Q
  cc -c -o hello.o hello.c
  cc -o hello hello.o
% scons --cache-disable
  Removed hello.o
  Removed hello
% scons -Q
  Retrieved 'hello.o' from cache
  Retrieved 'hello' from cache
% scons --cache-disable
  Removed hello.o
  Removed hello
% scons --cache-force
  cc -c -o hello.o hello.c
  cc -o hello hello.o
% scons -Q
  Retrieved 'hello.o' from cache
  Retrieved 'hello' from cache
```

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:

```bash
% scons --cache-disable
  cc -c -o hello.o hello.c
  cc -o hello hello.o
% scons --cache-disable
  Removed hello.o
  Removed hello
% scons --cache-force
  cc -c -o hello.o hello.c
  cc -o hello hello.o
% 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 21. Caching Built Files
Chapter 22. Alias Targets

We’ve already seen how you can use the `Alias` function to create a target named `install`:

```python
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:

```bash
% 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 another `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:

```python
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:

```bash
% 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.java

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.java
% 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.java
% scons -Q -c classes
Removed classes/Example1.class
Removed classes/AdditonalClass1.class
Removed classes/Example2$Inner2.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
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:

```bash
% scons -Q javac -d classes -sourcepath src src/Example1.java src/Example2.java src/Example3.java
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:

```java
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:

```bash
% 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:

```java
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:
Chapter 23. Java Builds

% 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.Exa

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:
Chapter 23. Java Builds

% scons -Q
   javac -d classes -sourcepath src/pkg/sub src/pkg/sub/Example1.java src/pkg/sub/Example2.java
   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:

```python
# 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:

```bash
% 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.oout 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:

```bash
% 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:

```bash
% 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
```
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```
c -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 included .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

```python
import glob
files = glob.glob(wildcard)
```

Example A-2. Filename extension substitution

```python
import os.path
filename = os.path.splitext(filename)[0]+extension
```

Example A-3. Appending a path prefix to a list of filenames

```python
import os.path
filenames = [os.path.join(prefix, x) for x in filenames]
```

or in Python 1.5.2:

```python
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

```python
if filename.find(old_prefix) == 0:
    filename = filename.replace(old_prefix, new_prefix)
```

or in Python 1.5.2:

```python
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

```python
import os.path
filenames = [x for x in filenames if os.path.splitext(x)[1] in extensions]
```

or in Python 1.5.2:

```python
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

```python
import os
output = os.popen(command).read()
```