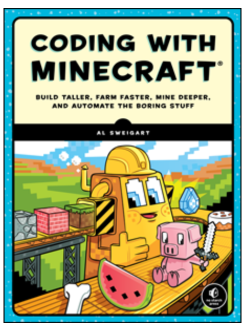

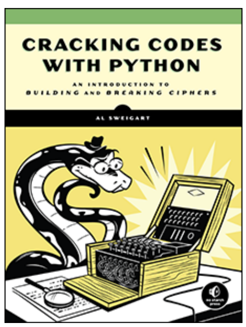

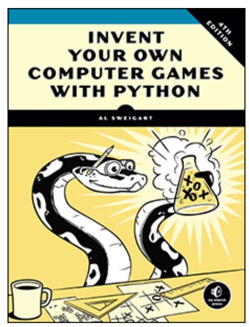

11
DEBUGGING

Now that you know enough to write more complicated programs, you may start finding not-so-simple bugs in them. This chapter covers some tools and techniques for finding the root cause of bugs in your program to help you fix bugs faster and with less effort.

To paraphrase an old joke among programmers, writing code accounts for 90 percent of programming. Debugging code accounts for the other 90 percent.

Your computer will do only what you tell it to do; it won't read your mind and do what you *intended* it to do. Even professional programmers create bugs all the time, so don't feel discouraged if your program has a problem.

Fortunately, there are a few tools and techniques to identify what exactly your code is doing and where it's going wrong. First, you will look at logging and assertions, two features that can help you detect bugs early. In general, the earlier you catch bugs, the easier they will be to fix.

Second, you will look at how to use the debugger. The debugger is a feature of Mu that executes a program one instruction at a time, giving you a chance to inspect the values in variables while your code runs, and track how the values change over the course of your program. This is much slower than running the program at full speed, but it is helpful to see the actual values in a program while it runs, rather than deducing what the values might be from the source code.

Raising Exceptions

Python raises an exception whenever it tries to execute invalid code. In Chapter 3, you read about how to handle Python's exceptions with try and except statements so that your program can recover from exceptions that you anticipated. But you can also raise your own exceptions in your code. Raising an exception is a way of saying, "Stop running the code in this function and move the program execution to the except statement."

Exceptions are raised with a raise statement. In code, a raise statement consists of the following:

- The raise keyword
- A call to the Exception() function
- A string with a helpful error message passed to the Exception() function

For example, enter the following into the interactive shell:

```
>>> raise Exception('This is the error message.')
Traceback (most recent call last):
  File "<pyshell#191>", line 1, in <module>
```

```
    raise Exception('This is the error message.')
Exception: This is the error message.
```

If there are no try and except statements covering the raise statement that raised the exception, the program simply crashes and displays the exception's error message.

Often it's the code that calls the function, rather than the function itself, that knows how to handle an exception. That means you will commonly see a raise statement inside a function and the try and except statements in the code calling the function. For example, open a new file editor tab, enter the following code, and save the program as *boxPrint.py*:

```
def boxPrint(symbol, width, height):
    if len(symbol) != 1:
      ❶ raise Exception('Symbol must be a single character string.')
    if width <= 2:
      ❷ raise Exception('Width must be greater than 2.')
    if height <= 2:
      ❸ raise Exception('Height must be greater than 2.')

    print(symbol * width)
    for i in range(height - 2):
        print(symbol + (' ' * (width - 2)) + symbol)
    print(symbol * width)

for sym, w, h in (('*', 4, 4), ('O', 20, 5), ('x', 1, 3), ('ZZ', 3, 3)):
    try:
        boxPrint(sym, w, h)
  ❹ except Exception as err:
      ❺ print('An exception happened: ' + str(err))
```

You can view the execution of this program at *https://autbor.com/boxprint*. Here we've defined a boxPrint() function that takes a character, a width, and a height, and uses the character to make a little picture of a box with that width and height. This box shape is printed to the screen.

Say we want the character to be a single character, and the width and height to be greater than 2. We add if statements to raise exceptions if these requirements aren't satisfied. Later, when we call boxPrint() with various arguments, our try/except will handle invalid arguments.

This program uses the except Exception as err form of the except statement ❹. If an Exception object is returned from boxPrint() ❶ ❷ ❸, this except statement will store it in a variable named err. We can then convert the Exception object to a string by passing it to str() to produce a user-friendly error message ❺. When you run this *boxPrint.py*, the output will look like this:

```
****
*  *
*  *
****
OOOOOOOOOOOOOOOOOOOO
O                  O
O                  O
O                  O
OOOOOOOOOOOOOOOOOOOO
An exception happened: Width must be greater than 2.
An exception happened: Symbol must be a single character string.
```

Using the try and except statements, you can handle errors more gracefully instead of letting the entire program crash.

Getting the Traceback as a String

When Python encounters an error, it produces a treasure trove of error information called the *traceback*. The traceback includes the error message, the line number of the line that caused the error, and the sequence of the function calls that led to the error. This sequence of calls is called the *call stack*.

Open a new file editor tab in Mu, enter the following program, and save it as *errorExample.py*:

```
def spam():
    bacon()

def bacon():
    raise Exception('This is the error message.')
```

```
spam()
```

When you run *errorExample.py*, the output will look like this:

```
Traceback (most recent call last):
  File "errorExample.py", line 7, in <module>
    spam()
  File "errorExample.py", line 2, in spam
    bacon()
  File "errorExample.py", line 5, in bacon
    raise Exception('This is the error message.')
Exception: This is the error message.
```

From the traceback, you can see that the error happened on line 5, in the bacon() function. This particular call to bacon() came from line 2, in the spam() function, which in turn was called on line 7. In programs where functions can be called from multiple places, the call stack can help you determine which call led to the error.

Python displays the traceback whenever a raised exception goes unhandled. But you can also obtain it as a string by calling traceback.format_exc(). This function is useful if you want the information from an exception's traceback but also want an except statement to gracefully handle the exception. You will need to import Python's traceback module before calling this function.

For example, instead of crashing your program right when an exception occurs, you can write the traceback information to a text file and keep your program running. You can look at the text file later, when you're ready to debug your program. Enter the following into the interactive shell:

```
>>> import traceback
>>> try:
...       raise Exception('This is the error message.')
except:
...       errorFile = open('errorInfo.txt', 'w')
...       errorFile.write(traceback.format_exc())
...       errorFile.close()
...       print('The traceback info was written to errorInfo.txt.')
```

```
111
The traceback info was written to errorInfo.txt.
```

The 111 is the return value from the write() method, since 111 characters were written to the file. The traceback text was written to *errorInfo.txt*.

```
Traceback (most recent call last):
  File "<pyshell#28>", line 2, in <module>
Exception: This is the error message.
```

In “Logging” on page 255, you’ll learn how to use the logging module, which is more effective than simply writing this error information to text files.

Assertions

An *assertion* is a sanity check to make sure your code isn’t doing something obviously wrong. These sanity checks are performed by assert statements. If the sanity check fails, then an AssertionError exception is raised. In code, an assert statement consists of the following:

- The assert keyword
- A condition (that is, an expression that evaluates to True or False)
- A comma
- A string to display when the condition is False

In plain English, an assert statement says, “I assert that the condition holds true, and if not, there is a bug somewhere, so immediately stop the program.” For example, enter the following into the interactive shell:

```
>>> ages = [26, 57, 92, 54, 22, 15, 17, 80, 47, 73]
>>> ages.sort()
>>> ages
[15, 17, 22, 26, 47, 54, 57, 73, 80, 92]
>>> assert
ages[0] <= ages[-1] # Assert that the first age is <= the last age.
```

The assert statement here asserts that the first item in ages should be less than or equal to the last one. This is a sanity check; if the code in sort() is bug-free and did its job, then the assertion would be true.

Because the ages[0] <= ages[-1] expression evaluates to True, the assert statement does nothing.

However, let's pretend we had a bug in our code. Say we accidentally called the reverse() list method instead of the sort() list method. When we enter the following in the interactive shell, the assert statement raises an AssertionError:

```
>>> ages = [26, 57, 92, 54, 22, 15, 17, 80, 47, 73]
>>> ages.reverse()
>>> ages
[73, 47, 80, 17, 15, 22, 54, 92, 57, 26]
>>> assert ages[0] <= ages[-1] # Assert that the first age is <= the last age.
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AssertionError
```

Unlike exceptions, your code should *not* handle assert statements with try and except; if an assert fails, your program *should* crash. By "failing fast" like this, you shorten the time between the original cause of the bug and when you first notice the bug. This will reduce the amount of code you will have to check before finding the bug's cause.

Assertions are for programmer errors, not user errors. Assertions should only fail while the program is under development; a user should never see an assertion error in a finished program. For errors that your program can run into as a normal part of its operation (such as a file not being found or the user entering invalid data), raise an exception instead of detecting it with an assert statement. You shouldn't use assert statements in place of raising exceptions, because users can choose to turn off assertions. If you run a Python script with python -O myscript.py instead of python myscript.py, Python will skip assert statements. Users might disable assertions when they're developing a program and need to run it in a production setting that requires peak performance. (Though, in many cases, they'll leave assertions enabled even then.)

Assertions also aren't a replacement for comprehensive testing. For instance, if the previous ages example was set to [10, 3, 2, 1, 20], then the assert ages[0] <= ages[-1] assertion wouldn't notice that the list was unsorted, because it just happened to have a first age that was less than or equal to the last age, which is the only thing the assertion checked for.

Using an Assertion in a Traffic Light Simulation

Say you're building a traffic light simulation program. The data structure representing the stoplights at an intersection is a dictionary with keys 'ns' and 'ew', for the stoplights facing north-south and east-west, respectively. The values at these keys will be one of the strings 'green', 'yellow', or 'red'. The code would look something like this:

```
market_2nd = {'ns': 'green', 'ew': 'red'}
mission_16th = {'ns': 'red', 'ew': 'green'}
```

These two variables will be for the intersections of Market Street and 2nd Street, and Mission Street and 16th Street. To start the project, you want to write a switchLights() function, which will take an intersection dictionary as an argument and switch the lights.

At first, you might think that switchLights() should simply switch each light to the next color in the sequence: Any 'green' values should change to 'yellow', 'yellow' values should change to 'red', and 'red' values should change to 'green'. The code to implement this idea might look like this:

```
def switchLights(stoplight):
    for key in stoplight.keys():
        if stoplight[key] == 'green':
            stoplight[key] = 'yellow'
        elif stoplight[key] == 'yellow':
            stoplight[key] = 'red'
        elif stoplight[key] == 'red':
            stoplight[key] = 'green'

switchLights(market_2nd)
```

You may already see the problem with this code, but let's pretend you wrote the rest of the simulation code, thousands of lines long, without noticing it. When you finally do run the simulation, the program doesn't crash—but your virtual cars do!

Since you've already written the rest of the program, you have no idea where the bug could be. Maybe it's in the code simulating the cars or in the code simulating the virtual drivers. It could take hours to trace the bug back to the switchLights() function.

But if while writing switchLights() you had added an assertion to check that *at least one of the lights is always red*, you might have included the following at the bottom of the function:

```
assert 'red' in stoplight.values(), 'Neither light is red! ' + str(stoplight)
```

With this assertion in place, your program would crash with this error message:

```
Traceback (most recent call last):
  File "carSim.py", line 14, in <module>
    switchLights(market_2nd)
  File "carSim.py", line 13, in switchLights
    assert 'red' in stoplight.values(), 'Neither light is red! ' +
str(stoplight)
❶ AssertionError: Neither light is red! {'ns': 'yellow', 'ew': 'green'}
```

The important line here is the AssertionError ❶. While your program crashing is not ideal, it immediately points out that a sanity check failed: neither direction of traffic has a red light, meaning that traffic could be going both ways. By failing fast early in the program's execution, you can save yourself a lot of future debugging effort.

Logging

If you've ever put a print() statement in your code to output some variable's value while your program is running, you've used a form of *logging* to debug your code. Logging is a great way to understand what's happening in your program and in what order it's happening. Python's logging module makes it easy to create a record of custom messages that you write. These log messages will describe when the program execution has reached the logging function call and list any variables you have specified at that point in time. On the other hand, a missing log message indicates a part of the code was skipped and never executed.

Using the logging Module

To enable the logging module to display log messages on your screen as your program runs, copy the following to the top of your program (but under the #! python shebang line):

```
import logging
logging.basicConfig(level=logging.DEBUG, format=' %(asctime)s -  %(levelname)
s -  %(message)s')
```

You don't need to worry too much about how this works, but basically, when Python logs an event, it creates a LogRecord object that holds information about that event. The logging module's basicConfig() function lets you specify what details about the LogRecord object you want to see and how you want those details displayed.

Say you wrote a function to calculate the *factorial* of a number. In mathematics, factorial 4 is 1 × 2 × 3 × 4, or 24. Factorial 7 is 1 × 2 × 3 × 4 × 5 × 6 × 7, or 5,040. Open a new file editor tab and enter the following code. It has a bug in it, but you will also enter several log messages to help yourself figure out what is going wrong. Save the program as *factorialLog.py*.

```
import logging
logging.basicConfig(level=logging.DEBUG, format='%(asctime)s -  %(levelname)s
-  %(message)s')
logging.debug('Start of program')


def factorial(n):
    logging.debug('Start of factorial(%s%%)'  % (n))
    total = 1
    for i in range(n + 1):
        total *= i
        logging.debug('i is ' + str(i) + ', total is ' + str(total))
    logging.debug('End of factorial(%s%%)'  % (n))
    return total


print(factorial(5))
logging.debug('End of program')
```

Here, we use the logging.debug() function when we want to print log information. This debug() function will call basicConfig(), and a line of information will be printed. This information will be in the format we specified in basicConfig() and will include the messages we passed to debug(). The print(factorial(5)) call is part of the original program, so the result is displayed even if logging messages are disabled.

The output of this program looks like this:

```
2019-05-23 16:20:12,664 - DEBUG - Start of program
2019-05-23 16:20:12,664 - DEBUG - Start of factorial(5)
2019-05-23 16:20:12,665 - DEBUG - i is 0, total is 0
```

```
2019-05-23 16:20:12,668 - DEBUG - i is 1, total is 0
2019-05-23 16:20:12,670 - DEBUG - i is 2, total is 0
2019-05-23 16:20:12,673 - DEBUG - i is 3, total is 0
2019-05-23 16:20:12,675 - DEBUG - i is 4, total is 0
2019-05-23 16:20:12,678 - DEBUG - i is 5, total is 0
2019-05-23 16:20:12,680 - DEBUG - End of factorial(5)
0
2019-05-23 16:20:12,684 - DEBUG - End of program
```

The factorial() function is returning 0 as the factorial of 5, which isn't right. The for loop should be multiplying the value in total by the numbers from 1 to 5. But the log messages displayed by logging.debug() show that the i variable is starting at 0 instead of 1. Since zero times anything is zero, the rest of the iterations also have the wrong value for total. Logging messages provide a trail of breadcrumbs that can help you figure out when things started to go wrong.

Change the for i in range(n + 1): line to for i in range(**1,** n + 1):, and run the program again. The output will look like this:

```
2019-05-23 17:13:40,650 - DEBUG - Start of program
2019-05-23 17:13:40,651 - DEBUG - Start of factorial(5)
2019-05-23 17:13:40,651 - DEBUG - i is 1, total is 1
2019-05-23 17:13:40,654 - DEBUG - i is 2, total is 2
2019-05-23 17:13:40,656 - DEBUG - i is 3, total is 6
2019-05-23 17:13:40,659 - DEBUG - i is 4, total is 24
2019-05-23 17:13:40,661 - DEBUG - i is 5, total is 120
2019-05-23 17:13:40,661 - DEBUG - End of factorial(5)
120
2019-05-23 17:13:40,666 - DEBUG - End of program
```

The factorial(5) call correctly returns 120. The log messages showed what was going on inside the loop, which led straight to the bug.

You can see that the logging.debug() calls printed out not just the strings passed to them but also a timestamp and the word *DEBUG*.

Don't Debug with the print() Function

Typing import logging and logging.basicConfig(level=logging.DEBUG, format='%(asctime)s - %(levelname)s - %(message)s') is somewhat unwieldy. You may want to use print() calls instead, but don't give in to this temptation! Once you're done debugging, you'll end up spending a lot of time removing print() calls from your code for each log message. You might even accidentally remove some print() calls that were being used for nonlog messages. The nice thing about log messages is that you're free to fill your program with as many as you like, and you can always disable them later by adding a single logging.disable(logging.CRITICAL) call. Unlike print(), the logging module makes it easy to switch between showing and hiding log messages.

Log messages are intended for the programmer, not the user. The user won't care about the contents of some dictionary value you need to see to help with debugging; use a log message for something like that. For messages that the user will want to see, like *File not found* or *Invalid input, please enter a number*, you should use a print() call. You don't want to deprive the user of useful information after you've disabled log messages.

Logging Levels

Logging levels provide a way to categorize your log messages by importance. There are five logging levels, described in Table 11-1 from least to most important. Messages can be logged at each level using a different logging function.

Table 11-1: Logging Levels in Python

Level	Logging function	Description
DEBUG	logging.debug()	The lowest level. Used for small details. Usually you care about these messages only when diagnosing problems.
INFO	logging.info()	Used to record information on general events in your program or confirm that things are working at their point in the program.

Level	Logging function	Description
WARNING	logging.warning()	Used to indicate a potential problem that doesn't prevent the program from working but might do so in the future.
ERROR	logging.error()	Used to record an error that caused the program to fail to do something.
CRITICAL	logging.critical()	The highest level. Used to indicate a fatal error that has caused or is about to cause the program to stop running entirely.

Your logging message is passed as a string to these functions. The logging levels are suggestions. Ultimately, it is up to you to decide which category your log message falls into. Enter the following into the interactive shell:

```
>>> import logging
>>> logging.basicConfig(level=logging.DEBUG, format=' %(asctime)s -
%(levelname)s -  %(message)s')
>>> logging.debug('Some debugging details.')
2019-05-18 19:04:26,901 - DEBUG - Some debugging details.
>>> logging.info('The logging module is working.')
2019-05-18 19:04:35,569 - INFO - The logging module is working.
>>> logging.warning('An error message is about to be logged.')
2019-05-18 19:04:56,843 - WARNING - An error message is about to be logged.
>>> logging.error('An error has occurred.')
2019-05-18 19:05:07,737 - ERROR - An error has occurred.
>>> logging.critical('The program is unable to recover!')
2019-05-18 19:05:45,794 - CRITICAL - The program is unable to recover!
```

The benefit of logging levels is that you can change what priority of logging message you want to see. Passing logging.DEBUG to the basicConfig() function's level keyword argument will show messages from all the logging levels (DEBUG being the lowest level). But after developing your program some more, you may be interested only in errors. In that case, you can set basicConfig()'s level argument to logging.ERROR. This will show only ERROR and CRITICAL messages and skip the DEBUG, INFO, and WARNING messages.

Disabling Logging

After you've debugged your program, you probably don't want all these log messages cluttering the screen. The logging.disable() function disables these so that you don't have to go into your program and remove all the logging calls by hand. You simply pass logging.disable() a logging level, and it will suppress all log messages at that level or lower. So if you want to disable logging entirely, just add logging.disable(logging.CRITICAL) to your program. For example, enter the following into the interactive shell:

```
>>> import logging
>>> logging.basicConfig(level=logging.INFO, format=' %(asctime)s -
%(levelname)s -  %(message)s')
>>> logging.critical('Critical error! Critical error!')
2019-05-22 11:10:48,054 - CRITICAL - Critical error! Critical error!
>>> logging.disable(logging.CRITICAL)
>>> logging.critical('Critical error! Critical error!')
>>> logging.error('Error! Error!')
```

Since logging.disable() will disable all messages after it, you will probably want to add it near the import logging line of code in your program. This way, you can easily find it to comment out or uncomment that call to enable or disable logging messages as needed.

Logging to a File

Instead of displaying the log messages to the screen, you can write them to a text file. The logging.basicConfig() function takes a filename keyword argument, like so:

```
import logging
logging.basicConfig(filename='myProgramLog.txt', level=logging.DEBUG, format='
%(asctime)s -  %(levelname)s -  %(message)s')
```

The log messages will be saved to *myProgramLog.txt*. While logging messages are helpful, they can clutter your screen and make it hard to read the program's output.

Writing the logging messages to a file will keep your screen clear and store the messages so you can read them after running the program. You can open this text file in any text editor, such as Notepad or TextEdit.

MU'S DEBUGGER

The *debugger* is a feature of the Mu editor, IDLE, and other editor software that allows you to execute your program one line at a time. The debugger will run a single line of code and then wait for you to tell it to continue. By running your program "under the debugger" like this, you can take as much time as you want to examine the values in the variables at any given point during the program's lifetime. This is a valuable tool for tracking down bugs.

To run a program under Mu's debugger, click the **Debug** button in the top row of buttons, next to the Run button. Along with the usual output pane at the bottom, the Debug Inspector pane will open along the right side of the window. This pane lists the current value of variables in your program. In Figure 11-1, the debugger has paused the execution of the program just before it would have run the first line of code. You can see this line highlighted in the file editor.

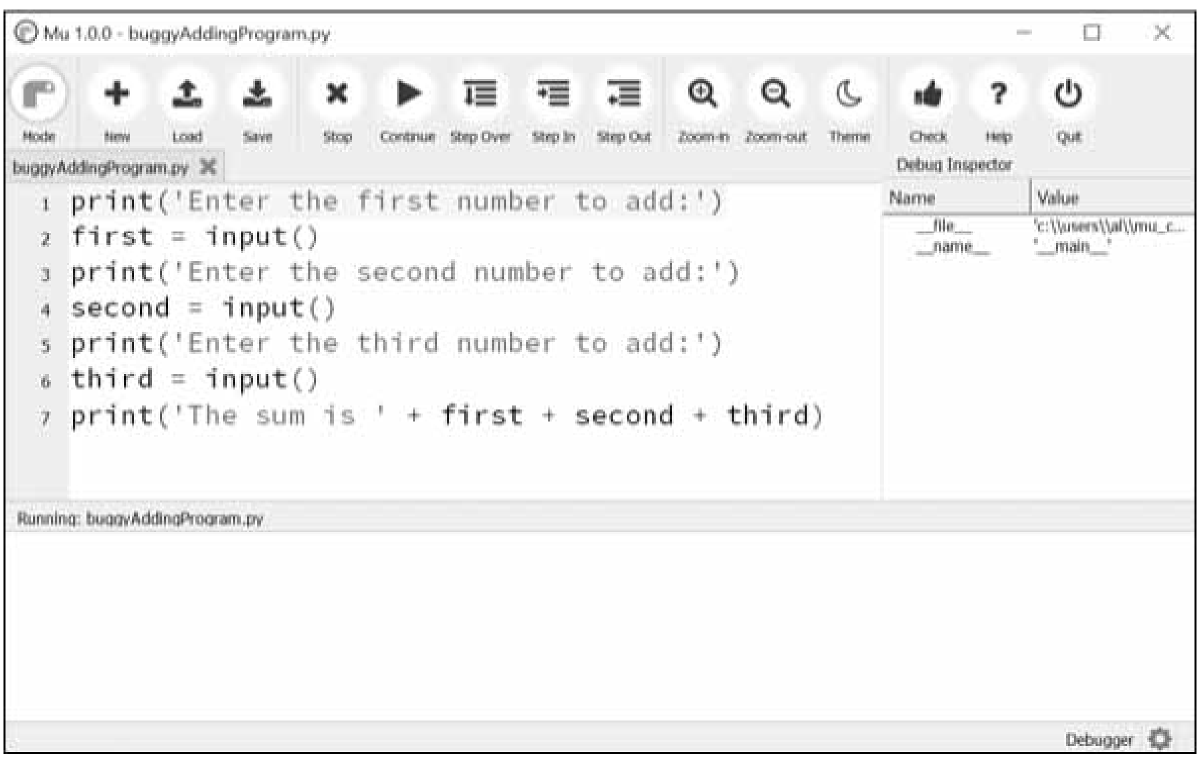

Figure 11-1: Mu running a program under the debugger

Debugging mode also adds the following new buttons to the top of the editor: Continue, Step Over, Step In, and Step Out. The usual Stop button is also available.

Continue

Clicking the Continue button will cause the program to execute normally until it terminates or reaches a *breakpoint*. (I will describe breakpoints later in this chapter.) If you are done debugging and want the program to continue normally, click the Continue button.

Step In

Clicking the Step In button will cause the debugger to execute the next line of code and then pause again. If the next line of code is a function call, the debugger will "step into" that function and jump to the first line of code of that function.

Step Over

Clicking the Step Over button will execute the next line of code, similar to the Step In button. However, if the next line of code is a function call, the Step Over button will "step over" the code in the function. The function's code will be executed at full speed, and the debugger will pause as soon as the function call returns. For example, if the next line of code calls a spam() function but you don't really care about code inside this function, you can click Step Over to execute the code in the function at normal speed, and then pause when the function returns. For this reason, using the Over button is more common than using the Step In button.

Step Out

Clicking the Step Out button will cause the debugger to execute lines of code at full speed until it returns from the current function. If you have stepped into a function call with the Step In button and now simply want to keep executing instructions until you get back out, click the Out button to "step out" of the current function call.

Stop

If you want to stop debugging entirely and not bother to continue executing the rest of the program, click the Stop button. The Stop button will immediately terminate the program.

Debugging a Number Adding Program

Open a new file editor tab and enter the following code:

```
print('Enter the first number to add:')
first = input()
print('Enter the second number to add:')
second = input()
print('Enter the third number to add:')
third = input()
print('The sum is ' + first + second + third)
```

Save it as *buggyAddingProgram.py* and run it first without the debugger enabled. The program will output something like this:

```
Enter the first number to add:
5
Enter the second number to add:
3
Enter the third number to add:
42
The sum is 5342
```

The program hasn’t crashed, but the sum is obviously wrong. Run the program again, this time under the debugger.

When you click the Debug button, the program pauses on line 1, which is the line of code it is about to execute. Mu should look like Figure 10-1.

Click the **Step Over** button once to execute the first `print()` call. You should use Step Over instead of Step In here, since you don’t want to step into the code for the `print()` function. (Although Mu should prevent the debugger from entering Python’s built-in functions.) The debugger moves on to line 2, and highlights line 2 in the file editor, as shown in Figure 11-2. This shows you where the program execution currently is.

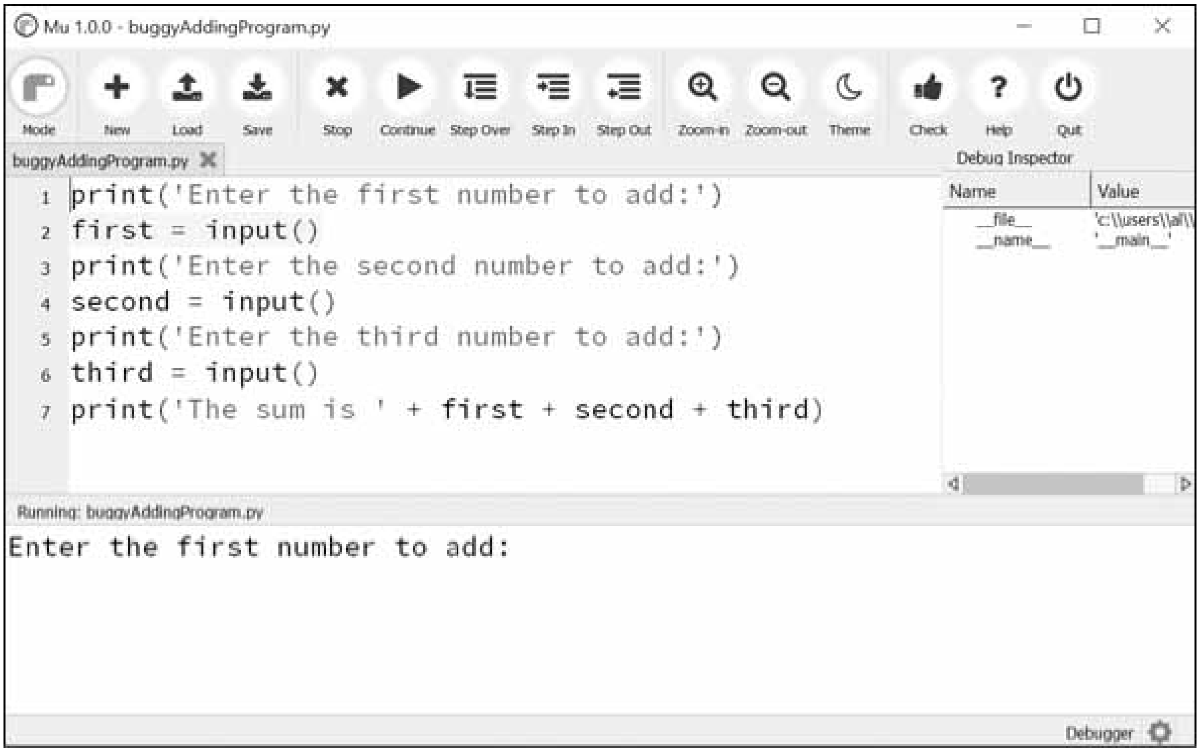

Figure 11-2: The Mu editor window after clicking Step Over

Click **Step Over** again to execute the input() function call. The highlighting will go away while Mu waits for you to type something for the input() call into the output pane. Enter 5 and press ENTER. The highlighting will return.

Keep clicking **Step Over**, and enter **3** and **42** as the next two numbers. When the debugger reaches line 7, the final print() call in the program, the Mu editor window should look like Figure 11-3.

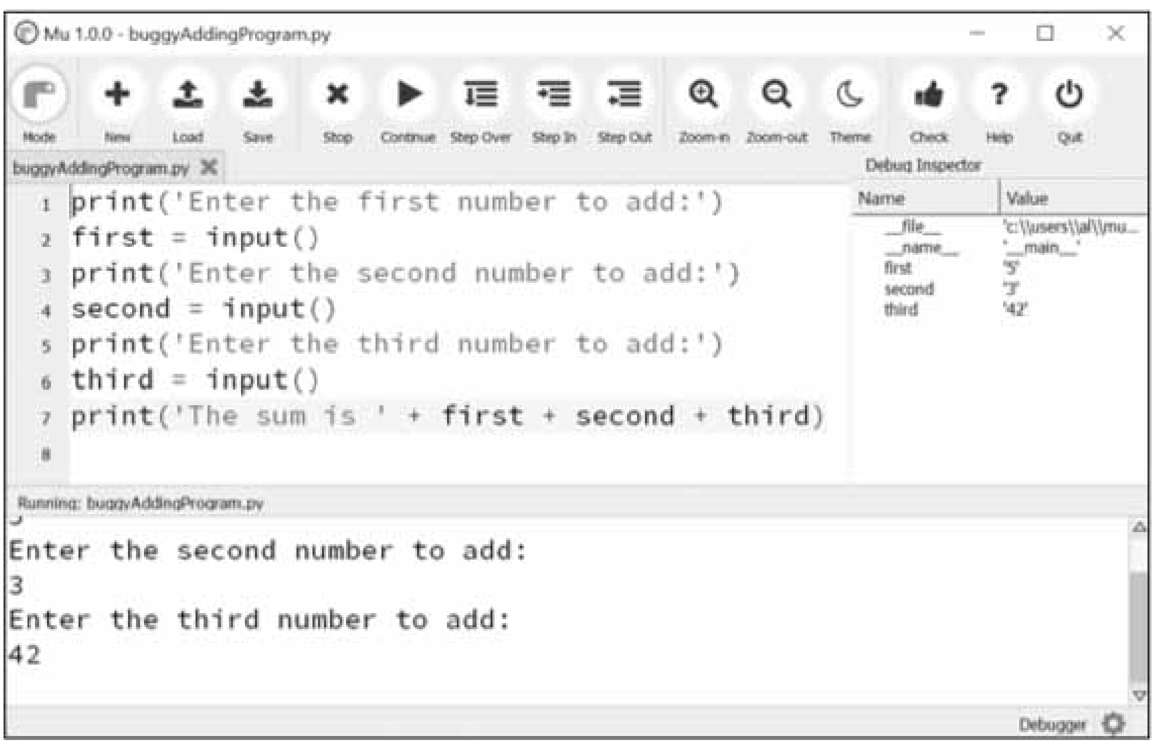

Figure 11-3: The Debug Inspector pane on the right side shows that the variables are set to strings instead of integers, causing the bug.

In the Debug Inspector pane, you should see that the first, second, and third variables are set to string values '5', '3', and '42' instead of integer values 5, 3, and 42. When the last line is executed, Python concatenates these strings instead of adding the numbers together, causing the bug.

Stepping through the program with the debugger is helpful but can also be slow. Often you'll want the program to run normally until it reaches a certain line of code. You can configure the debugger to do this with breakpoints.

Breakpoints

A *breakpoint* can be set on a specific line of code and forces the debugger to pause whenever the program execution reaches that line. Open a new file editor tab and enter the following program, which simulates flipping a coin 1,000 times. Save it as *coinFlip.py*.

```
import random
heads = 0
for i in range(1, 1001):
  ❶ if random.randint(0, 1) == 1:
        heads = heads + 1
    if i == 500:
      ❷ print('Halfway done!')
print('Heads came up ' + str(heads) + ' times.')
```

The random.randint(0, 1) call ❶ will return 0 half of the time and 1 the other half of the time. This can be used to simulate a 50/50 coin flip where 1 represents heads. When you run this program without the debugger, it quickly outputs something like the following:

```
Halfway done!
Heads came up 490 times.
```

If you ran this program under the debugger, you would have to click the Step Over button thousands of times before the program terminated. If you were interested in the value of heads at the halfway point of the program's execution, when 500 of 1,000 coin flips have been completed, you could instead just set a breakpoint on the line print('Halfway done!') ❷. To set a breakpoint, click the line number in the file editor to cause a red dot to appear, marking the breakpoint like in Figure 11-4.

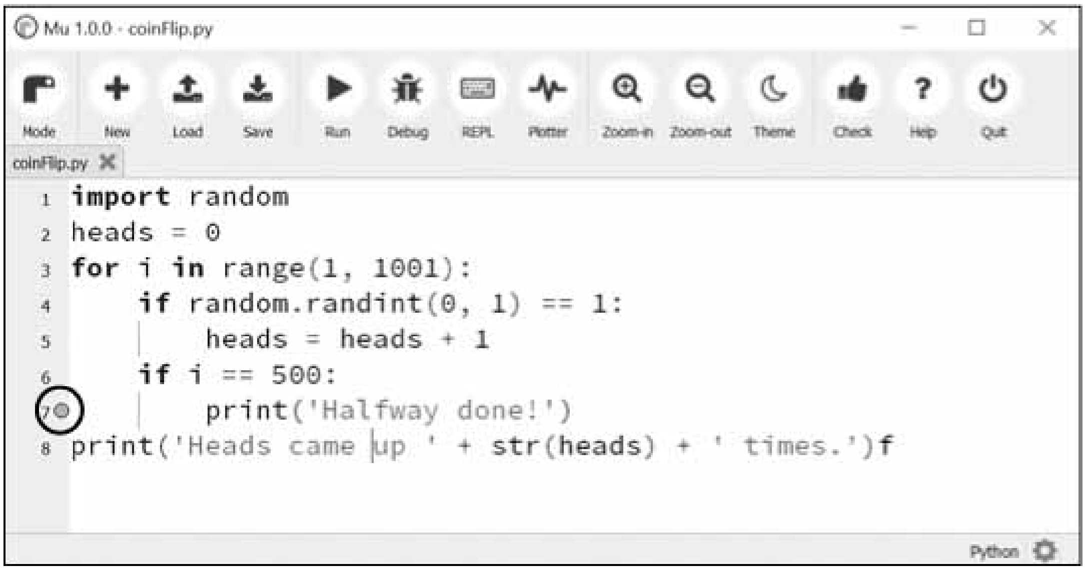

Figure 11-4: Setting a breakpoint causes a red dot (circled) to appear next to the line number.

You don't want to set a breakpoint on the if statement line, since the if statement is executed on every single iteration through the loop. When you set the breakpoint on the code in the if statement, the debugger breaks only when the execution enters the if clause.

The line with the breakpoint will have a red dot next to it. When you run the program under the debugger, it will start in a paused state at the first line, as usual. But if you click Continue, the program will run at full speed until it reaches the line with the breakpoint set on it. You can then click Continue, Step Over, Step In, or Step Out to continue as normal.

If you want to remove a breakpoint, click the line number again. The red dot will go away, and the debugger will not break on that line in the future.

Summary

Assertions, exceptions, logging, and the debugger are all valuable tools to find and prevent bugs in your program. Assertions with the Python assert statement are a good way to implement "sanity checks" that give you an early warning when a necessary condition doesn't hold true. Assertions are only for errors that the program shouldn't try to recover from and should fail fast. Otherwise, you should raise an exception.

An exception can be caught and handled by the try and except statements. The logging module is a good way to look into your code while it's running and is much more convenient to use than the print() function because of its different logging levels and ability to log to a text file.

The debugger lets you step through your program one line at a time. Alternatively, you can run your program at normal speed and have the debugger pause execution whenever it reaches a line with a breakpoint set. Using the debugger, you can see the state of any variable's value at any point during the program's lifetime.

These debugging tools and techniques will help you write programs that work. Accidentally introducing bugs into your code is a fact of life, no matter how many years of coding experience you have.

Practice Questions

1. Write an `assert` statement that triggers an `AssertionError` if the variable `spam` is an integer less than `10`.
2. Write an `assert` statement that triggers an `AssertionError` if the variables `eggs` and `bacon` contain strings that are the same as each other, even if their cases are different (that is, `'hello'` and `'hello'` are considered the same, and `'goodbye'` and `'GOODbye'` are also considered the same).
3. Write an `assert` statement that *always* triggers an `AssertionError`.
4. What are the two lines that your program must have in order to be able to call `logging.debug()`?
5. What are the two lines that your program must have in order to have `logging.debug()` send a logging message to a file named *programLog.txt*?
6. What are the five logging levels?
7. What line of code can you add to disable all logging messages in your program?
8. Why is using logging messages better than using `print()` to display the same message?
9. What are the differences between the Step Over, Step In, and Step Out buttons in the debugger?
10. After you click Continue, when will the debugger stop?
11. What is a breakpoint?
12. How do you set a breakpoint on a line of code in Mu?

Practice Project

For practice, write a program that does the following.

Debugging Coin Toss

The following program is meant to be a simple coin toss guessing game. The player gets two guesses (it's an easy game). However, the program has several bugs in it. Run through the program a few times to find the bugs that keep the program from working correctly.

```
import random
guess = ''
while guess not in ('heads', 'tails'):
    print('Guess the coin toss! Enter heads or tails:')
    guess = input()
toss = random.randint(0, 1) # 0 is tails, 1 is heads
if toss == guess:
    print('You got it!')
else:
    print('Nope! Guess again!')
    guesss = input()
    if toss == guess:
        print('You got it!')
    else:
        print('Nope. You are really bad at this game.')
```

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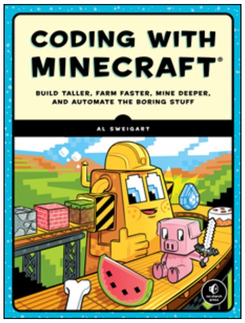
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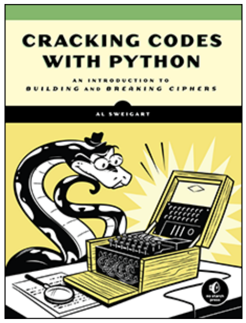
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