CHAPTER 5

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Testing and Debugging

The MATLAB unit test framework now allows you to incorporate testing into your MATLAB software just as you would your C++ or Java packages. Since entire textbooks have been written on testing methodologies, we will limit ourselves in this chapter to covering the mechanics of using the test framework itself. We also present a couple of recipes that are useful for debugging.

We should, however, say a few words about the goal of software testing. Testing should determine if your software functions as designed. The first step is to have a concrete design against which you are coding. The functionality needs to be carefully described as a set of requirements. The requirements need to specify what inputs the software expects and what outputs it will generate. Testing needs to verify that for all valid inputs, it generates the expected outputs. A second consideration is that the software should handle expected errors and warn the user. For example, a simple function adds two MATLAB variables:

```
c = a + b;
```

You need to verify that it will work for any numeric `a` and `b`. You would not generally need to have a warning to the user if `a` or `b` is not numeric; that would just fill your code up with unneeded tests. A case where you might want a check is a function containing

```
b = acos(a);
```

If it is supposed to return a real number (perhaps as part of another function), you might want to limit `a` to have a magnitude less than 1. If you have the code

```
if( abs(a) > 1 )
  a = sign(a);
end
b = acos(a);
```

M. Paluszek and S. Thomas, *MATLAB Recipes*,
https://doi.org/10.1007/978-1-4842-6124-8_5

in this case, your test code needs to pass in values of a that are greater than one. This is also a case where you might want to add a custom warning to the user if the magnitude limiting code is exercised, as shown in the following. If you have custom warnings and errors in your code, you also need to test them.

```
if( abs(a) > 1 )
  warning('MyToolbox:MyFunction:OutOfBounds','Input a is out of bounds');
  a = sign(a);
end
b = acos(a);
```

For engineering software, your test code should include known outputs generated by known inputs. In the preceding code, you might include inputs of 1.1, 1, 0.5, 0, -0.5, -1, and -1.1. This would span the range of expected inputs. You might also be very thorough and input `linspace(-1.1,1.1)` and test against another source of values for the inverse cosine. As shown in the later chapters, we usually include a demo function that tests the function with an interesting set of inputs. Your test code can use the code from the demo function as part of the testing.

All test procedures should employ the MATLAB code coverage tools. The Coverage Report, used in conjunction with the MATLAB Profiler, keeps track of what lines of code are exercised during execution. For a given function or script, it is essential that all code be exercised in its test. Studies have shown that testing done without coverage tools typically exercises only 55% of the code. In reality, it is impossible to actually test every path in anything but the simplest software, and this must be factored into the software development and quality assurance processes. MATLAB does not currently support running the coverage tools on a suite of tests, or during your regression testing, so you should exercise the coverage tools on a per-test basis as you design them.

Once you start using your software, any bug you find should be used to add an additional test case to your software.

5.1 Creating a Unit Test

Problem

Your functions require unit tests.

Solution

Use MATLAB's built-in test capabilities (now available using Java classes) to write and execute unit test functions. Test functions and scripts are identified by using the word "test" as a prefix or suffix to the filename and are run via the `runtests` function.

How It Works

The `matlab.unittest` package is an xUnit-style, unit testing framework for MATLAB. You can write scripts with test cases separated using cell titles, or functions with test cases in subfunctions, and execute them using the framework. We will show an example of each. There is extensive documentation of the framework and examples in the MATLAB documentation; these lists will get you started.

These are the relevant MATLAB packages implementing the framework:

- matlab.unittest
- matlab.unittest.constraints
- matlab.unittest.fixtures
- matlab.unittest.qualifications

The qualifications package provides all the methods for checking function results, including numerical values, errors, and warnings. The fixtures package allows you to provide setup and teardown code for individual or groups of tests.

Here are the relevant classes you will use when coding tests:

- matlab.unittest.TestCase
- matlab.unittest.TestResult
- matlab.unittest.TestSuite
- matlab.unittest.qualifications.Verifiable

TestCase is the superclass for writing test classes.

Here are the relevant functions:

- `assert`
- `runtest`
- `functiontests`
- `localfunctions`

The simplest way to implement some tests for a function is to write a script. Each test case is identified with a cell title, using %%. Use the `assert` function to check the function output. The script can then be run via `runtest`, which will run each test even if a prior test fails, and collate the output into a useful report.

Let's write tests for an example function, `CompleteTriangle`, that computes the remaining data for a triangle given two sides and the interior angle:

CompleteTriangle.m

```
function [A,B,c] = CompleteTriangle(a,b,C)

c = sqrt(a^2 + b^2 - 2*a*b*cosd(C));
sinA = sind(C)/c*a;
sinB = sind(C)/c*b;
```

```
cosA = (c^2+b^2-a^2)/2/b/c;
cosB = (c^2+a^2-b^2)/2/a/c;
A = atan2(sinA,cosA)*180/pi;
B = atan2(sinB,cosB)*180/pi; % insert typo: change a B to A

end
```

This is similar to the right triangle function used as an example in the MATLAB documentation, but we need the four quadrant inverse tangent as we are allowing obtuse triangles. Since there are very similar lines of code for the two angles `A` and `B`, we've made a note that having a typo in one of these lines would be likely, especially if you use copy/paste while writing the function; we'll demonstrate the effect of such a typo via our tests.

Now let's look at a script that defines a few test cases for this function, `TriangleTest`. We use `assert` with a logical statement for every check.

TriangleTest.m

```
%% Test 1: sum of angles
% Test that the angles add up to 180 degrees.
C = 30;
[A,B] = CompleteTriangle(1,2,C);
theSum = A+B+C;
assert(theSum == 180,'PSS:Book:triangle','Sum of angles: %f',theSum)

%% Test 2: isosceles right triangles
% Test that if sides a and b are equal, angles A and B are equal.
C = 90;
[A,B] = CompleteTriangle(2,2,C);
assert(A == B,'PSS:Book:triangle','Isoceles Triangle')

%% Test 3: 3-4-5 right triangle
% Test that if side a is 3 and side b is 4, side c (hypotenuse) is 5.
C = 90;
[~,~,c] = CompleteTriangle(3,4,C);
assert(c == 5,'PSS:Book:triangle','3-4-5 Triangle')

%% Test 4: equilateral triangle
% Test that if sides a and b are equal, all angles are 60.
[A,B,c] = CompleteTriangle(1,1,60);
assert(A == 60,'PSS:Book:triangle','Equilateral Triangle %d',1)
assert(B == 60,'PSS:Book:triangle','Equilateral Triangle %d',2)
assert(c == 1,'PSS:Book:triangle','Equilateral Triangle %d',3)
```

Note how we have used the additional inputs available to `assert` to add a message ID string and an error message. The error message can take formatted strings with any of the specifiers supported by `sprintf`, such as `%d` and `%f`.

You can simply execute this script, in which case it will exit on the first `assert` that fails. Even better, you can run it with `runtests`, which will automatically distinguish between the test cases and run them independently should one fail.

```
>> runtests('TriangleTest');

Running TriangleTest
...
=========================================================================
Error occurred in TriangleTest/Test4_EquilateralTriangle and it did not
    run to completion.

    --------------
    Error Details:
    --------------
    Equilateral Triangle 1
=========================================================================
.
Done TriangleTest
__________

Failure Summary:

    Name                                    Failed  Incomplete  Reason(s)
    =====================================================================
    TriangleTest/Test4_EquilateralTriangle    X         X       Errored.
```

The equilateral triangle test failed, and we know it was the first `assert` in that case due to the index we printed out, `Equilateral Triangle 1`. If you run the code for that test at the command line, you will see that the output does in fact look correct:

```
>> [A,B,c] = CompleteTriangle(1,1,60)
A =
           60
B =
           60
c =
     1
```

If we actually subtract the expected value, 60, from A and B, we see why our test has failed.

```
>> A-60
ans =
   7.1054e-15
>> B-60
ans =
   7.1054e-15
```

We are within the tolerances of the trigonometric functions in MATLAB, but our assert did not take that into account. You can add a tolerance like so:

```
assert(abs(A-60)<1e-10,'PSS:Book:triangle','Equilateral Triangle %d',1)
assert(abs(B-60)<1e-10,'PSS:Book:triangle','Equilateral Triangle %d',2)
```

And now our tests all pass:

```
>> runtests('TriangleTest')
Running TriangleTest
....
Done TriangleTest
__________

ans =
  1x4 TestResult array with properties:

    Name
    Passed
    Failed
    Incomplete
    Duration
Totals:
   4 Passed, 0 Failed, 0 Incomplete.
   0.012243 seconds testing time.
```

Note that we left off the terminating semicolon, so in addition to the brief report, we see that `runtests` returns an array of `TestResult` objects and prints additional total information, including the test duration.

Now let's consider the case of a typo in the function that you have not yet debugged. We will change a `B` to an `A` on the last line of the function, so that it reads

```
B = atan2(sinB,cosA)*180/pi; % insert typo: change a B to A
```

and run the tests again, using the tolerance check. We use the `table` class with the `TestResult` output to get a nicely formatted version of the test results.

```
>> tr = runtests('TriangleTest');
>> table(tr)
ans =
                   Name                         Passed   Failed   Incomplete
```

```
                           Duration
    _________________________________________    _____    _____    _______

       ______
  'TriangleTest/Test1_SumOfAngles'            false    true     true
            0.0040209
  'TriangleTest/Test2_IsoscelesRightTriangles'  true     false    false
            0.002971
  'TriangleTest/Test3_3_4_5RightTriangle'       true     false    false
           0.0027831
  'TriangleTest/Test4_EquilateralTriangle'      true     false    false
           0.0031556
```

Despite this being a major error in the code, only one test has failed: the sum of the angles test. The isosceles and equilateral triangle tests still passed because `A` and `B` are equal in both cases. You could introduce errors into each line of your code to see if your tests catch them!

Now let's consider the other possibility for the unit tests: a test function, as opposed to the script. In this case, each test case has to be in its own subfunction, and the main function has to return an array of tests. This provides you the opportunity to write setup and teardown functions for the tests. It also makes use of the `TestCase` class and the qualifications package. Here is what our tests look like in this format:

TriangleFunctionTest.m

```
function tests = TriangleFunctionTest
% Create an array of local functions
tests = functiontests(localfunctions);
end

%%% Test Functions
function testAngleSum(testCase)
C       = 30;
[A,B]   = CompleteTriangle(1,2,C);
theSum = A+B+C;
testCase.verifyEqual(theSum,180)
end

function testIsosceles(testCase)
C      = 90;
[A,B]  = CompleteTriangle(2,2,C);
testCase.verifyEqual(A,B)
end

function test345(testCase)
C        = 90;
[~,~,c]  = CompleteTriangle(3,4,C);
testCase.verifyEqual(c,5)
end

function testEquilateral(testCase)
[A,B,c]  = CompleteTriangle(1,1,60);
```

```
assert(abs(A-60)<testCase.TestData.tol)
testCase.verifyEqual(B,60,'absTol',1e-10)
testCase.verifyEqual(c,1)
end

%%% Optional file fixtures
function setupOnce(testCase)  % do not change function name
% set a tolerance that can be used by all tests
testCase.TestData.tol = 1e-10;
end

function teardownOnce(testCase)  % do not change function name
% change back to original path, for example
end

%%% Optional fresh fixtures
function setup(testCase)  % do not change function name
% open a figure, for example
end

function teardown(testCase)  % do not change function name
% close figure, for example
end
```

If you just run this function, you will get an array of the four test methods.

```
>> TriangleFunctionTest
ans =
  1x4 Test array with properties:

    Name
    Parameterization
    SharedTestFixtures
```

We have showed two methods for setting a tolerance for the tests in `testEquilateral`; in one case, we hard-coded a tolerance in using the `absTol` parameters, and in the other we used a setup function to pass a tolerance in via `TestData`. There are two types of setup and teardown functions to choose from: *file* fixtures, which will run just once for the entire set of tests in the file, and *fresh* fixtures, which will run for each test case. The file fixtures are identified with the *Once* suffix. In the case of this tolerance, the `setupOnce` function is appropriate.

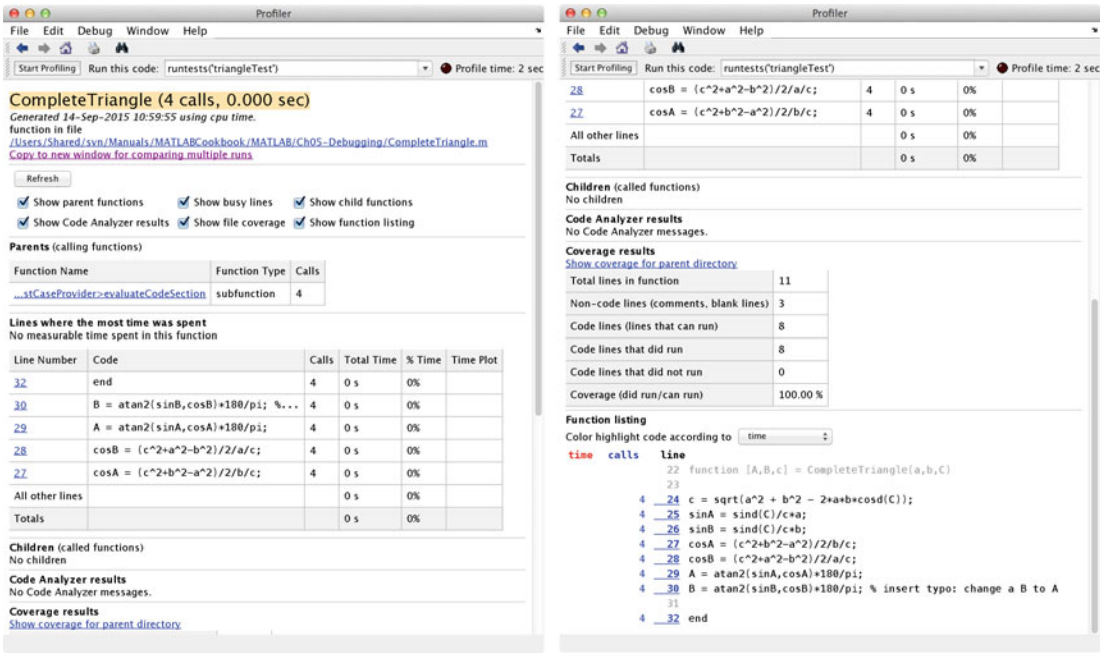
To run the tests, use `runtests` as for the script. Happily, our tests all pass!

```
>> runtests('TriangleFunctionTest')
Running TriangleFunctionTest
....
Done TriangleFunctionTest
__________
```

```
...
Totals:
   4 Passed, 0 Failed, 0 Incomplete.
   0.043001 seconds testing time.
```

You can run either set of tests in the Profiler (i.e., Run and Time) to verify the coverage of the function being tested. It is a bit easier to navigate to the results for `CompleteTriangle` using the script version of the tests; the results from the test function list many functions from the test framework. The result in the Profiler, showing 100% coverage of our function, is shown in Figure 5.1.

After you have run the Profiler, you can run a Coverage Report. To run the report, you have to use the Current Folder pane of the editor, and select Reports/Coverage Report from the context menu. We show an example in Figure 5.2. Our example function runs too quickly to take any measurable time, but generally this report will give you insight into the time taken by your function as well as the coverage you achieved.



Run this code: runtests('triangleTest')
Profile time: 2 sec

CompleteTriangle (4 calls, 0.000 sec)
Generated 14-Sep-2015 10:59:55 using cpu time.
function in file
/Users/Shared/svn/Manuals/MATLABCookbook/MATLAB/Ch05-Debugging/CompleteTriangle.m
Copy to new window for comparing multiple runs

✓ Show parent functions ✓ Show busy lines ✓ Show child functions
✓ Show Code Analyzer results ✓ Show file coverage ✓ Show function listing

Parents (calling functions)

Function Name	Function Type	Calls
...stCaseProvider>evaluateCodeSection	subfunction	4

Lines where the most time was spent
No measurable time spent in this function

Line Number	Code	Calls	Total Time	% Time	Time Plot
32	end	4	0 s	0%	
30	B = atan2(sinB,cosB)*180/pi; %...	4	0 s	0%	
29	A = atan2(sinA,cosA)*180/pi;	4	0 s	0%	
28	cosB = (c^2+a^2-b^2)/2/a/c;	4	0 s	0%	
27	cosA = (c^2+b^2-a^2)/2/b/c;	4	0 s	0%	
All other lines			0 s	0%	
Totals			0 s	0%	

Children (called functions)
No children

Code Analyzer results
No Code Analyzer messages.

Coverage results
Show coverage for parent directory

Run this code: runtests('triangleTest')
Profile time: 2 sec

28	cosB = (c^2+a^2-b^2)/2/a/c;	4	0 s	0%	
27	cosA = (c^2+b^2-a^2)/2/b/c;	4	0 s	0%	
All other lines			0 s	0%	
Totals			0 s	0%	

Children (called functions)
No children

Code Analyzer results
No Code Analyzer messages.

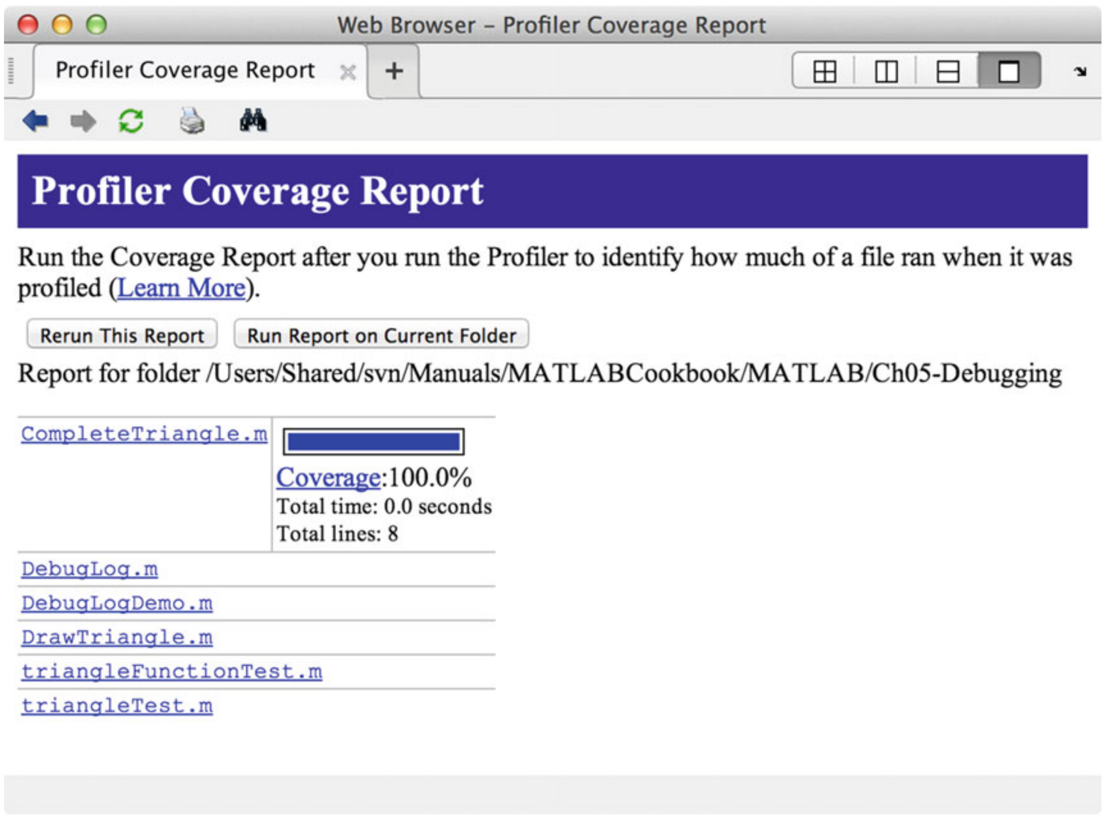
Coverage results
Show coverage for parent directory

Total lines in function	11
Non-code lines (comments, blank lines)	3
Code lines (lines that can run)	8
Code lines that did run	8
Code lines that did not run	0
Coverage (did run/can run)	100.00 %

Function listing
Color highlight code according to time

```
time  calls   line
               22 function [A,B,c] = CompleteTriangle(a,b,C)
               23
         4     24 c = sqrt(a^2 + b^2 - 2*a*b*cosd(C));
         4     25 sinA = sind(C)/c*a;
         4     26 sinB = sind(C)/c*b;
         4     27 cosA = (c^2+b^2-a^2)/2/b/c;
         4     28 cosB = (c^2+a^2-b^2)/2/a/c;
         4     29 A = atan2(sinA,cosA)*180/pi;
         4     30 B = atan2(sinB,cosB)*180/pi; % insert typo: change a B to A
               31
         4     32 end
```

Figure 5.1: *Triangle tests in the Profiler.*


Web Browser – Profiler Coverage Report
Profiler Coverage Report
Rerun This Report
Run Report on Current Folder

Profiler Coverage Report

Run the Coverage Report after you run the Profiler to identify how much of a file ran when it was profiled (Learn More).

Report for folder /Users/Shared/svn/Manuals/MATLABCookbook/MATLAB/Ch05-Debugging

CompleteTriangle.m	Coverage:100.0% Total time: 0.0 seconds Total lines: 8
DebugLog.m	
DebugLogDemo.m	
DrawTriangle.m	
triangleFunctionTest.m	
triangleTest.m	

Figure 5.2: *Coverage Report for CompleteTriangle.*

5.2 Running a Test Suite

Problem

Your toolbox has dozens or hundreds of functions, each with unit tests, and you need an efficient way to run them all or, even better, run subsets.

Solution

MATLAB's test framework includes the construction of test suites.

How It Works

After you have generated tests for the functions in your toolbox, you can group them into suites in several ways. The help for the `TestSuite` class lists the options:

```
    TestSuite methods:
        fromName    - Create a suite from the name of the test element
        fromFile    - Create a suite from a TestCase class filename
        fromFolder  - Create a suite from all tests in a folder
        fromPackage - Create a suite from all tests in a package
        fromClass   - Create a suite from a TestCase class
        fromMethod  - Create a suite from a single test method
```

You can also concatenate test suites made using these methods and pass the array to the test runner. In this way, you can easily generate subsets of your tests to run.

In the previous recipe, we create two test files for `CompleteTriangle`: a test script and a test function. We can create a test suite for the folder containing this code, and it will automatically find both sets of test cases. We assume that the current folder contains the two test files.

```
>> import matlab.unittest.TestSuite
>> testSuite = TestSuite.fromFolder(pwd);
>> result = run(testSuite)

Running TriangleFunctionTest
....
Done TriangleFunctionTest
__________

Running TriangleTest
.......
Done TriangleTest
__________
result =
  1x8 TestResult array with properties:

    Name
    Passed
    Failed
    Incomplete
    Duration
Totals:
   8 Passed, 0 Failed, 0 Incomplete.
   0.04218 seconds testing time.
```

As you can see, test suites are really quite simple. Some advanced features of suites include the ability to apply selectors to a suite to obtain a subset of tests. To see the full documentation of `TestSuite` at the command line, type either

```
>> help matlab.unittest.TestSuite
```

or

```
>> import matlab.unittest.TestSuite
>> help TestSuite
```

The function for performing selections is `selectIf`. Here is an example that selects the two tests of an equilateral triangle from the suite:

```
>> subSuite = testSuite.selectIf('Name', '*Equilateral*');
>> subSuite
subSuite =
  1x2 Test array with properties:

    Name
    Parameterization
    SharedTestFixtures
>> subSuite.Name
ans =
TriangleFunctionTest/testEquilateral
ans =
TriangleTest/Test4_EquilateralTriangle
```

You can run the tests in the resulting suite, or concatenate it with other suites, as before.

5.3 Setting Verbosity Levels in Tests

Problem

The printouts from your tests are getting out of control, but you don't want to just delete or comment out all the information you have needed as you are developing the tests. If a test fails in the future, you may need those messages.

Solution

The test framework includes a logging feature that has four levels of verbosity. To utilize it, you create a test runner using the logging plugin and add `log` calls in your test cases.

How It Works

The four verbosity levels supported are Terse, Concise, Detailed, and Verbose, and they are enumerated as follows:

1	Terse	Minimal amount of information
2	Concise	Typical amount of information
3	Detailed	Supplemental amount of information
4	Verbose	Surplus of information

The default test runner uses the lowest verbosity setting, Terse. The `log` function you use in your test cases is a method of `TestCase`, so to access the help, you need to use the fully qualified name:

```
>> help matlab.unittest.TestCase/log
```

The log method syntax from the help is as follows:

> log(TESTCASE, LEVEL, DIAG) logs the diagnostic at the specified LEVEL. LEVEL can be either a numeric value (1, 2, 3, or 4) or a value from the matlab.unittest.Verbosity enumeration. When level is unspecified, the log method uses level Concise (2).

Logging requires a `TestCase` object. The diagnostic data for `DIAG` can be a string or an instance of `matlab.unittest.diagnostics.Diagnostic`. Let's write an example test for `eig` that demonstrates verbosity.

VerboseEigTest.m

```
%% VERBOSEEIGTEST Demonstrate verbosity levels in tests
% Run a test of the eig function using log messages. Demonstrates
% all four levels of verbosity. To run the tests, at the command line
   use
% a TestRunner configured with the LoggingPlugIn:
%
%   import matlab.unittest.TestRunner;
%   import matlab.unittest.plugins.LoggingPlugin;
%   runner = TestRunner.withNoPlugins;
%   runner.addPlugin(LoggingPlugin.withVerbosity(4));
%   results = runner.run(VerboseEigTest);
%% Form
%   tests = VerboseEigTest
%% Inputs
% None.
%% Outputs
%   tests  (:)  Array of test functions

function tests = VerboseEigTest
% Create an array of local functions
tests = functiontests(localfunctions);
end

%% Test Functions
function eigTest(testCase)
log(testCase,'Generating test data'); % default is level 2
m = rand(2000);
A = m'*m;
log(testCase, 1, 'About to call eig.');
[V,D,W] = eig(A);
log(testCase, 4, 'Eig finished.');
assert(norm(W'*A-D*W')<1e-6)
```

```
log(testCase, 3, 'Test of eig completed.');
end

% If you want to use the Verbose enumeration in your code instead of
    numbers,
% import the class matlab.unittest.Verbosity
function eigWithEnumTest(testCase)
import matlab.unittest.Verbosity
m = rand(1000);
A = m'*m;
log(testCase, Verbosity.Detailed, 'About to call eig (with enum).');
[V,D,W]  = eig(A);
assert(norm(W'*A-D*W')<1e-6)
log(testCase, Verbosity.Terse, 'Test of eig (with enum) completed.');
end
```

If you just run this test with `runtests`, you will get the Terse level of output. Note that the system time is displayed along with your log message.

```
>> runtests('VerboseEigTest');
Running VerboseEigTest
   [Terse] Diagnostic logged (2015-09-14T12:15:29): About to call eig.
.   [Terse] Diagnostic logged (2015-09-14T12:15:40): Test of eig (with
    enum) completed.
.
Done VerboseEigTest
__________
```

To get higher levels of verbosity requires a test runner with the logging plugin. This requires a few imports at the command line (or in your script). You need to generate a "plain" runner, with no plugins, then add the logging plugin with the desired level of verbosity. The verbosity level of the message is displayed in the output.

```
>> import matlab.unittest.TestRunner;
>> import matlab.unittest.plugins.LoggingPlugin;
>> runner = TestRunner.withNoPlugins;
>> runner.addPlugin(LoggingPlugin.withVerbosity(4));
>> results = runner.run(VerboseEigTest);
 [Concise] Diagnostic logged (2015-09-14T12:19:57): Generating test data
   [Terse] Diagnostic logged (2015-09-14T12:19:57): About to call eig.
 [Verbose] Diagnostic logged (2015-09-14T12:20:01): Eig finished.
[Detailed] Diagnostic logged (2015-09-14T12:20:07): Test of eig completed
    .
[Detailed] Diagnostic logged (2015-09-14T12:20:07): About to call eig (
    with enum).
   [Terse] Diagnostic logged (2015-09-14T12:20:08): Test of eig (with
       enum) completed.
```

5.4 Create a Logging Function to Display Data

Problem

It is easy and convenient to print out variable values by removing the semicolons from statements, but code left in this state can produce unwanted printouts that are very difficult to track down. Even using `disp` and `fprintf` can make unwanted printouts hard to find as you probably use these functions elsewhere.

Solution

Create a custom logging function to display a variable with a helpful identifying message. You can extend this to a logging mechanism with verbosity settings similar to that described in the previous recipe, as used in the MATLAB testing framework and in most C++ and Java testing frameworks.

How It Works

Our example logging function is implemented in `DebugLog`. `DebugLog` prints out a message, which can be anything, and before that displays the path to where `DebugLog` is called. The backtrace is obtained using `dbstack`.

DebugLog.m

```
%% DEBUGLOG Logging function for debugging
% Use this function instead of adding disp() statements or leaving out
% semicolons.
%% Form
%   DebugLog( msg, fullPath )
%% Decription
% Prints out the data in in msg using disp() and shows the path to the
    message.
% The full path option will print a complete backtrace.
%% Inputs
%   msg          (.)      Any message
%   fullPath     (1,1)    If entered, print the full backtrace
%% Outputs
%   None

function DebugLog( msg, fullPath )

% Demo
if( nargin < 1 )
  DebugLog(rand(2,2));
  return;
end

% Get the function that calls this one
f = dbstack;

% The second path is only if called directly from the command line
```

```
if( length(f) > 1 )
  f1 = 2;
else
  f1 = 1;
end

if( nargin > 1 && fullPath )
  f2 = length(f);
else
  f2 = f1;
end

for k = f1:f2
  disp(['-> ' f(k).name]);
end
disp(msg);
```

DebugLog is demonstrated in DebugLogDemo. The function has a subfunction to demonstrate the backtrace.

DebugLogDemo.m

```
%% Demonstrate DebugLog
% Log a variable to the command window using DebugLog.

function DebugLogDemo

y = linspace(0,10);
i = FindInY(y);

function i = FindInY(y)

i = find(y < 0.5);
DebugLog( i, true );
```

The output of the demo is shown as follows:

```
>> DebugLogDemo
-> FindInY
-> DebugLogDemo
     1     2     3     4     5
```

One extension of this function is to add the name of the variable being logged, if msg is a variable, using the function inputname. These additional lines of code look like this:

```
str = inputname(1);
if ~isempty(str)
  disp(['Variable: ' str]);
end
```

The demo output now looks like this:

```
>> DebugLogDemo
-> FindInY
-> DebugLogDemo
Variable: i
     1     2     3     4     5
```

Consistently using your own logging functions for displaying messages to the user and printing debug data will make your code easier to maintain.

5.5 Generating and Tracing MATLAB Errors and Warnings

Problem

You would like to display errors and warnings to the user in an organized fashion.

Solution

Always use the additional inputs to `warning` and `error` to specify a message ID. This allows your message to be traced back to the function in your code that generated it, as well as controlling the display of certain warnings.

How It Works

The `warning` function has several helpful parameters for customizing and controlling warning displays. When you are generating a warning, use the full syntax with a message identifier:

```
warning('MSGID', 'MESSAGE', A, B, ...)
```

The `MSGID` is a mnemonic in the form `<component>[:<component>]:<mnemonic>`, such as `PSS:FunctionName:IllegalInput`. The ID is not normally displayed when you give a warning, unless you have turned verbose display on, via `warning on verbose` and `warning off verbose`. This is easy to demonstrate at the command line:

```
>> warning('PSS:Example:DemoWarning', 'This is an example warning')
Warning: This is an example warning
>> warning verbose on
>> warning('PSS:Example:DemoWarning', 'This is an example warning')
Warning: This is an example warning
(Type "warning off PSS:Example:DemoWarning" to suppress this warning.)
```

As displayed, you can turn a given warning off using its message ID by using the command form shown or the functional form, `warning('off', 'msgid')`.

The `lastwarn` function also can return the message ID if passed an additional output, as in

```
>> [lastmsg, lastid] = lastwarn
lastmsg =
This is an example warning
lastid =
PSS:Example:DemoWarning
```

The `error` and `lasterr` functions work the same way. An added benefit of using message identifiers is that you can select them when debugging, as an option when stopping for errors or warnings. The debugger is integrated into the editor window, and the debugger options are grouped under the Breakpoints toolbar button. The button and the “more options” pop-up window are shown in Figure 5.3.

In this case, we entered an example PSS message identifier. Remember, you should always mention any warnings and errors that may be generated by a function in its header!

5.6 Testing Custom Errors and Warnings

Problem

You have code that generates warnings or errors for problematic inputs, and you need to test it.

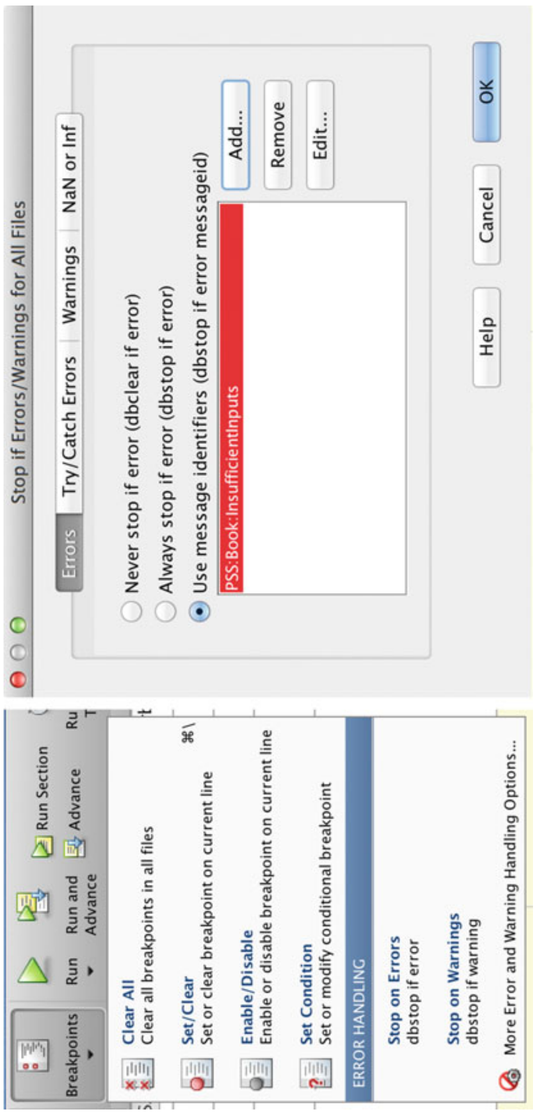
Solution

You have two possibilities for testing the generation of errors in your code: try/catch blocks with `assert` and the `verifyError` method available to a TestCase. With warnings, you can either use `lastwarn` or `verifyWarning`.

How It Works

A comprehensive set of tests for your code that includes all paths, or as close to all paths as possible, must necessarily exercise all the warnings and errors that can be generated by your code. You can do this manually, using try/catch blocks to catch errors and comparing the error (MException object) to the expected error. For warnings, you can check `lastwarn` to see that a warning was issued, like so:

```
>> lastwarn('');
>> warning('PSS:Book:id','Warning!')
Warning: Warning!
>> [anywarn,anyid] = lastwarn;
>> assert(strcmp(anyid,'PSS:Book:wrongid'))
Assertion failed.
```



Never stop if error (dbclear if error)
Always stop if error (dbstop if error)
[✓ Use message identifiers (dbstop if error messageid)]
PSS:Book:InsufficientInputs

Figure 5.3: *Option to stop on an error in the debugger.*

Here is an example of a try/catch block with `assert` to detect a specific error.

CatchErrorTest.m

```matlab
%% Test that we get the expected error, and pass
errFun = @() error('PSS:Book:id','Error!');
try
  feval(errFun);
catch ME
  assert(strcmp(ME.identifier,'PSS:Book:id'));
end
```

This test will verify that the error thrown is the one expected; however, it will not detect if no error is thrown at all. For this, we need to add a boolean variable to the try block.

```matlab
%% This time we don't get any error at all
wrongFun = @() disp('Some error-free code.');
tf = false;
try
  feval(wrongFun);
  tf = true;
catch ME
  assert(strcmp(ME.identifier,'PSS:Book:id'));
end
if (tf)
  assert(false,'CatchErrorTest: No error thrown');
end
```

When you run this code segment, you get the following output:

```
Some error-free code.
CatchErrorTest: No error thrown
```

If you run the test as part of a test script with `runtests`, the test will fail.

A far better way to test for warnings and errors is to use the unit test framework's qualifiers to check that the desired warning or error is generated. Here is an example of verifying a warning, with one test that will pass and one that will fail; note that you need to pass a function handle to the `verifyWarning` function.

WarningsTest.m

```matlab
%% WARNINGSTEST Test generation of warnings.
%% Form
%   tests = WarningsTest
%% Output
%   tests   (:)   Array of Tests.

function tests = WarningsTest
```

```
% Create an array of local functions
tests = functiontests(localfunctions);
end

%% Test Functions
function passTest(testCase)
warnFun = @() warning('PSS:Book:id','Warning!');
testCase.verifyWarning(warnFun, 'PSS:Book:id');
end

function failTest(testCase)
warnFun = @() warning('Wrong:id','Warning!');
testCase.verifyWarning(warnFun, 'PSS:id', 'Wrong id');
end
```

When we run this test function with `runtests`, we can see that `failTest` did in fact fail.

```
>> runtests('WarningsTest')
Running WarningsTest
.Warning: Warning!

==========================================================================
Verification failed in WarningsTest/failTest.

    ----------------
    Test Diagnostic:
    ----------------
    Wrong id

    ---------------------
    Framework Diagnostic:
    ---------------------
    verifyWarning failed.
    --> The function handle did not issue the expected warning.

        Actual Warnings:
                Wrong:id
        Expected Warning:
                PSS:id

    Evaluated Function:
            @()warning('Wrong:id','Warning!')

    ------------------
    Stack Information:
    ------------------
    In /Users/Shared/svn/Manuals/MATLABCookbook/MATLAB/Ch05-Debugging/
        WarningsTest.m (failTest) at 12
==========================================================================
.
```

```
Done WarningsTest
__________

Failure Summary:

     Name                   Failed  Incomplete  Reason(s)
    ==================================================================
     WarningsTest/failTest    X                 Failed by verification.

Totals:
   1 Passed, 1 Failed, 0 Incomplete.
   0.047691 seconds testing time.
```

`verifyError` works the same way. In practice, you will need to make a function handle that includes the inputs to your function that cause the error or warning to be generated.

For advanced programmers, there is a further mechanism for constructing tests using `verifyThat` with the `Constraint` class. You can supply your own `Diagnostic` objects as well. For more information, see the reference pages for these classes along with the `Verifiable` class.

5.7 Testing Generation of Figures

Problem

Your function generates a figure instead of an output variable. How do you test it?

Solution

While you may need a human to verify that the figure looks correct, you can at least verify that the correct set of figures is generated by your function using `findobj`.

How It Works

Routinely assigning names to your figures makes it easy to test that they have been generated, even if you don't have access to the handles. You can also assign tags to figures, such as having a single tag for your entire toolbox, which allows you to locate sets of figures.

```
>> figure('Name','Figure 1','Tag','PSS');
>> figure('Name','Figure 2','Tag','PSS')
>> h = findobj('Tag','PSS')
h =
  2x1 Figure array:

  Figure    (PSS)
  Figure    (PSS)
>> h = findobj('Name','Figure 1')
h =
  Figure (PSS) with properties:

      Number: 1
```

```
         Name: 'Figure 1'
        Color: [0.94 0.94 0.94]
     Position: [440 378 560 420]
        Units: 'pixels'
```

In your test, you can then check that you have the correct number of figures generated using `length(h)` or that each specific named figure exists using `strcmp`. If you are storing any data in your figures using `UserData`, you can test that as well.

If you are not using tags or need to check for figures that do not have names or tags, you can find all figures currently open using the `type` input to `findobj`:

```
>> findobj('type','figure')
ans =
  2x1 Figure array:

  Figure    (PSS)
  Figure    (PSS)
```

Note that figures will only be returned by `findobj` if they are visible to the command line via their `HandleVisibility` property. This property can have the values `'on'`, `'off'`, and `'callback'`. GUIs generated by the App Designer are generally hidden to prevent users from accidentally altering the GUI using `plot` or similar commands; these figures use the value `'callback'`. Regular figures will have the value `'on'` and can be located as before. A figure with `HandleVisibility` set to `'off'` can only be accessed using its handle.

Summary

This chapter has demonstrated how to use MATLAB's unit test framework and provided some recipes to help you in debugging your functions. Table 5.1 lists the code developed in the chapter.

Table 5.1: *Chapter Code Listing*

File	Description
`CatchErrorTest`	Script showing how to catch errors in a try block
`CompleteTriangle`	Example function calculating angles in a triangle
`DebugLog`	Custom data logging function
`DebugLogDemo`	Demo of `DebugLog` showing a backtrace
`TriangleFunctionTest`	A function with test cases for `CompleteTriangle`
`TriangleTest`	A script with test cases for `CompleteTriangle`
`VerboseEigTest`	A test function showing all levels of verbosity
`WarningsTest`	A test function using `verifyWarning`