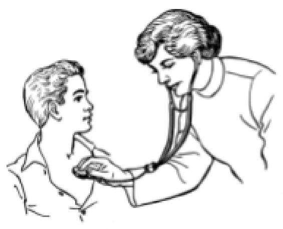
2.20 Debugging

Debugging is the process of determining and fixing the cause of a problem in a computer program. ***Troubleshooting*** is another word for debugging. Far from being an occasional nuisance, debugging is a core programmer task, like diagnosing is a core medical doctor task. Skill in carrying out a methodical debugging process can improve a programmer's productivity.

Figure 2.20.1: A methodical debugging process.



- *Predict a possible cause* of the problem
- *Conduct a test* to validate that cause
- Repeat

Feedback?

A common error among new programmers is to try to debug without a methodical process, instead staring at the program, or making random changes to see if the output is improved.

Consider a program that, given a circle's circumference, computes the circle's area. Below, the output area is clearly too large. In particular, if circumference is 10, then radius is 10 / (2 * PI_VAL), so about 1.6. The area is then PI_VAL * 1.6 * 1.6, or about 8, but the program outputs about 775.

Figure 2.20.2: Circle area program: Problem detected.

```
Enter circumference: 10
Circle area is: 775.157
```

```
#include <iostream>
using namespace std;

int main() {
   const double PI_VAL = 3.14159265;

   double circleRadius;
   double circleCircumference;
   double circleArea;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;
   circleArea = PI_VAL * circleRadius * circleRadius;

   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

Feedback?

First, a programmer may predict that the problem is a bad output statement. This prediction can be tested by adding the statement `circleArea = 999;`. The output statement is OK, and the predicted problem is invalidated. Note that a temporary statement commonly has a "FIXME" comment to remind the programmer to delete this statement.

Figure 2.20.3: Circle area program: Predict problem is bad output.

```
#include <iostream>
using namespace std;

int main() {
   const double PI_VAL = 3.14159265;

   double circleRadius;
   double circleCircumference;
   double circleArea;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;
   circleArea = PI_VAL * circleRadius * circleRadius;

   circleArea = 999; // FIXME delete
   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

```
Enter circumference: 0
Circle area is: 999
```

Feedback?

Next, the programmer predicts the problem is a bad area computation. This prediction is tested by assigning the value 0.5 to radius and checking to see if the output is 0.7855 (which was computed by hand). The area computation is OK, and the predicted problem is invalidated. Note that a temporary statement is commonly left-aligned to make clear it is temporary.

Figure 2.20.4: Circle area program: Predict problem is bad area computation.

```
#include <iostream>
using namespace std;

int main() {
   const double PI_VAL = 3.14159265;

   double circleRadius;
   double circleCircumference;
   double circleArea;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

   circleRadius = circleCircumference / 2 * PI_VAL;

circleRadius = 0.5; // FIXME delete
   circleArea = PI_VAL * circleRadius * circleRadius;

   cout << "Circle area is: " << circleArea << endl;

   return 0;
}
```

```
Enter circumference: 0
Circle area is: 0.785398
```

Feedback?

The programmer then predicts the problem is a bad radius computation. This prediction is tested by assigning PI_VAL to the circumference, and checking to see if the radius is 0.5. The radius computation fails, and the prediction is likely validated. Note that unused code was temporarily commented out.

Figure 2.20.5: Circle area program: Predict problem is bad radius computation.

```
Enter circumference: 0
Radius: 4.9348
```

```
#include <iostream>
using namespace std;

int main() {
   const double PI_VAL = 3.14159265;

   double circleRadius;
   double circleCircumference;
   double circleArea;

   cout << "Enter circumference: ";
   cin  >> circleCircumference;

circleCircumference = PI_VAL;                   // FIXME delete
   circleRadius = circleCircumference / 2 * PI_VAL;
cout << "Radius: " << circleRadius << endl; // FIXME delete

   /*
    circleArea = PI_VAL * circleRadius * circleRadius;

    cout << "Circle area is: " << circleArea << endl;
    */

   return 0;
}
```

Feedback?

The last test seems to validate that the problem is a bad radius computation. The programmer visually examines the expression for a circle's radius given the circumference, which looks fine at first glance. However, the programmer notices that `radius = circumference / 2 * PI_VAL;` should have been `radius = circumference / (2 * PI_VAL);`. The parentheses around the product in the denominator are necessary and represent the desired order of operations. Changing to `radius = circumference / (2 * PI_VAL);` solves the problem.

The above example illustrates several common techniques used while testing to validate a predicted problem:

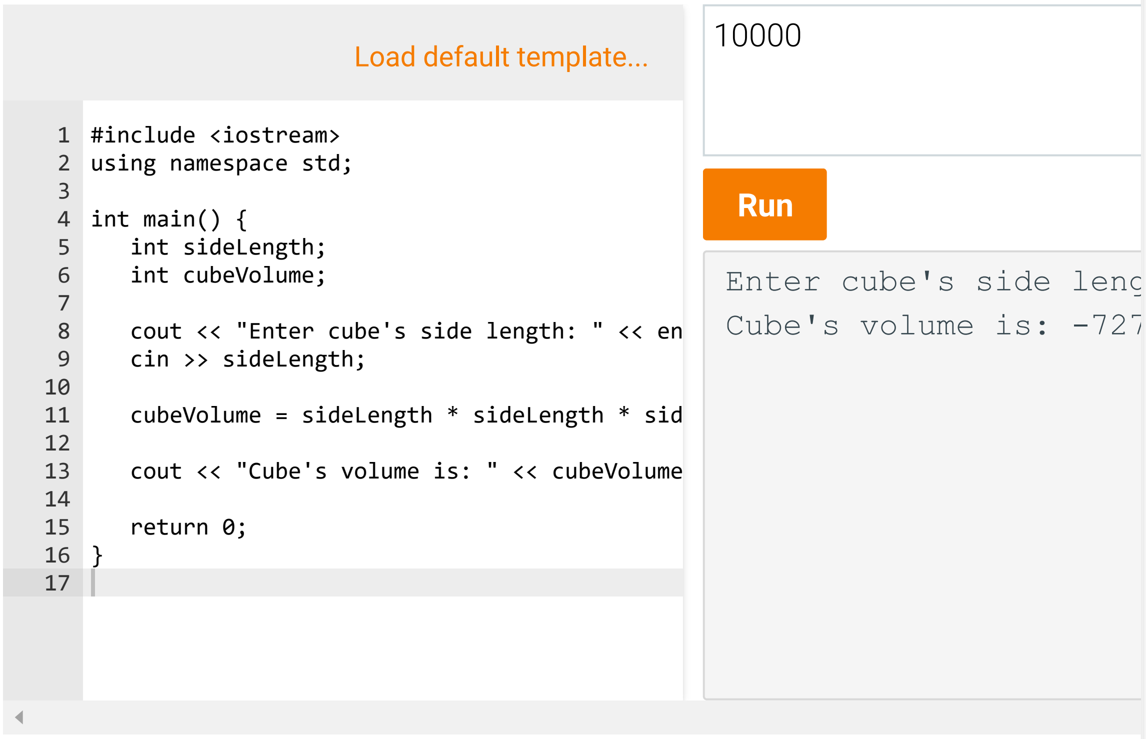
- Manually set a variable to a value.
- Insert print statements to observe variable values.
- Comment out unused code.
- Visually inspect the code (not every test requires modifying/running the code).

Statements inserted for debugging must be created and removed with care. A common error is to forget to remove a debug statement, such as a temporary statement that manually sets a variable to a value. Left-aligning such a statement and/or including a FIXME comment can help the programmer remember. Another common error is to use /* */ to comment out code that itself contains /* */ characters. The first */ ends the comment before intended, which usually yields a syntax error when the second */ is reached or sooner.

The predicted problem is commonly vague, such as "Something is wrong with the input values." Conducting a general test (like printing all input values) may give the programmer new ideas as to a more-specific predicted problems. The process is highly iterative—new tests may lead to new predicted problems. A programmer typically has a few initial predictions, and tests the most likely ones first.

zyDE 2.20.1: Debugging using a repeated two-step process.

Use the above repeating two-step process (predict problem, test to validate) to fin
problem in the following code for the provided input.



Load default template...

```
#include <iostream>
using namespace std;

int main() {
   int sideLength;
   int cubeVolume;

   cout << "Enter cube's side length: " << en
   cin >> sideLength;

   cubeVolume = sideLength * sideLength * sid

   cout << "Cube's volume is: " << cubeVolume

   return 0;
}

```

```
10000
```

Run

```
Enter cube's side leng
Cube's volume is: -727
```

Feedback?

PARTICIPATION ACTIVITY 2.20.1: Debugging.

Answer based on the above discussion.

1) The first step in debugging is to make random changes to the code and see what happens.

True

Correct

While a common first step among beginners, a methodical process starts with predicting a problem (or at least a problem area).

False

2) A common predicted-problem testing approach is to insert print statements.

[✓ True]
False

Correct

This is perhaps the most common predicted-problem testing approach.

✓

3) Variables in temporary statements can be written in uppercase, as in MYVAR = 999, to remind the programmer to remove them.

True
[✓ False]

Correct

The language is case sensitive, so using uppercase refers to a different variable.

✓

4) A programmer lists all possible predicted problems first, then runs tests to validate each.

True
[✓ False]

Correct

The list of all possible problems is typically huge. A programmer thinks of a few possible problems, then tests the most likely first. Testing may lead to new predictions.

✓

5) Most beginning programmers naturally follow a methodical process.

True
[✓ False]

Correct

In contrast, beginning programmers commonly stare at the code or make random changes. A good skill to develop is to think methodically. Predict likely problems, then carefully test to validate each prediction.

✓

6) A program's output should be positive and usually is, but in some instances the output becomes negative. Overflow is a good prediction of the problem.

[✓ True]
False

Correct

A reasonable test is to try small and large numbers and see if the large numbers consistently exhibit the problem. Hand calculation of the expected output and determination of whether the output value fits in the variable's size is also a good test.

✓

Feedback?