Chapter

9

Overloading & Defaults

Function overloading allows you to use the same name for different functions in the same program, provided each takes a different **type or number** of arguments. You can sometimes get a similar effect by providing **default arguments**, allow you to write a single function that can be **called in several different ways**.

Function Overloading

Different functions may have the **same name** if the **pattern of arguments** is different. The pattern of arguments taken by a function—which refers only to the number and types of the arguments and not the parameter names—is called its **signature**.

Both `<cmath>` and `<cstdlib>` have `abs()`functions:

```
int abs(int n);
long abs(long n);
long long abs(long long n);
```

Above are the versions in `<cstdlib>` while below are the four versions in `<cmath>`:

```
double abs(double x);
float abs(float x);
long double abs(long double x);
double abs(T x);
```

There are even versions for **complex numbers** in the header `<complex>`.

The only difference between these functions is the **types of the parameters**. The compiler chooses **which version to call** by looking at the types of the arguments supplied.

- Called with an `int`, the compiler calls the `int` version which returns an `int`.
- Called with a `double`, the compiler will choose the version from `<cmath>`.

If you call `abs()` with an integer, and **only** include `<cmath>`, but forget `<cstdlib>`, then a special **generic version** of `abs()` that takes a type `T` parameter will be called. The difference between the generic version, and the overloaded `abs(int)` version, is that the generic version **always** returns a `double`, not an `int`.

Overloading makes it **easier for programmers to remember function names** when the same operation is applied in slightly different contexts. C, which **does not** have overloading, requires different names for each different absolute value function: `iabs`, `fabs`, `dabs`, `labs`, `llabs`, and so on.

Overloading Rules

When you overload a function:

- The parameter **number** must differ, or
- The parameter **types** must differ, or
- The parameter **order** must differ

You **cannot** merely change the return type of a function. That is an error.

Overload Resolution

To determine which function is called, your compiler follows a process called **overload resolution**. Resolving which version of the `abs()` function to call is easy, since it only takes one argument. Things are more complex when a function takes several arguments.

Here are the rules:

1. Functions **with the same name** are gathered into a **candidate set**.
2. The candidate set is narrowed to produce the **viable set**; those functions that have **the correct number of parameters** and whose parameters **could** accept the supplied arguments using standard conversions.
3. If there are any **exact matches** in the viable set, use that version.
4. If there are no exact matches, find the **best match** involving conversions. The rules for this can be quite complex. You can find all of the details in the C++ Primer, Section 6.6.

There are **two possible errors** that can occur **at the end** of the matching process:

- There are **no members** left in the viable set. This produces an **undeclared name** compiler error.
- The process **can't pick a winner** among several viable functions. This produces an **ambiguity** compiler error.

When this occurs, **the function definition is not in error**, but **the function call**.

Default Arguments

In your function declaration, you may indicate that **certain arguments are optional** by providing them with a value to be used when no argument is passed in the call. These are called **default arguments**.

To indicate that an argument is optional, include an initial value **in the declaration** of that parameter in the function prototype. For example, you might define a procedure with the following prototype:

```
void formatInColumns(int nColumns = 2);
```

The `{2}` in the prototype declaration means that this **argument** may be omitted when calling the function. You can now call the function in two different ways:

```
formatInColumns();  // use 2 for nColumns
formatInColumns(3); // use 3 for nColumns
```

The `getline()` function which you have been using, actually has a third parameter, the line-ending character, that is given the default value `'\n'`. Since most of the time you want to read an entire line, ending in a newline, that makes sense. However, if you supply a third argument, say `';'`, `getline` will only read up to a `';'` and discard it.

Default Argument Rules

- The default value appears **only in the function prototype**. If you repeat the default arguments in the implementation file you will get a compiler error.
- Parameters with defaults must **appear at the end of the parameter list** and cannot be followed by a parameter without a default. Here's an example:

```
void badOrder(int a = 3, int b); // how to call this?
```

- Default arguments are only used with value, **not reference** parameters. Here's another example:

```
void badType(int& a = ???);  // what to use?
```

Since a reference must refer to an `lvalue`, there is no way to specify which `lvalue` should be used when the function is called.

Normally Prefer Overloading

Overloading is usually preferable to default arguments. Suppose you wish to define a procedure `setLocation()` that takes `x` and a `y` coordinates as arguments.

You may write the prototype, **using default arguments**, like this:

```
void setLocation(double x = 0, double y = 0);
```

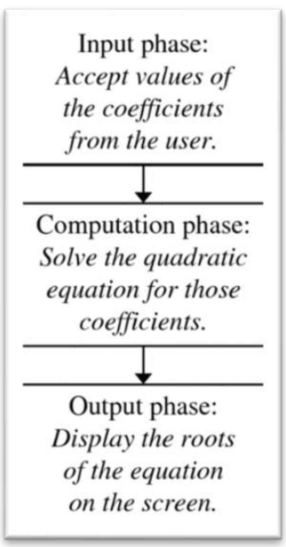
Now, the default location defaults to the origin `{0, 0}`. However, it is possible to call the function with **only one argument**, which is **confusing** to anyone reading the code. It is **better to just define a pair of overloaded** functions like this:

```
void setLocation(double x, double y);
inline void setLocation() { setLocation(0, 0); }
```

The body of the second function, can just calls the first, passing `0`, `0` as the arguments.

Functions & Data Flows

You may return more than one value from a function by using reference parameters to pass values back and forth through the argument list.



As an example, suppose that you are writing a program to solve the quadratic equation below and you want to structure that program into three IPO phases like this.

$$ax^2 + bx + c = 0$$

Using this plan, your `main` function might look like this:

```
int main()
{
    double a, b, c, root1, root2;
    getCoefficients(a, b, c);
    solveQuadratic(a, b, c, root1, root2);
    printRoots(root1, root2);
}
```

The variables `a`, `b` and `c` are the coefficients, while `root1` and `root2` will hold the roots.

```
void getCoefficients(double& x, double& y, double& z)
{
    cout << "Enter 3 coefficients: ";
    cin >> x >> y >> z;
}
```

If a function **returns more than one** piece of information, use **reference parameters**.

> Note that when you call `getCoefficients`, information **does not** flow from `main` **into** the function; instead, information **flows out of the function** back to `main`, through the three **output parameters** `x`, `y`, and `z`, which **are not new variables**, but are **new names** or **aliases** for the variables `a`, `b`, and `c` used when calling it.

- Instead of separate inputs, this reads three variables using a **single input statement**. The values entered by the user must be **separated from each other by whitespace**, not commas. Spaces, tabs or newlines all work fine.
- When **documenting your parameters**, **annotate** each of the parameters with the direction of the information flow: `[in]`, `[in,out]`, `[out]`. If you don't. it is **assumed** to be an input parameter.

Input *and* Output Parameters

The ***`solveQuadratic()`*** function needs **both** input and output parameters. The arguments **`a`**, **`b`**, and **`c`** are used as **input** to the function, while **`root1`** and **`root2`** are **output parameters**, allowing the function to **pass back** the two roots to **`main`**.

```
void solveQuadratic(double a, double b, double c, // input
                    double& x1, double& x2)    // output
{
    if (a == 0) die("a == 0"); // no discriminate

    double discriminate = b * b - 4 * a * c;
    if (discriminate < 0) die("No real roots.");

    double sqrtDisc{sqrt(discriminate)};
    x1 = (-b + sqrtDisc) / (2 * a);
    x2 = (-b - sqrtDisc) / (2 * a);
}
```

Fatal Errors

Whenever the code encounters a condition that makes further progress impossible, it calls a function **`die()`** which prints a message and then terminates the program.

```
void die(const string& msg, int code{-1})
{
    cerr << "FATAL ERROR: " << msg << endl;
    exit(code);
}
```

- The **`cerr`** stream is similar to **`cout`**, but is reserved for reporting errors.
- The **`exit()`** function terminates a program immediately, using the value of the parameter to report the program status.
- The default error code is set to **`-1`**. If you want to use different error codes for different errors, just pass the code (preferably as a **`const`**).

This function could be useful in many programs, so you might put it in a utility library.

Input-Output Parameters

We can use a single parameter for both input and for output. Consider `toUpperCase()` in Java. It takes a `String` as an argument, and returns a new, uppercase version of the original. This builder method does not (indeed cannot) change its argument. However, that is a little inefficient, especially when assigned to the same variable.

Since C++ strings **may be modified**, we can write a more efficient version like this:

```
void toUpperCase(string& str)
{
    for (auto& c : str) { c = toupper(c); }
}
```

Here, `str` is **both an input and an output parameter**. Because of that, it is passed by reference, **not** const reference. Note that the loop variable `c` is a reference, not a value, so we can **modify the character it refers to**. Here's how to use it:

```
string str;
getline(cin, str);
toUpperCase(str);
```

A Data Flow Checklist

Consider the `string::getline(in, str)` function:

- `in` is an **input-output** parameter. The function depends on its initial state (formatting, etc.) and it is changed by calling the function (error value).
- `str` is an **output only** parameter; it makes no difference what is inside `str` when you can the function—data **only flows out**.

The Java idea of data flow – parameters are input, return statements are output – is too simplistic for C++. In C++ (as in many other languages), parameters can be used as input, as output, or as a combination of both.

Use this checklist to determine the direction of data flow:

- ☐ Argument not modified by function: **input parameter**
- ☐ Argument modified, input value not used: **output** parameter
- ☐ Argument used and changed by function: **input-output** parameter

Parameter Declaration Checklist

Use this checklist to determine **how to declare** the parameter variable:

- ☐ Output and Input-Output parameters: **by reference**
- ☐ Input primitive (built-in and enumerated) types: **by value**
- ☐ Input library and class types: by **const** **reference**

> ***Never*** *pass by value for class or library types*

Here are some examples.

```
string s1{"cat"};
string s2 = upper(s1);
// s1->cat, s2->CAT
```

- What is the direction of the **data flow** for `upper`?
  - → This is an **input parameter.** The argument (**"`cat`"**) is not changed
- What is the correct parameter declaration? `const string&`

```
string s1{"cat"};
upper(s1);
//s1->CAT
```

- What is the direction of the **data flow** for `upper`?
  - → This is an **input-output parameter.** The argument **is** changed
- What is the correct parameter declaration? `string&`

```
string s1;
generate(s1);
//s1->CAT
```

- What is the direction of the **data flow** for `generate`?
  - → This is an **output parameter.** `s1` **is** uninitialized when called.
- What is the correct parameter declaration? `string&`

More Selection & Iteration

We have covered the basics of selection, iteration and functions in C++, but here are several additional features you might to use:

- **The `switch`** statement which provides an efficient multi-way branch based on the concept of an integer selector.
- **The conditional operator** which allows you to turn a 4-line if-else statement into a single, compact, expression.
- **The `do-while`**, (or **hasty**) **loop**, for when you want to leap before you look.

Let's take these in order.

The switch Statement

The `switch` statement implicitly **compares** an integral expression (called the **selector**) to a series of constants (called the **case labels**). Here's the syntax:

```
switch(integral-expr)
{
    case constexpr1:
        statement;
        break;
    case constexpr2:
        statement;
        break;
    default:
        statement;
}
```

The `switch` selector is an **integral expression**. It is evaluated and compared against the `case` labels `constexpr1`, then `constexpr2`, and so forth. As indicated, each label **must be a constant** integer expression. If selector match is found, then **control jumps** to the first statement in the `case` block. When control reaches the `break` at the end of the clause, it **jumps** to the statement that follows the entire `switch` statement.

The optional `default` specifies an action if **none of the constants** match the selector; if there is no `default` clause, the program simply continues after the `switch`.

The constants in each `case` **label** statement must be **an integral type**. That means `char`s and enumerated types are fine; **strings or doubles are not**.

Falling Through a switch

Consider this code fragment inside a switch:

```
case 'a':
case 'e':
case 'i':
case 'o':
case 'u':
    cout << "vowel";
case ' ': case '\t': case '\n':
    cout << "whitespace";
```

As you can see, **break** statements are **not required** at the end of each **case**. If the **break** is missing, the program starts executing the **next clause** after it finishes the selected one. We say the **case** **falls-through**.

This is useful as shown here where the output is printed for all of the lower-case vowels. If there is nothing in the body of the case, it may be more readable to format it like the whitespace block.

If there is **any code** inside a **case** block that falls through, most compilers will issue a warning. If you **intend** to fall through, and you want to suppress the warning, add a comment like this, just before the second **case**:

```
// fall through
```

A Few More Rules

- Two **case** labels may not have the same value
- A label must precede a statement or another **case** label. It may not be alone.
- Variables **may not** be defined inside one block and used in another.

The Conditional Operator

The **conditional** or **selection** operator uses two symbols: **?** and **:** , along with three different operands. It is also known as **the ternary operator** or **tertiary** operator for the number of operands. The general form is

```
(condition) ? exp1 : exp2
```

The parentheses are not technically required, but programmers often include them.

Here's how the conditional operator works:

- The condition is evaluated.
- If the condition is **true**, ***exp1*** is evaluated and used as the return value.
- If the condition is **false**, the expression value is ***exp2***.

Here are two examples:

```
int largest = (x > y) ? x : y;
cout << ((cats != 1) ? "cats" : "cat") << endl;
```

- **Line** 1 assigns the larger of **x** or **y** to the variable **largest**.
- Line 2 prints **"cat"** if there is only one cat, and **"cats"** otherwise.

Note that when you use the conditional operator as part of an output statement, you **must** parenthesize the whole expression, since it has very low precedence.

A Hasty Loop

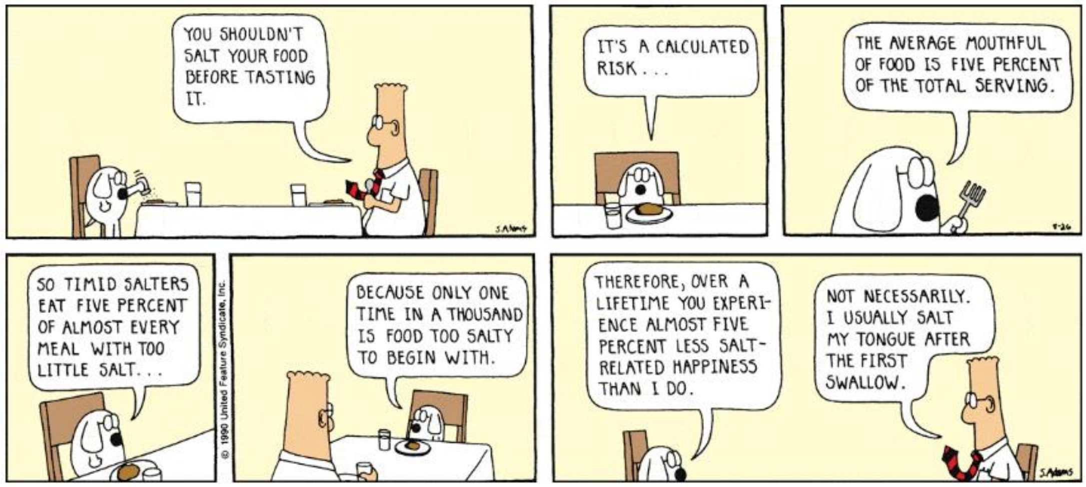
In addition to **for** and **while**, C++ has a loop that tests **after** the loop body completes. The **do-while** loop always executes the statements inside its body at least once.

```
do
{
    // statements
}
while (condition);
```

The body of the ***do-while*** loop appears between the keywords **do** (which precedes the loop body) and **while**. The body of the ***do-while*** loop can be a single statement, ending with a semicolon, or it can be a compound statement enclosed in braces.

In the ***do-while*** loop, the condition is **followed by a semicolon**, unlike the ***while*** loop, where following the condition with a semicolon leads to subtle, hard to find bugs.

The ***do-while*** loop is often employed by beginning programmers because it seems more natural. If you find yourself in this situation, think twice. 99% of the time, a ***while*** loop or a ***for*** loop is better than a ***do-while***. In fact, except for salting your food...



which should **always be done before tasting**, there are relatively few other situations where a test-at-the-bottom strategy is superior to "looking before you leap."

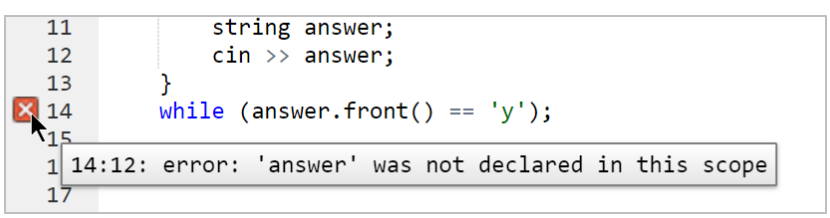
Confirmation Loops

When you make a withdrawal at your ATM, before your card is returned, the machine will ask you "Do you want to make another transaction?" This is a **confirmation loop**, and the ***do-while*** loop seems ideal for solving this problem.

However, there are still some things you need to watch out for. Consider this code:

```
do
{
    completeSomeTransaction();
    cout << "Do you want another transaction? ";
    string answer;
    cin >> answer;
}
while (answer.front() == 'y');
```

While this **looks reasonable** (other than not providing for the empty string or an upper-case 'Y'), it actually **won't compile**. When you get to the **loop condition**, the **string** variable **answer** has **gone out of scope**.



So, even in this natural use-case, the ***while*** loop is a little more efficient.

Finish Up

- Complete the **reading exercises (REX)** for this chapter.
- Complete the homework using the **CS50 IDE**. The link is on Canvas.
  a. Make sure you submit the assignment using `make submit`.
  b. Make sure you check the CS150 Homework Console to see that your scores got reported, before the beginning of the next lecture.
- Take the **pre-class reading quiz** on Canvas. You have two attempts.

See you in class or on the Canvas discussion board.