Control Statements and Functions

EECS 211

Winter 2017

Agenda

- Computation
  - What is computable? How best to compute it?
  - Abstractions, algorithms, heuristics, data structures
- Language constructs and ideas
  - Sequential order of execution
  - Expressions and statements
  - Selection
  - Iteration
  - Functional abstraction
- How to talk about syntax

You already know most of this

- You know how to do arithmetic:
  - $d = a + b \times c$

You already know most of this

- You know how to do arithmetic:
  - $d = a + b \times c$
- You know how to sequence:
  - “Open the door, then walk through.”

You already know most of this

- You know how to do arithmetic:
  - $d = a + b \times c$
- You know how to sequence:
  - "Open the door, then walk through."
- You know how to select:
  - "If it's raining, take an umbrella; otherwise take sunglasses."

You already know most of this

- You know how to do arithmetic:
  - $d = a + b \times c$
- You know how to sequence:
  - "Open the door, then walk through."
- You know how to select:
  - "If it's raining, take an umbrella; otherwise take sunglasses."
- You know how to iterate:
  - "Do 20 reps."
  - "Stir until no lumps remain."

You already know most of this

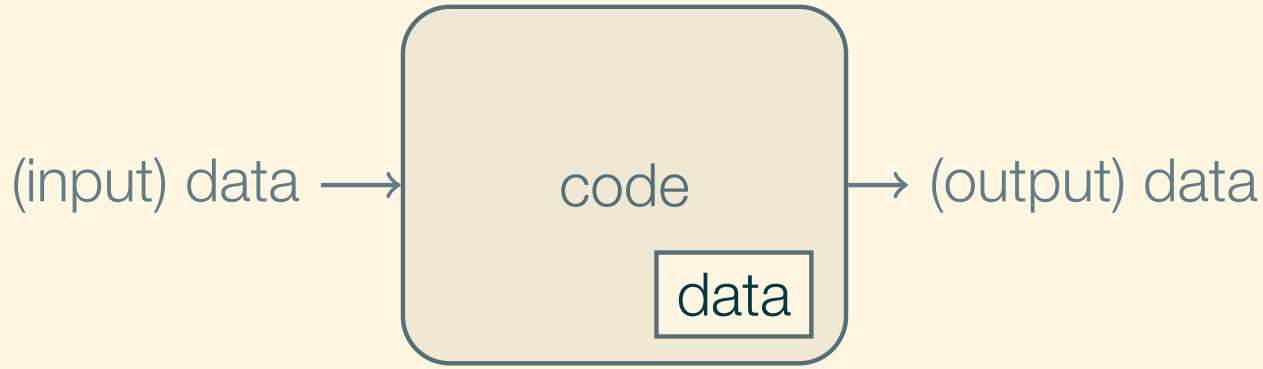
- You know how to do arithmetic:
  - $d = a + b \times c$
- You know how to sequence:
  - "Open the door, then walk through."
- You know how to select:
  - "If it's raining, take an umbrella; otherwise take sunglasses."
- You know how to iterate:
  - "Do 20 reps."
  - "Stir until no lumps remain."
- You know how to do function calls (sort of):
  - "Go ask Alice and report back to me."

You already know most of this

- You know how to do arithmetic:
  - $d = a + b \times c$
- You know how to sequence:
  - "Open the door, then walk through."
- You know how to select:
  - "If it's raining, take an umbrella; otherwise take sunglasses."
- You know how to iterate:
  - "Do 20 reps."
  - "Stir until no lumps remain."
- You know how to do function calls (sort of):
  - "Go ask Alice and report back to me."

So what I'll be showing you is mainly syntax for things you already know.

Computation: the big picture



- Input: from keyboard, files, mouse, other input devices, the network, other programs
- Code: consumes the input and does something to produce the output
- Output: to the screen, files, printer, other output devices, the network, other programs

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Tools:

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Tools:

- Divide and conquer
  - Break a big computation into several smaller ones

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Tools:

- Divide and conquer
  - Break a big computation into several smaller ones
- Abstraction
  - Use a higher-level concept that hides detail

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Tools:

- Divide and conquer
  - Break a big computation into several smaller ones
- Abstraction
  - Use a higher-level concept that hides detail
- Data organization (often key to good code)
  - Input/output formats
  - Communication protocols
  - Data structures

Expressing computation

Our job is to express computations

- simply,
- correctly, and
- efficiently.

Tools:

- Divide and conquer
  - Break a big computation into several smaller ones
- Abstraction
  - Use a higher-level concept that hides detail
- Data organization (often key to good code)
  - Input/output formats
  - Communication protocols
  - Data structures

Note the emphasis is on structure and organization

Programming language features

Each language feature exists to express a fundamental idea:

+	addition
*	multiplication
{ *stm stm* ... }	sequencing
if (*expr*) *stm* else *stm*	selection
while (*expr*) *stm*	iteration
f(x);	function call

Programming language features

Each language feature exists to express a fundamental idea:

`+`	addition
`*`	multiplication
`{ stm stm ... }`	sequencing
`if (expr) stm else stm`	selection
`while (expr) stm`	iteration
`f(x);`	function call

The meaning of each feature is simple, but we combine them into programs of arbitrary complexity.

Expressions

An expression computes a value:

```
int length = 20;          // simplest expression is a literal
int width  = 40;
```

Expressions

An expression computes a value:

```
int length = 20;              // simplest expression is a literal
int width  = 40;

int area   = length * width;  // multiplication
```

Expressions

An expression computes a value:

```
int length = 20;                    // simplest expression is a literal
int width  = 40;

int area   = length * width;        // multiplication

// as in algebra, you can compose operations
int average = (length + width) / 2;
```

Expressions

An expression computes a value:

```
int length   = 20;              // simplest expression is a literal
int width    = 40;

int area     = length * width;  // multiplication

// as in algebra, you can compose operations
int average = (length + width) / 2;
```

The usual rules of precedence apply:
a * b + c / d means (a * b) + (c / d), not ((a * b) + c) / d

Expressions

An expression computes a value:

```
int length = 20;                // simplest expression is a literal
int width  = 40;

int area   = length * width;    // multiplication

// as in algebra, you can compose operations
int average = (length + width) / 2;
```

The usual rules of precedence apply:
a * b + c / d means (a * b) + (c / d), not ((a * b) + c) / d

When in doubt, parenthesize (but don't overdo it)

What expressions are made of

Operators and operands

- operators specify what to do
- operands specify the data to do it to

What expressions are made of

Operators and operands

- operators specify what to do
- operands specify the data to do it to

Some common operators:

Operator(s)	Meaning	bool	int	double
+, −, *, /	arithmetic		Yes	Yes
%	remainder		Yes	
==	equal	Yes	Yes	Yes
!=	not equal	Yes	Yes	Yes
<, <=, >, >=	comparisons		Yes	Yes
&&, ||	and, or	Yes		

Concise operators

For many binary operators, there are (roughly) equivalent more concise versions:

a += c	means	a = a + c
a *= scale	means	a = a * scale
++a	means	a += 1
	or	a = a + 1

Use them when they make your code clearer

Syntax of Expressions

In BNF:

⟨*expr*⟩ := ⟪*numeric-literal*⟫
| ⟪*string-literal*⟫
| ⟪*variable*⟫
| ⟨*expr*⟩ ⟪*op*⟫ ⟨*expr*⟩
| ⟨*expr*⟩ **(** ⟨*expr-list*⟩ **)**
| **(** ⟨*expr*⟩ **)**

⟨*expr-list*⟩ :=
| ⟨*expr*⟩ ⟨*expr-cont*⟩

⟨*expr-cont*⟩ :=
| **,** ⟨*expr*⟩ ⟨*expr-cont*⟩

Syntax of Expressions

In BNF:

⟨*expr*⟩ := ⟪*numeric-literal*⟫
| ⟪*string-literal*⟫
| ⟪*variable*⟫
| ⟨*expr*⟩ ⟪*op*⟫ ⟨*expr*⟩
| ⟨*expr*⟩ **(** ⟨*expr-list*⟩ **)**
| ⟨*expr*⟩ **?** ⟨*expr*⟩ **:** ⟨*expr*⟩
| **(** ⟨*expr*⟩ **)**

⟨*expr-list*⟩ :=
| ⟨*expr*⟩ ⟨*expr-cont*⟩

⟨*expr-cont*⟩ :=
| **,** ⟨*expr*⟩ ⟨*expr-cont*⟩

Statements

A statement is one of:

- an expression followed by a semicolon,
- a declaration, or
- a *control* statement that determines control flow.

Statements

A statement is one of:

- an expression followed by a semicolon,
- a declaration, or
- a *control* statement that determines control flow.

Examples:

- `a = b;`
- `double d2 = 2.5;`
- `if (x == 2) y = 4;`
- `while (cin >> number) numbers.push_back(number);`
- `int average = (length + width) / 2;`
- `return x;`

Statements

A statement is one of:

- an expression followed by a semicolon,
- a declaration, or
- a *control* statement that determines control flow.

Examples:

- `a = b;`
- `double d2 = 2.5;`
- `if (x == 2) y = 4;`
- `while (cin >> number) numbers.push_back(number);`
- `int average = (length + width) / 2;`
- `return x;`

I don't expect you to recognize all of these…yet.

Syntax of Statements

⟨*type*⟩ := `int` | `double` | `string` | ···

⟨*decl*⟩ := ⟨*type*⟩ ⟨⟨*variable*⟩⟩ `=` ⟨*expr*⟩
| ⟨*type*⟩ ⟨⟨*variable*⟩⟩

⟨*stmt*⟩ := ⟨*expr*⟩ `;`
| ⟨*decl*⟩ `;`
| `if (` ⟨*expr*⟩ `)` ⟨*stmt*⟩ `else` ⟨*stmt*⟩
| `if (` ⟨*expr*⟩ `)` ⟨*stmt*⟩
| `while (` ⟨*expr*⟩ `)` ⟨*stmt*⟩
| `for (` ⟨*decl*⟩ `;` ⟨*expr*⟩ `;` ⟨*expr*⟩ `)` ⟨*stmt*⟩
| `return` ⟨*expr*⟩ `;`
| `{` ⟨*stmt-list*⟩ `}`

⟨*stmt-list*⟩ :=
| ⟨*stmt*⟩ ⟨*stmt-list*⟩

Selection

Sometimes we must choose between alternatives.

For example, suppose we want to identify the larger of two numbers. We can use an if statement:

```
if (a < b)
        max = b;
else
        max = a;
```

Selection

Sometimes we must choose between alternatives.

For example, suppose we want to identify the larger of two numbers. We can use an if statement:

```
if (a < b)
        max = b;
else
        max = a;
```

The syntax is

⟨*stmt*⟩ := `if (` ⟨*expr*⟩ `)` ⟨*stmt*⟩ `else` ⟨*stmt*⟩

Sequencing

What if you want to do more than one thing in an if?

Sequencing

What if you want to do more than one thing in an if?

Use a compound statement:

```
if (a < b) {
        max = b;
        min = a;
} else {
        max = a;
        min = b;
}
```

Sequencing

What if you want to do more than one thing in an if?

Use a compound statement:

```
if (a < b) {
        max = b;
        min = a;
} else {
        max = a;
        min = b;
}
```

The syntax is

⟨*stmt*⟩ := **{** ⟨*stmt-list*⟩ **}**

⟨*stmt-list*⟩ :=
| ⟨*stmt*⟩ ⟨*stmt-list*⟩

Iteration (while)

```
int i = 0;

while (i < 100) {
        cout << i << '\t' << square(i) << '\n';
        ++i;
}
```

Iteration (while)

```
int i = 0;

while (i < 100) {
        cout << i << '\t' << square(i) << '\n';
        ++i;
}
```

The syntax is

⟨*stmt*⟩ := `while (` ⟨*expr*⟩ `)` ⟨*stmt*⟩

Iteration (for)

```
int i = 0;          // initialization

while (i < 100) {
        cout << i << '\t' << square(i) << '\n';
        ++i;        // step
}
```

This pattern—a loop with initialization and step—is so common that there's special syntax for it:

```
for (int i = 0; i < 100; ++i)
        cout << i << '\t' << square(i) << '\n';
```

Iteration (for)

```
int i = 0;          // initialization

while (i < 100) {
        cout << i << '\t' << square(i) << '\n';
        ++i;        // step
}
```

This pattern—a loop with initialization and step—is so common that there's special syntax for it:

```
for (int i = 0; i < 100; ++i)
        cout << i << '\t' << square(i) << '\n';
```

for loops are the idiomatic way to count in C++

Syntax of for

for (*init-decl*; *cond-expr*; *step-expr*)
    body-stm

Syntax of for

```
for (init-decl; cond-expr; step-expr)
    body-stm
```

means

```
init-decl;
while (cond-expr) {
    body-stm
    step-expr;
}
```

Functions

But what did square(i) mean?

Functions

But what did square(i) mean?

A call to the function square(int), which might be defined like

```
int square(int x)
{
        return x * x;
}
```

Functions

But what did square(i) mean?

A call to the function square(int), which might be defined like

```
int square(int x)
{
    return x * x;
}
```

The syntax is:

⟨*fun-decl*⟩ := ⟨*type*⟩ ⟨⟨*variable*⟩⟩ (⟨*args*⟩) { ⟨*stmt-list*⟩ }
⟨*args*⟩ :=
| ⟨*type*⟩ ⟨⟨*variable*⟩⟩ ⟨*more-args*⟩
⟨*more-args*⟩ :=
| , ⟨*type*⟩ ⟨⟨*variable*⟩⟩ ⟨*more-args*⟩

Why define a function?

Why define a function?

We want to separate and name a computation because it…

- …is logically separate.

Why define a function?

We want to separate and name a computation because it…

- …is logically separate.
- …make the program clearer.

Why define a function?

We want to separate and name a computation because it…

- …is logically separate.
- …make the program clearer.
- …can be reused.

Why define a function?

We want to separate and name a computation because it…

- …is logically separate.
- …make the program clearer.
- …can be reused.
- …eases testing, distribution of labor, and maintenance.

A function example

```
int square(int n) {
        return n * n;
}

int main () {
        cout << sqrt(square(3) + square(4)) << '\n';
}
```

A function example

```
int square(int n) {
        return n * n;
}

int main () {
        double a2 = square(3);
        double b2 = square(4);
        double c2 = a2 + b2;
        double c  = sqrt(c2);
        cout << c << '\n';
}
```

A function example

```
int main () {
        double a2 = square(3);
        double b2 = square(4);
        double c2 = a2 + b2;
        double c  = sqrt(c2);
        cout << c << '\n';
}
```

```
int square(int n) {
        return n * n;
}
```

A function example

```
int main () {
        double a2 = square(3);

        double b2 = square(4);

        double c2 = a2 + b2;
        double c  = sqrt(c2);

        cout << c << '\n';
}
```

```
int square(int n) {
        return n * n;
}
```

```
int square(int n) {
        return n * n;
}
```

```
double sqrt(double);
```