C++ functions()

Robotics 102

Introduction to AI and Programming

University of Michigan and Berea College

Fall 2021

Done

hello

```
Hello World!
Chad is in Robotics 102"
```

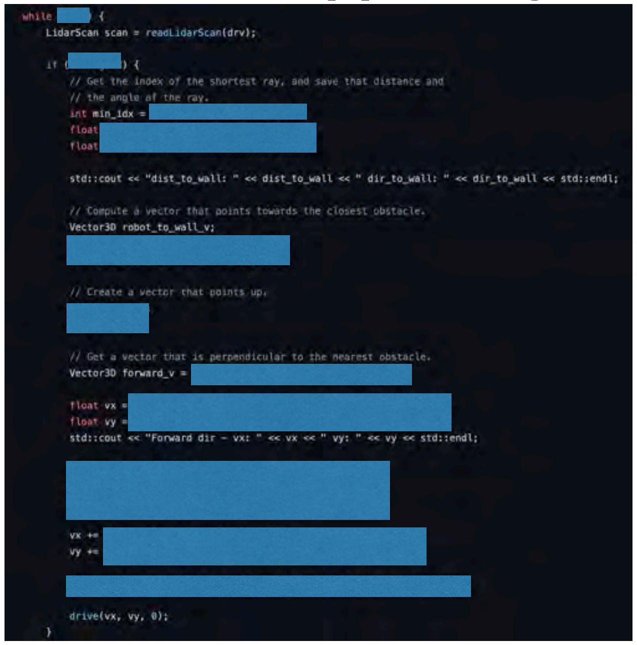
calculator (Version 24)

```
Please type a number and press enter: 22
Please type another number and press enter: 7
What is 22 plus 7? 29
What is 22 minus 7 ? 15
What is 22 times 7 ? 154
What is 22 divided by 7 ? 3.14286
```

- ☑ Program Structure
- ☑ Compile/Execute
- ☑ Operators
- ☑ Data Types
- ☑ Variables
- ☑ User Input/Output
- ☐ Functions
- ☐ Branching
- ☐ Iterators
- ☐ Vectors
- ☐ Structs
- ☐ File Input/Output

Coming

wall_follower.cpp - Project 1



```
while [redacted] {
    LidarScan scan = readLidarScan(drv);

    if ([redacted]) {
        // Get the index of the shortest ray, and save that distance and
        // the angle of the ray.
        int min_idx = [redacted]
        float [redacted]
        float

        std::cout << "dist_to_wall: " << dist_to_wall << " dir_to_wall: " << dir_to_wall << std::endl;

        // Compute a vector that points towards the closest obstacle.
        Vector3D robot_to_wall_v;
        [redacted]

        // Create a vector that points up.
        [redacted]

        // Get a vector that is perpendicular to the nearest obstacle.
        Vector3D forward_v = [redacted]

        float vx = [redacted]
        float vy =
        std::cout << "Forward dir - vx: " << vx << " vy: " << vy << std::endl;

        [redacted]

        vx += [redacted]
        vy +=

        [redacted]

        drive(vx, vy, 0);
    }
```

calculator.cpp (Version 24)

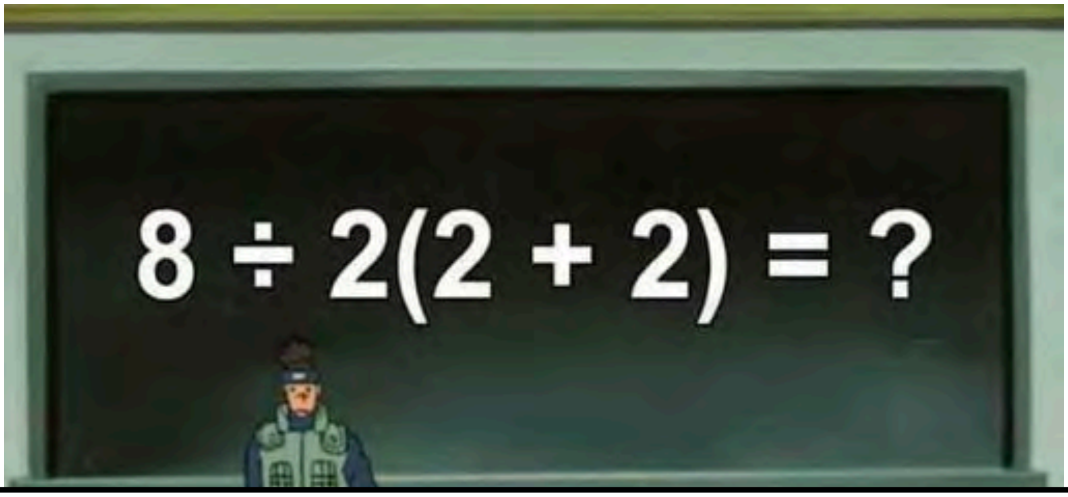
```
#include <iostream>

/* Let's write a calculator program for real numbers with variables
   that takes numbers from user input (no more magic numbers!)  */

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
   char multiplicationCharacter = '*';  // Character, for times
   char divisionCharacter = '/';  // Character, for division

   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << myNumber + myOtherNumber << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << myNumber - myOtherNumber << "\n";
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << myNumber * myOtherNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
}
```

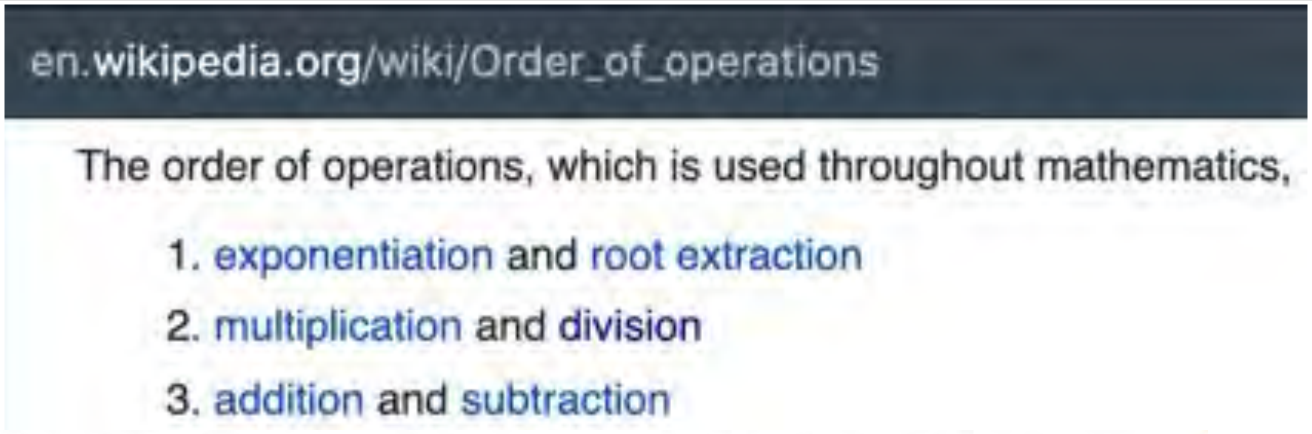
```
Please type a number and press enter: 22
Please type another number and press enter: 7
What is 22 plus 7? 29
What is 22 minus 7 ? 15
What is 22 times 7 ? 154
What is 22 divided by 7 ? 3.14286
```

Our main is not itself

Functions organize programs

A Brief Tangent



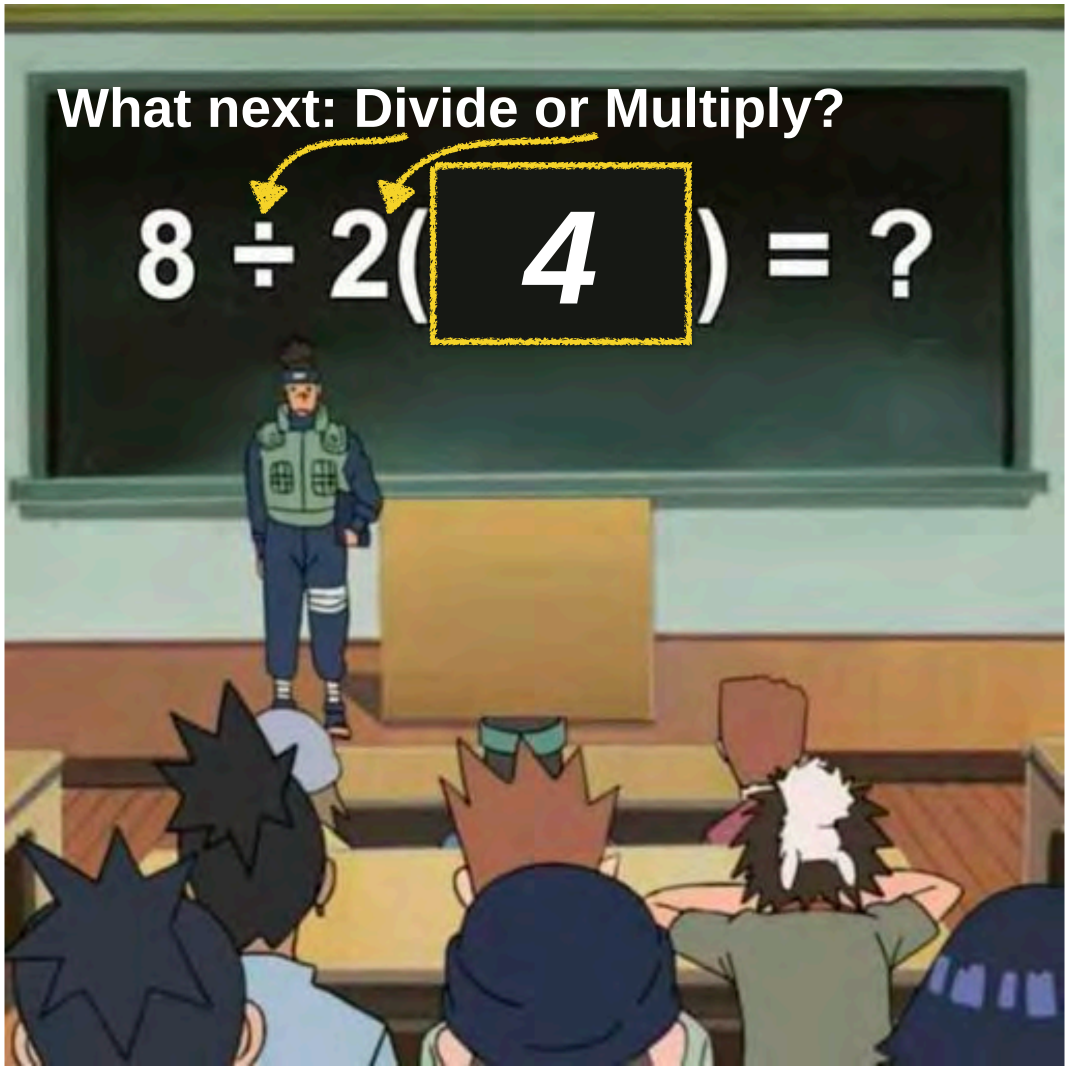

en.wikipedia.org/wiki/Order_of_operations

The order of operations, which is used throughout mathematics,

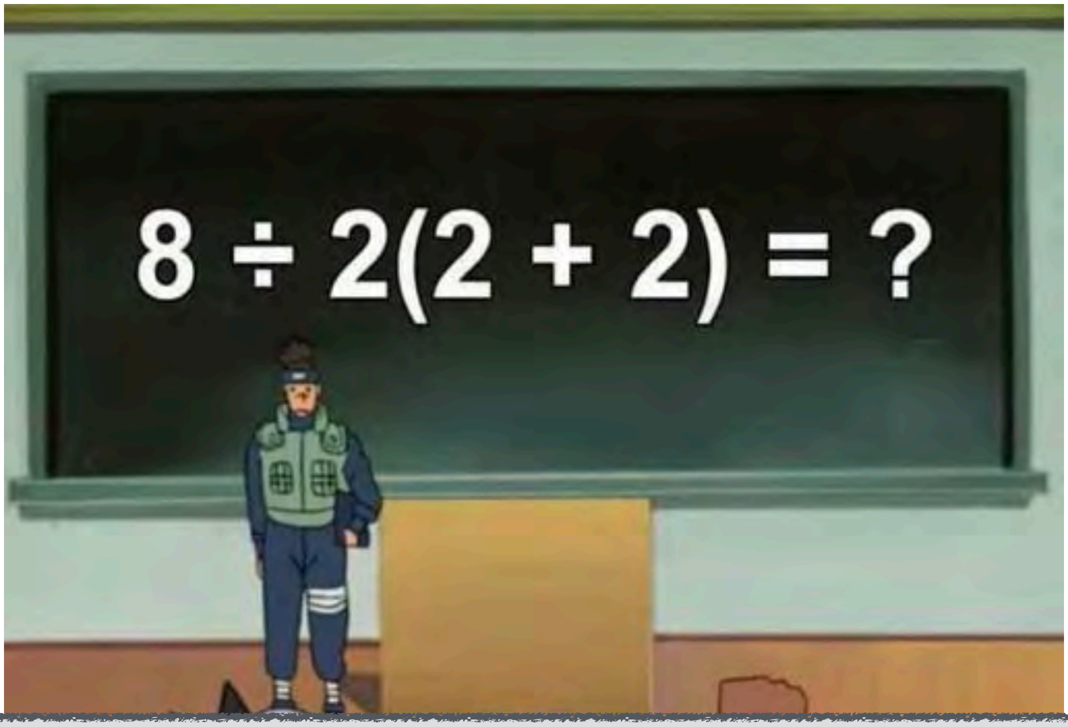
1. exponentiation and root extraction
2. multiplication and division
3. addition and subtraction

In the United States, the acronym ***PEMDAS*** is common.

It stands for *P*arentheses, *E*xponents, *M*ultiplication/*D*ivision, *A*ddition/*S*ubtraction.


What next: Divide or Multiply?
8 ÷ 2(4) = ?

16

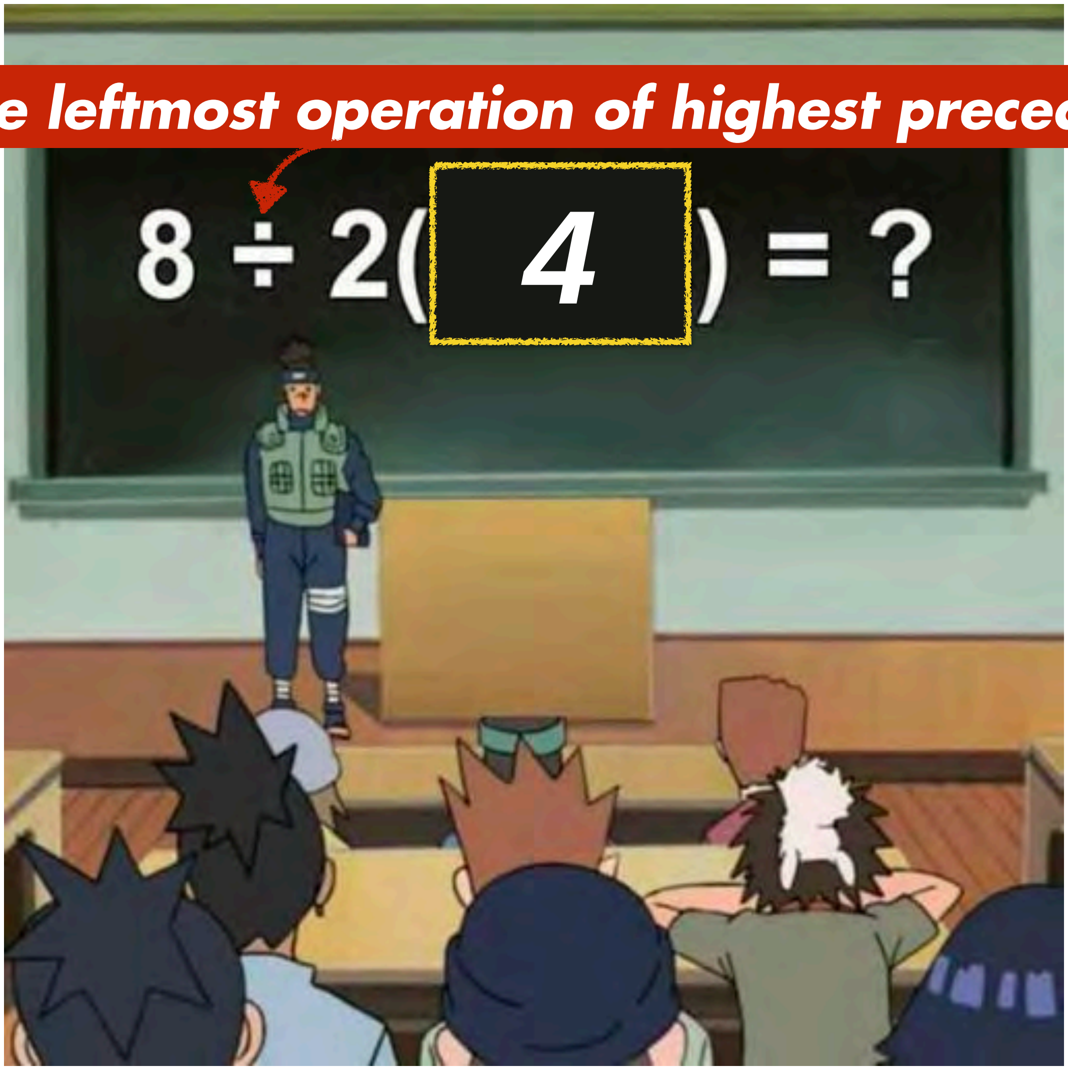


```
Hello Iruka Sensei!
The answer is: 16
```

naruto.cpp

```cpp
#include <iostream>

int main()
{
   std::cout << "Hello Iruka Sensei!" << "\n";
   std::cout << "The answer is: " << 8/2*(2+2) << "\n";
}
```

Perform the leftmost operation of highest precedence



Operators and Precedence

- A subset of C++ operators in order of precedence
  - grouping: `/*` open comment, `*/` close comment, `//` comment to end of line, `(` open parenthesis, `)` close parenthesis
  - increment/decrement: `++` increment variable, `--` decrement variable
  - arithmetic: `*` multiplication, `/` division, `%` modulus, `+` addition/ concatenation, `-` subtraction
  - comparison: `<` less than, `<=` less than or equal, `>` greater than, `>=` greater than or equal, `==` equality, `!=` inequality, `&&` logical AND, `||` logical OR
  - assignment: `=` assignment, `+=` add to variable, `*=` multiply to variable

Be careful with precedence

calculator.cpp (Version 24)

```
#include <iostream>

/* Let's write a calculator program for real numbers with variables
   that takes numbers from user input (no more magic numbers!)  */

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
   char multiplicationCharacter = '*';  // Character, for times
   char divisionCharacter = '/';  // Character, for division

   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << myNumber + myOtherNumber << "\n";
```

calculator.cpp (Version 24 - Branch 01)

A branch of our code for a digression about operator precedence

```
#include <iostream>

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   // Compute the average of two numbers?
   std::cout << "What is the average of " << myNumber << " and "
      << myOtherNumber << "? “
      << myNumber + myOtherNumber / 2 << "\n";  // Not average of two numbers
}
```

calculator.cpp (Version 24 - Branch 01)

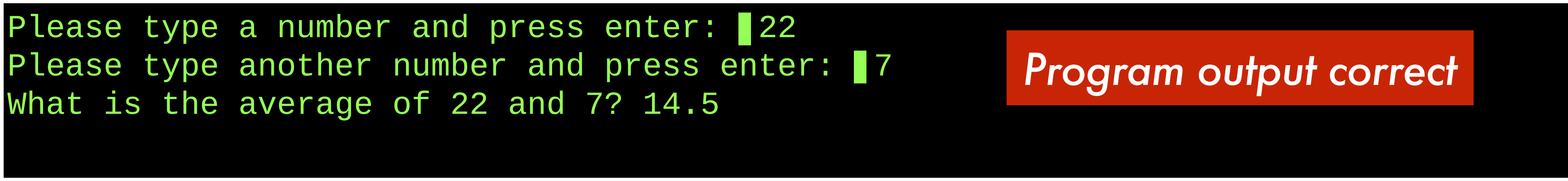
```cpp
#include <iostream>

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   // Compute the average of two numbers?
   std::cout << "What is the average of " << myNumber << " and "
      << myOtherNumber << "? “
      << myNumber + myOtherNumber / 2 << "\n";  // Not average of two numbers
}
```

```
Please type a number and press enter: 22
Please type another number and press enter: 7
What is the average of 22 and 7? 25.5
```

That Ain’t Right

calculator.cpp (Version 24 - Branch 02)

```
#include <iostream>

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   // Parenthesis containing groupings of C++ operations
   std::cout << "What is the average of " << myNumber << " and "
      << myOtherNumber << "? “
      << (myNumber + myOtherNumber) / 2 << "\n";
}
```



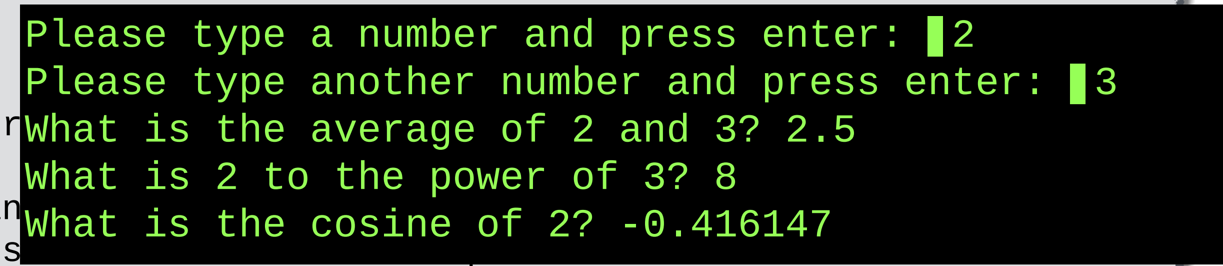
```
Please type a number and press enter: 22
Please type another number and press enter: 7
What is the average of 22 and 7? 14.5
```

calculator.cpp (Version 24 - Branch 03)

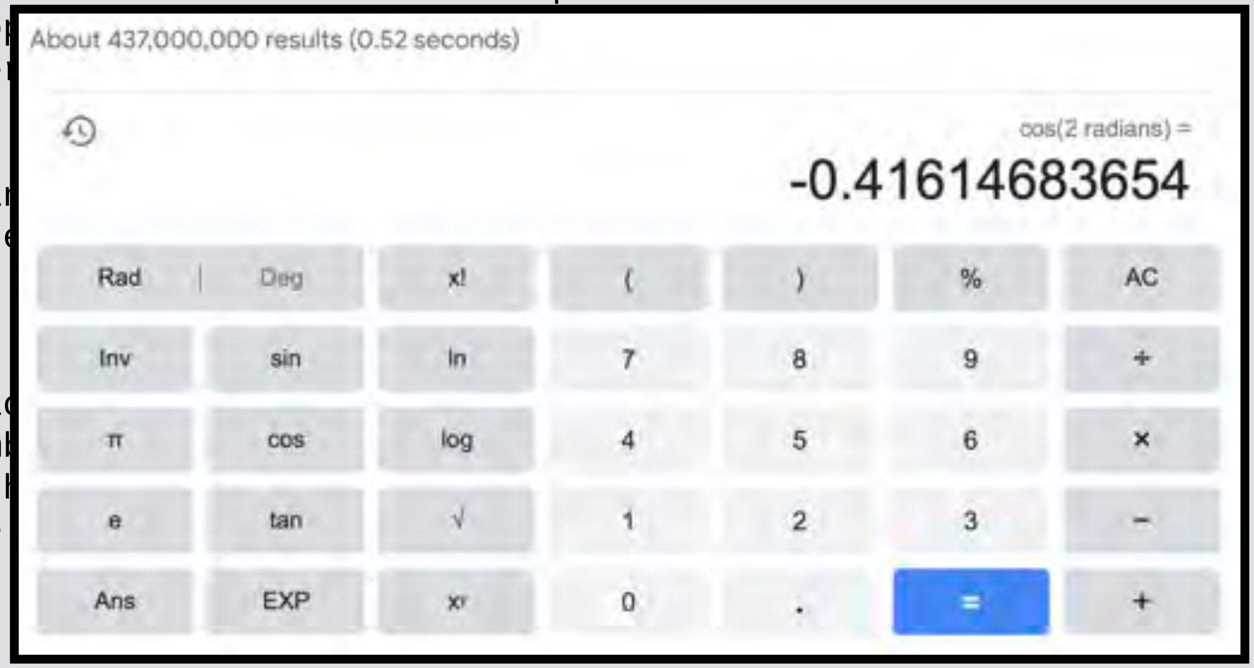
```cpp
#include <iostream>
#include <cmath>  // include cmath library for more math functions

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   // Parenthesis containing groupings of C++ operations
   std::cout << "What is the average of " << myNumber << " and "
      << myOtherNumber << "? “
      << (myNumber + myOtherNumber) / 2 << “\n”;

   // Function calls to math functions (we will discuss functions next)
   std::cout << "What is " << myNumber << " to the power of " << myOtherNumber
      << "? " << pow(myNumber, myOtherNumber) << "\n";
   std::cout << "What is the cosine of " << myNumber << "? "
      << cos(myNumber) << "\n";
}
```

calculator.cpp (Version 24 - Branch 03)

```
#include <iostream>
#include <cmath>  // include cmath library for more math functions

int main()
{
   // Ask the user to give us two number
   float myNumber, myOtherNumber;
   std::cout << "Please type a number an
   std::cin >> myNumber;  // Wait for us
   // Ask the user for our second op
   std::cout << "Please type anothe
   std::cin >> myOtherNumber;

   // Parenthesis containing groupi
   std::cout << "What is the average
      << myOtherNumber << "? “
      << (myNumber + myOtherNumber)

   // Function calls to math functio
   std::cout << "What is " << myNum
      << "? " << pow(myNumber, myOth
   std::cout << "What is the cosine
      << cos(myNumber) << "\n";
}
```



```
Please type a number and press enter: ▌2
Please type another number and press enter: ▌3
What is the average of 2 and 3? 2.5
What is 2 to the power of 3? 8
What is the cosine of 2? -0.416147
```



About 437,000,000 results (0.52 seconds)

cos(2 radians) =

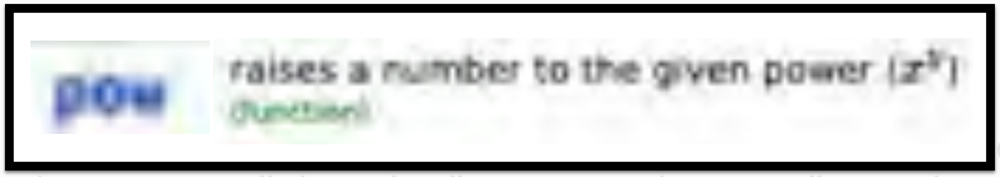
-0.41614683654

calculator.cpp (Version 24 - Branch 03)

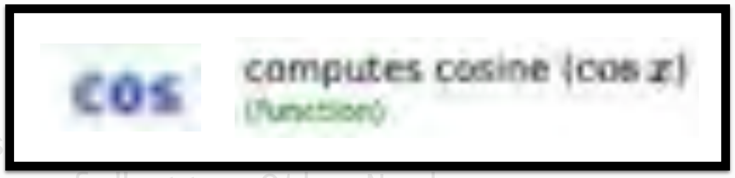
```
#include <iostream>
#include <cmath>  // include cmath library for more math functions

int main()
{
    // Ask the user to give us two numbers for our operands
    float myNumber, myOtherNumber;
    std::cout << "Please type a number and press enter: ";
    std::cin >> myNumber;  // Wait for user to enter a first operand
    // Ask the us
    std::cout <<                                                    rand
    std::cin >> m

    // Parenthesis containing groupings of C++ operations
    std::cout << "What is the average of " << myNumber << " and "

    /                                                          cuss
    std::cout << "What is " << myNumber << " to the power of " << myOtherNumber
        << "? " << pow(myNumber, myOtherNumber) << "\n";
    std::cout << "What is the cosine of " << myNumber << "? "
        << cos(myNumber) << "\n";
}
```

Includes a wealth of mathematical functions

What is a function ?



pow raises a number to the given power (x^y)
(function)



cos computes cosine ($\cos x$)
(function)

Function calls

What is a function ?

Intuitively, similar to a mathematical function

`cos(myNumber)`

$$f(x) = \cos(x)$$

`pow(myNumber, myOtherNumber)`

$$f(x) = x^y$$

What is a function ?

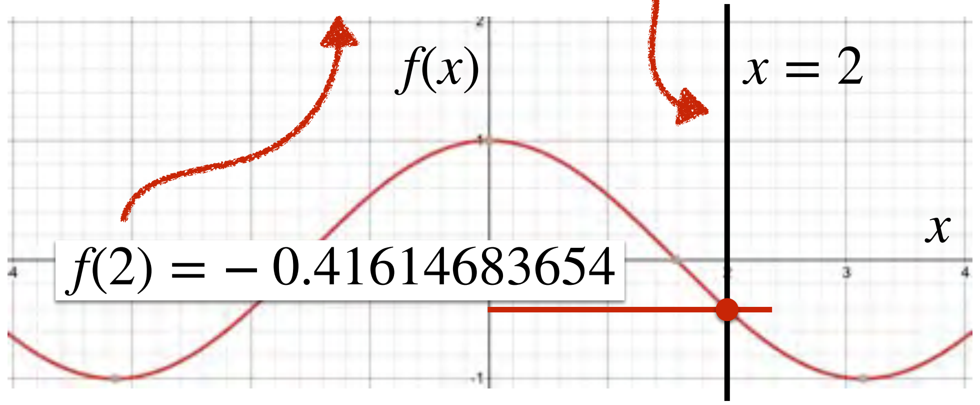
Function returns a value

-0.41614683654

`cos(2)`

Function called with input argument

$$f(x) = \cos(x)$$



Function evaluated for input argument

`pow(myNumber, myOtherNumber)`

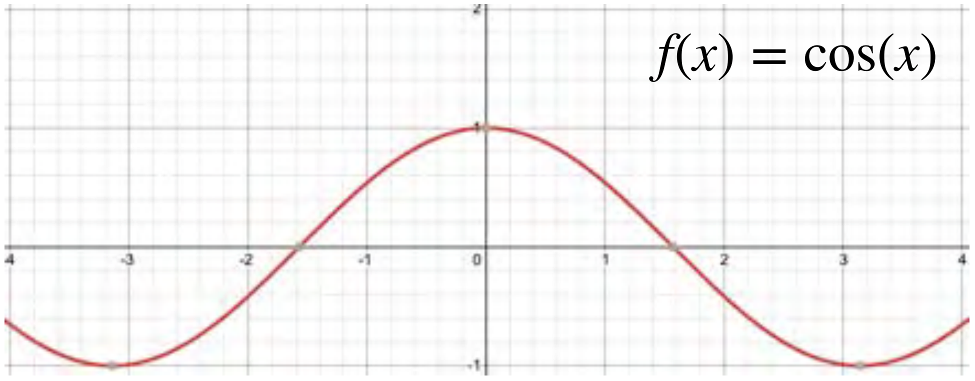
$$f(x) = x^y$$

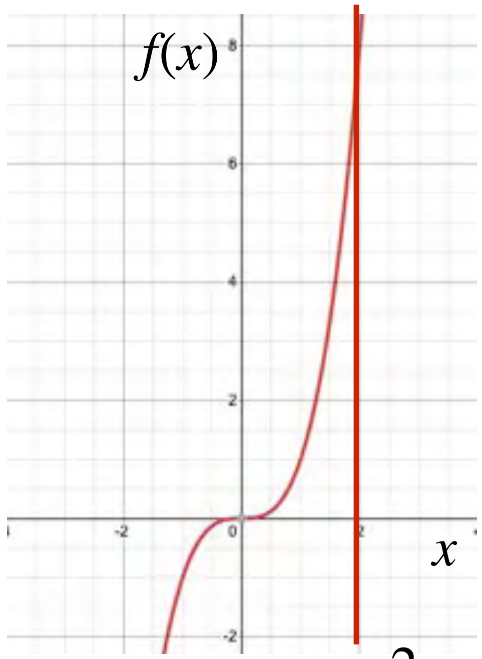
What is a function ?

Intuitively, similar to a mathematical function

`pow(2,3)`

`cos(myNumber)`





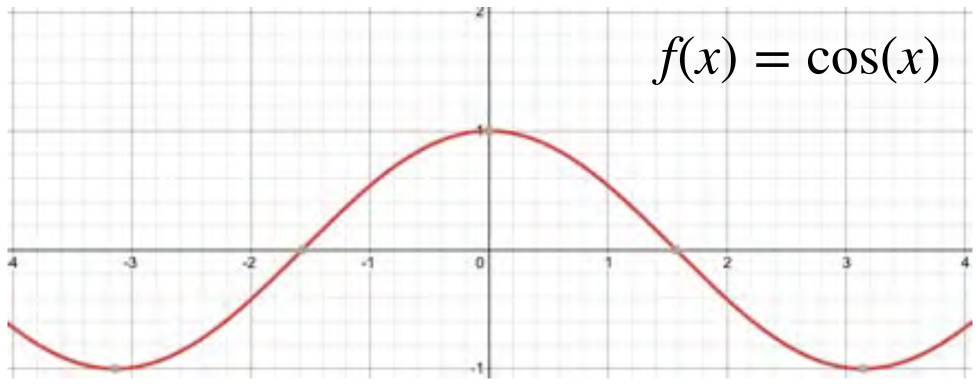
$f(x) = 2^3$

$x = 2$

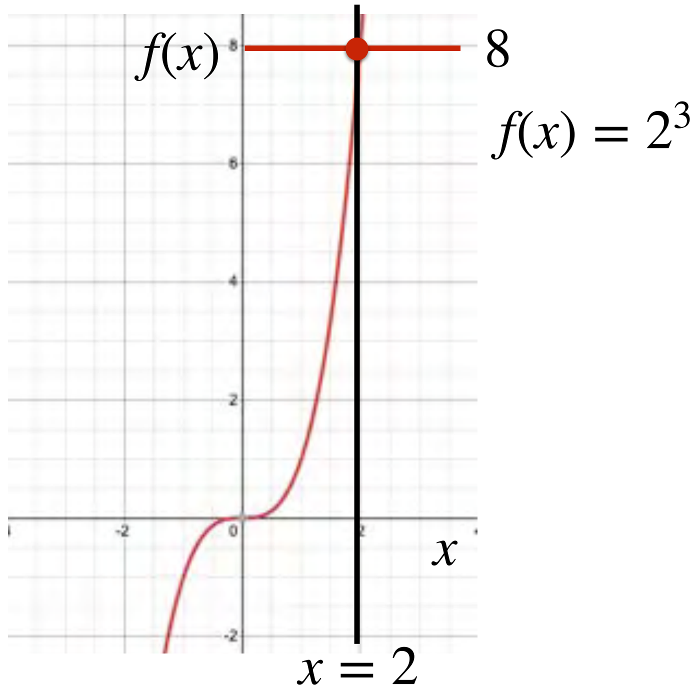
What is a function ?

Intuitively, similar to a mathematical function

`cos(myNumber)`



$8 \longleftarrow$ `pow(2,3)`



What is a function ?

Intuitively, similar to a mathematical function

Function calls	***Mathematically***
`cos(myNumber)`	$f(x) = \cos(x)$
`pow(myNumber, myOtherNumber)`	$f(x) = x^y$
`myFunction(myNumber)`	$f(x) = x^2 + 3$

Make our own functions

What is a function ?

C++ functions are not necessarily mathematical functions

Function calls	***Mathematically***	***Source code***
`cos(myNumber)`	$f(x) = \cos(x)$	
`pow(myNumber, myOtherNumber)`	$f(x) = x^y$	

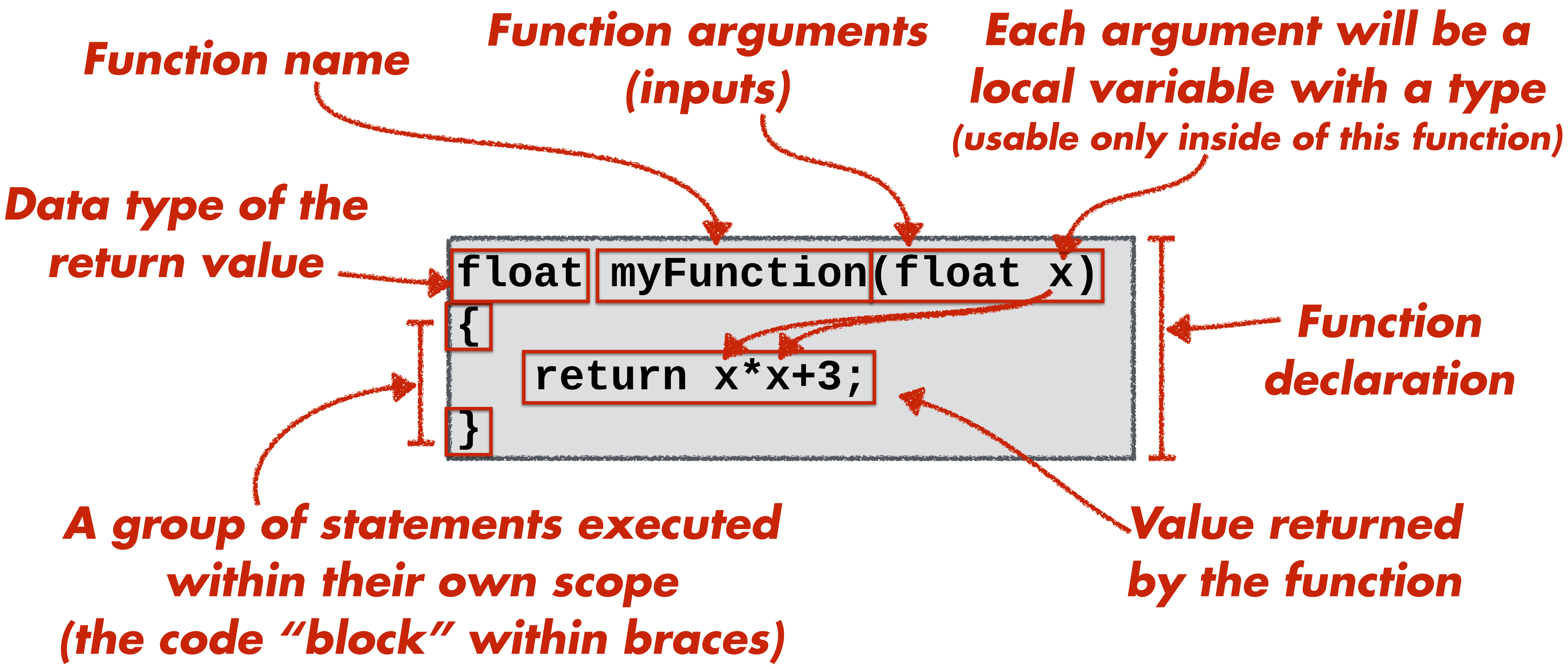
`myFunction(myNumber)`	$f(x) = x^2 + 3$	`float myFunction(float x) {`
		`   return x*x+3;`
		`}`

`printThisNumber(numberY)`		`void printThisNumber(float y) {`
		`   std::cout << y;`
		`}`

What is a C++ function ?

```
float myFunction(float x)
{
   return x*x+3;
}
```

What is a C++ function ?


Function name
Function arguments (inputs)
Each argument will be a local variable with a type (usable only inside of this function)
Data type of the return value
Function declaration
A group of statements executed within their own scope (the code "block" within braces)
Value returned by the function

```
float myFunction(float x)
{
    return x*x+3;
}
```

What is a C++ function ?

A defined function can be invoked (or called) from another part of the program

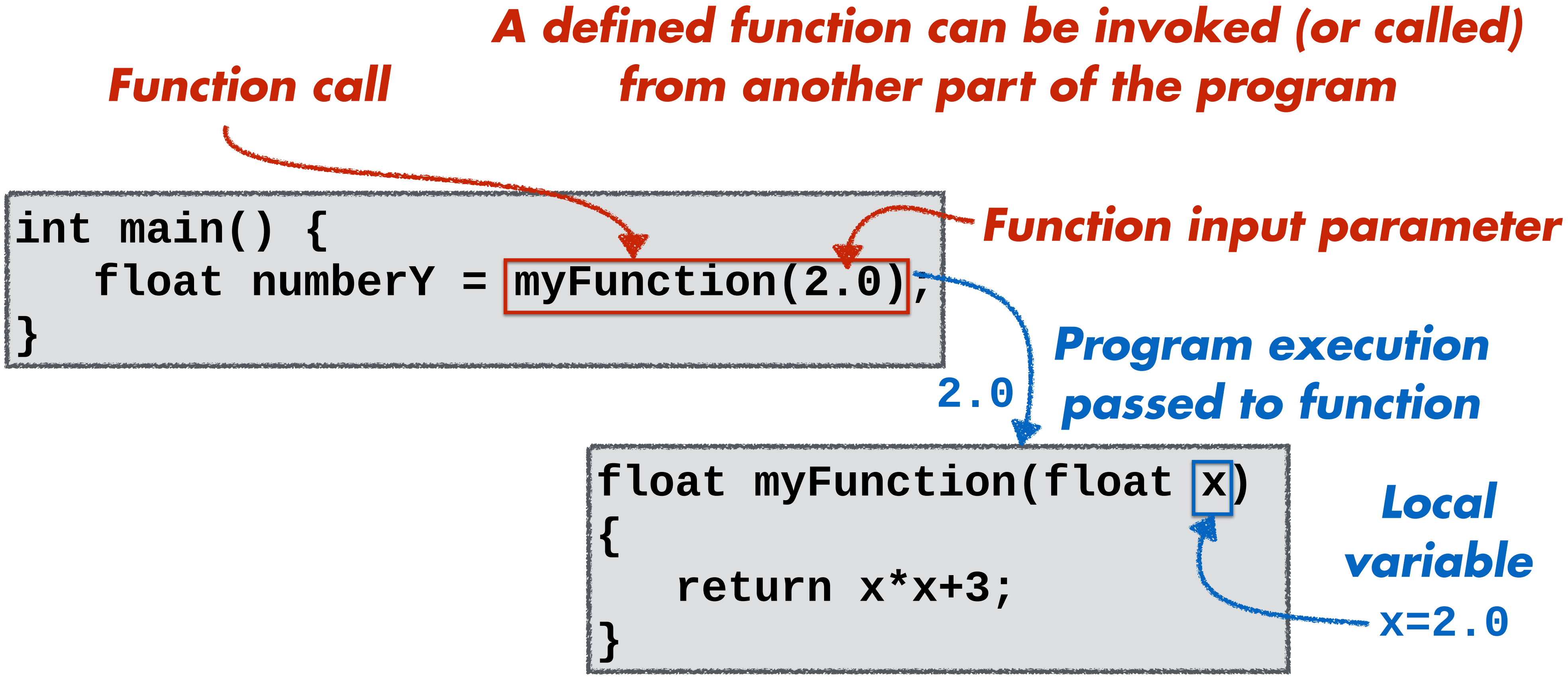
Function call

```
int main() {
   float numberY = myFunction(2.0);
}
```

Function input parameter

```
float myFunction(float x)
{
   return x*x+3;
}
```

What is a C++ function ?

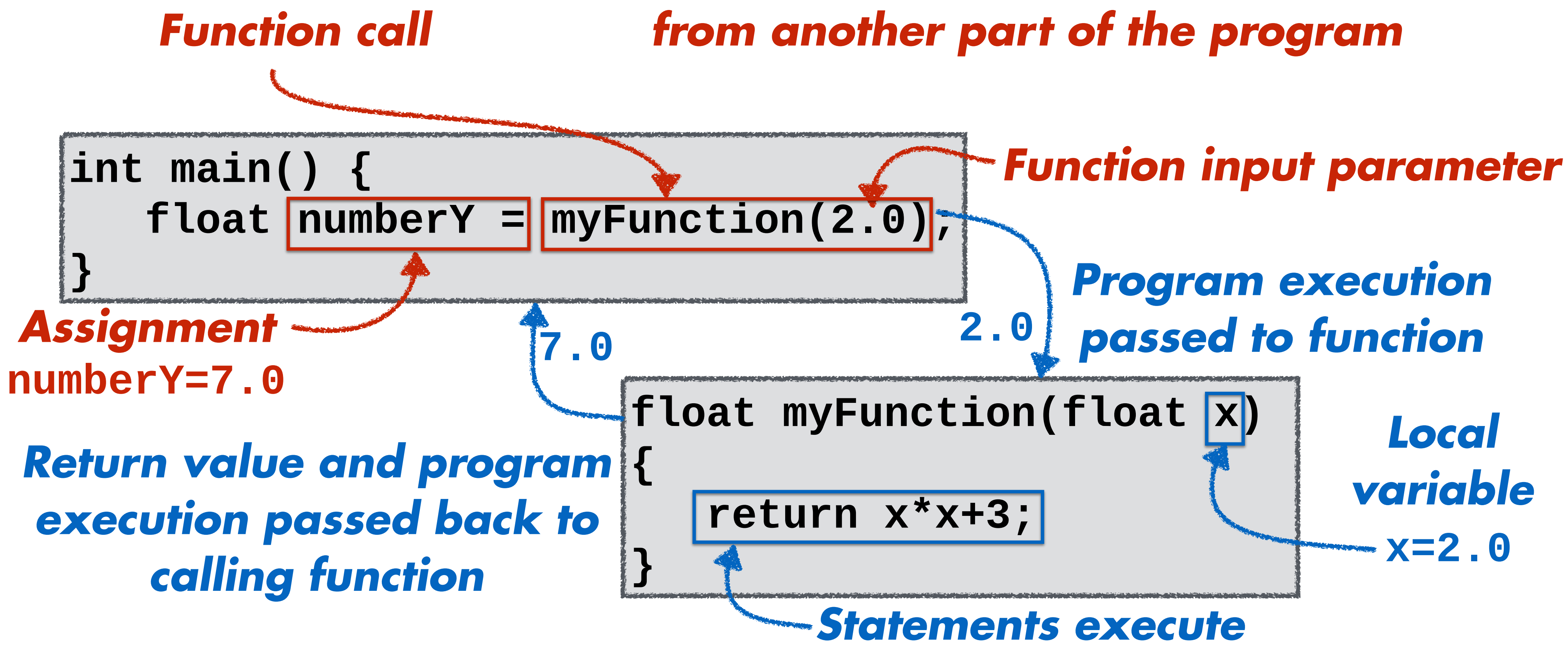

A defined function can be invoked (or called) from another part of the program
Function call
Function input parameter
2.0
Program execution passed to function
Local variable
x=2.0

```
int main() {
    float numberY = myFunction(2.0);
}
```

```
float myFunction(float x)
{
    return x*x+3;
}
```

What is a C++ function ?

A defined function can be invoked (or called) from another part of the program



```
int main() {
    float numberY = myFunction(2.0);
}
```

```
float myFunction(float x)
{
    return x*x+3;
}
```

Function call
Function input parameter
Assignment
numberY=7.0
7.0
2.0
Program execution passed to function
Return value and program execution passed back to calling function
Local variable
x=2.0
Statements execute

squaredPlusThree.cpp (Version 00)

```
float myFunction(float x) {
   return x*x+3;
}

int main() {
   float numberY = myFunction(2.0);
}
```

```
[No errors]
```

```
[No output]
```

squaredPlusThree.cpp (Version 01)

```
#include<iostream>

void printThisNumber(float y) {
   std::cout << y;
}

float myFunction(float x) {
   return x*x+3;
}

int main() {
   float numberY = myFunction(2.0);
   printThisNumber(numberY);
}
```

```
[No errors]
```

```
7
```

Let's write our calculator operations as functions

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Functions can take multiple input arguments (separated by commas)

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Variables can be declared within a function's scope

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Multiplication

Will not work properly

```
void multiplyTwoNumbers(float operand1, float operand2, float product) {
  product = operand1 * operand2;
}
```

Function arguments are "pass by value"

Modifying the variable in the function will not change its value outside the function

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Multiplication

Will work properly

```
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
```

Adding & to front makes function argument "pass by reference"

Modifying the variable in the function will change its value outside the function

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Multiplication

```
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
```

If no value is returned, the function should use `void` ***as the return type***

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Multiplication

```
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
```

Division

```
bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;
```

Return `false` if no errors occurred

Functions help organize our code

Addition

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
```

Subtraction

```
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
```

Multiplication

```
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
```

Division

```
bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;
```

calculator.cpp (Version 32)

```
#include <iostream>

/* Let's write a calculator program for real numbers with variables
   that takes numbers from user input (no more magic numbers!)  */

   float addTwoNumbers(float operand1, float operand2) {
     return operand1 + operand2;
   }

   float subtractTwoNumbers(float operand1, float operand2) {
      float difference = operand1 - operand2;
      return difference;
   }

   void multiplyTwoNumbers(float operand1, float operand2, float &product) {
     product = operand1 * operand2;
   }

   bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
      quotient = operand1 / operand2;
      return false;

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;
```

calculator.cpp (Version 32)

```cpp
#include <iostream>

/* Let's write a calculator program for real numbers with variables
   that takes numbers from user input using functions for modularity */

float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}

float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}

void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}

bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;

int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
```

Function declarations

calculator.cpp (Version 32)

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}

float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}

void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}

bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;
```

Function declarations

```
int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   // Ask the user for our second operand and assign it to "myOtherNumber"
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
```

calculator.cpp (Version 32)

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;
```

```
   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main function
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // function call
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n";
}
```

addTwoNumbers()

subtractTwoNumbers()

multiplyTwoNumbers()

divideTwoNumbers()

main()

Function calls

calculator.cpp (Version 32)

```
float addTwoNumbers(float operand1, float operand2) {
  return operand1 + operand2;
}
float subtractTwoNumbers(float operand1, float operand2) {
   float difference = operand1 - operand2;
   return difference;
}
void multiplyTwoNumbers(float operand1, float operand2, float &product) {
  product = operand1 * operand2;
}
bool divideTwoNumbers(float operand1, float operand2, float &quotient) {
   quotient = operand1 / operand2;
   return false;
```

```
   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main func
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // fu
   std::cout << myNumber << multiplicationCharacter << myOtherNumbe
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << '
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n";
}
```

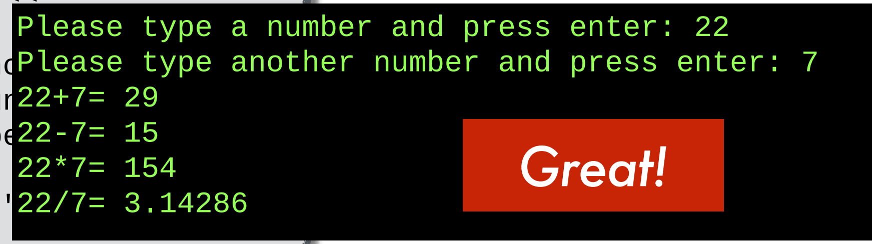
addTwoNumbers()

subtractTwoNumbers()

multiplyTwoNumbers()

divideTwoNumbers()

main()



```
Please type a number and press enter: 22
Please type another number and press enter: 7
22+7= 29
22-7= 15
22*7= 154
22/7= 3.14286
```

calculator.cpp (Version 32)

Functions

```
  addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
  divideTwoNumbers()
```

Functions available in this source file

Function scope for the code snippet below

```
main()
```

```
   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main function
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // function call
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n";
}
```

calculator.cpp (Version 32)

```
int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
   char multiplicationCharacter = '*';  // Character, for times
   char divisionCharacter = '/';  // Character, for division

   // Perform all operations and output result to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main function
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // function call
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n”;
   return 0;
}
```

Return* `false` *if no errors occurred

Functions

```
  addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
  divideTwoNumbers()
```

calculator.cpp (Version 32)

```
int main()
{
   // Ask the user to give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
   char multiplicationCharacter = '*';  // Character, for times
   char divisionCharacter = '/';

   // Perform all operations and
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main function
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // function call
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n”;
   return 0;
}
```

Functions

```
addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
divideTwoNumbers()
main()
```

Still very disorganized code :(

calculator.cpp (Version 32)

```
int main()
{
   // Ask the user to Give us two numbers for our operands
   float myNumber, myOtherNumber;
   std::cout << "Please type a number and press enter: ";
   std::cin >> myNumber;  // Wait for user to enter a first operand
   std::cout << "Please type another number and press enter: “;  // Second operand
   std::cin >> myOtherNumber;

   char additionCharacter = '+';  // Character, for plus
   char subtractionCharacter = '-';  // Character, for minus
   char multiplicationCharacter = '*';  // Character, for times
   char divisionCharacter = '/';  // Character, for division

   // Perform all operations and Output results to screen
   std::cout << myNumber << additionCharacter << myOtherNumber << "= "
      << addTwoNumbers(myNumber,myOtherNumber) << "\n";
   std::cout << myNumber << subtractionCharacter << myOtherNumber << "= "
      << subtractTwoNumbers(myNumber,myOtherNumber) << "\n";
   float productNumber;  // local variable only usable in main function
   multiplyTwoNumbers(myNumber,myOtherNumber,productNumber); // function call
   std::cout << myNumber << multiplicationCharacter << myOtherNumber << "= "
      << productNumber << "\n";
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << myNumber / myOtherNumber << “\n”;
   float quotient;  // NOT the same variable as quotient in function definition
   divideTwoNumbers(myNumber,myOtherNumber,quotient); // function call
   std::cout << myNumber << divisionCharacter << myOtherNumber << "= "
      << quotient << “\n”;
   return 0;
}
```

Functions

```
addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
divideTwoNumbers()
main()
```

What is this code doing ?

calculator.cpp (Version 41)

```
// Main function declaration, returns 0 if no errors encountered
int main()
{
   // Let's declare our variables
   float myNumber, myOtherNumber;  // Calculation operands
   float sumNumber, differenceNumber, productNumber, quotientNumber;

   // Ask the user for the first operand
   getNumber(myNumber);

   // Ask the user for the second operand
   getNumber(myOtherNumber);

   // Perform all operations and store results in variables
   performOperations(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

   // Output operation results to screen
   outputResults(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

  return 0;
}
```

Give us two numbers for our operands

Perform all operations

Output results to screen

Functions

```
addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
divideTwoNumbers()
main()
```

Only 4 function calls!

calculator.cpp (Version 41)

```
// Main function declaration, returns 0 if no errors encountered
int main()
{
   // Let's declare our variables
   float myNumber, myOtherNumber;  // Calculation operands
   float sumNumber, differenceNumber, productNumber, quotientNumber;

   // Ask the user for the first operand
   getNumber(myNumber);

   // Ask the user for the second operand
   getNumber(myOtherNumber);

   // Perform all operations and store results in variables
   performOperations(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

   // Output operation results to screen
   outputResults(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

  return 0;
}
```

Functions

```
    addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
  divideTwoNumbers()
             main()
```

Give us two numbers for our operands

```
bool getNumber(float &number) {
```

Perform all operations

```
bool performOperations(float operand1, float operand2, float &sum,
   float &difference, float &product, float &quotient) {
```

Output results to screen

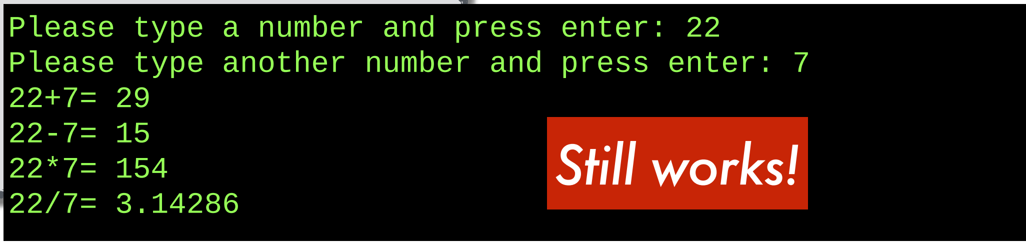
```
bool outputResults(float operand1, float operand2, float sum,
   float difference, float product, float quotient) {
```

calculator.cpp (Version 41)

```cpp
// Main function declaration, returns 0 if no errors encountered
int main()
{
   // Let's declare our variables
   float myNumber, myOtherNumber;  // Calculation operands
   float sumNumber, differenceNumber, productNumber, quotientNumber;

   // Ask the user for the first operand
   getNumber(myNumber);

   // Ask the user for the second operand
   getNumber(myOtherNumber);

   // Perform all operations and store results in variables
   performOperations(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

   // Output operation results to screen
   outputResults(myNumber,myOtherNumber,sumNumber,differenceNumber,
      productNumber,quotientNumber);

  return 0;
}
```

Functions

```
addTwoNumbers()
subtractTwoNumbers()
multiplyTwoNumbers()
divideTwoNumbers()
getNumber()
performOperations()
outputResults()
main()
```



```
Please type a number and press enter: 22
Please type another number and press enter: 7
22+7= 29
22-7= 15
22*7= 154
22/7= 3.14286
```

Still works!

Our calculator still needs more

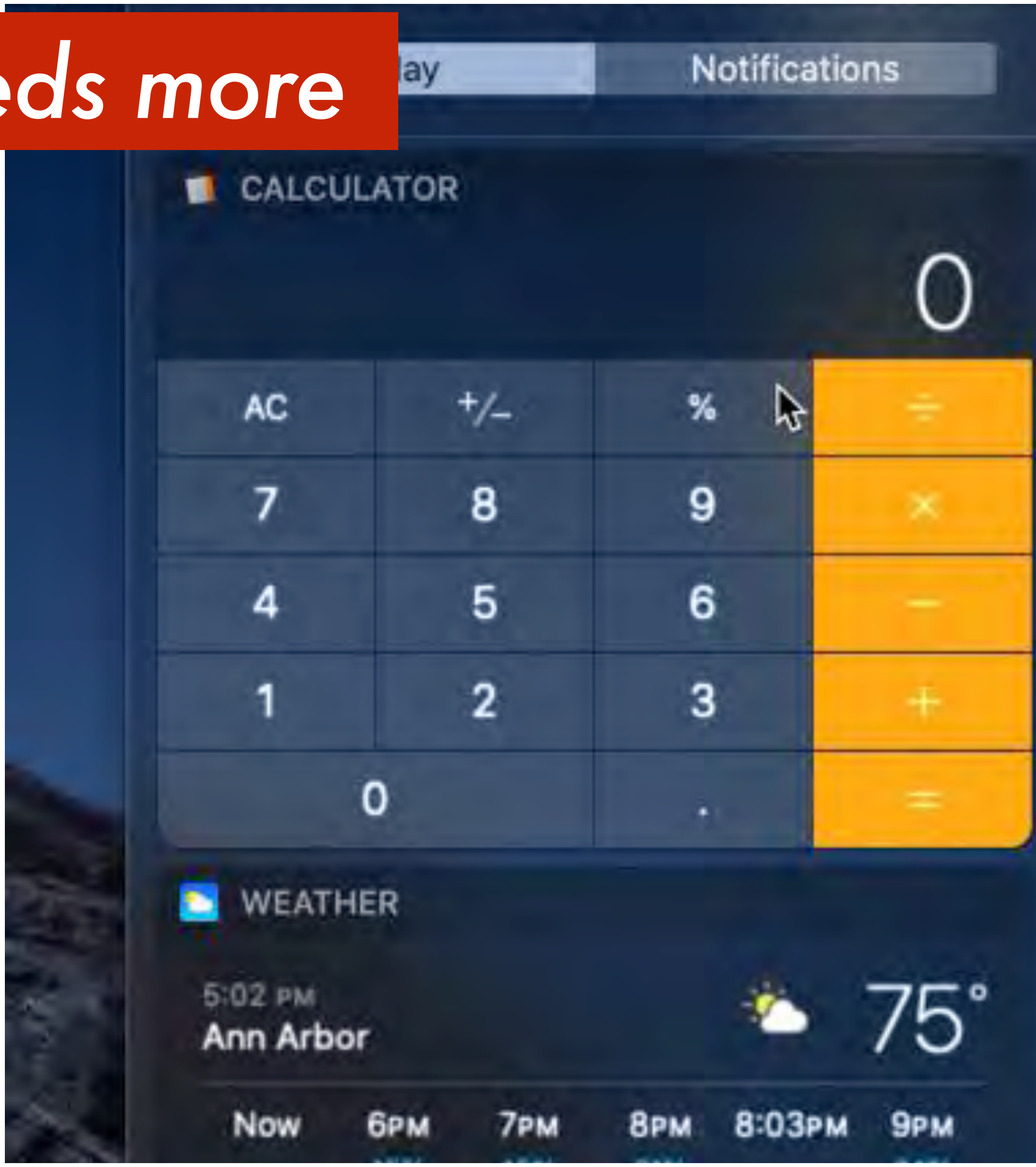
calculator (Version 41)

```
Please type a number and press enter: 22
Please type another number and press enter: 7
22+7= 29
22-7= 15
22*7= 154
22/7= 3.14286
```

Select a single operator to perform?

Perform multiple operations in succession?

Can we divide by zero?



Done

hello

```
Hello World!
Chad is in Robotics 102"
```

calculator (Version 24)

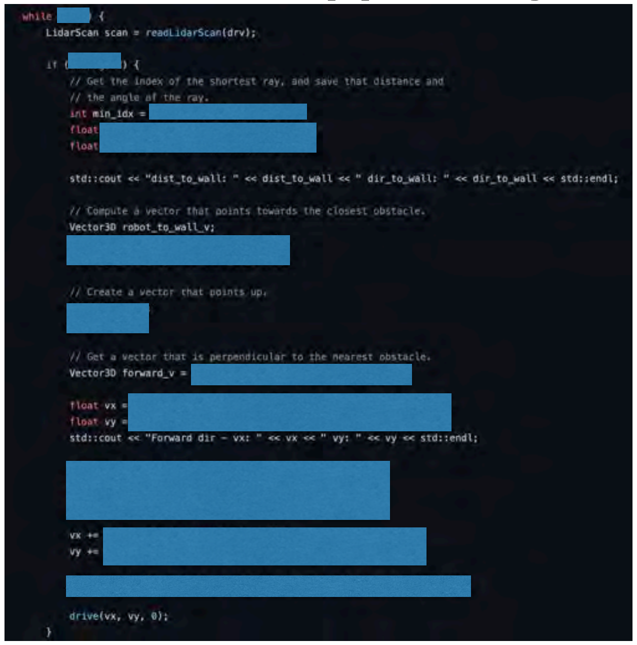
```
Please type a number and press enter: 22
Please type another number and press enter: 7
What is 22 plus 7? 29
What is 22 minus 7 ? 15
What is 22 times 7 ? 154
What is 22 divided by 7 ? 3.14286
```

calculator (Version 41)

- ✓ Program Structure
- ✓ Compile/Execute
- ✓ Operators
- ✓ Data Types
- ✓ Variables
- ✓ User Input/Output
- ✓ Functions
- ☐ Branching
- ☐ Iterators
- ☐ Vectors
- ☐ Structs
- ☐ File Input/Output

Coming

wall_follower.cpp - Project 1



```
while [redacted] {
    LidarScan scan = readLidarScan(drv);

    if ([redacted]) {
        // Get the index of the shortest ray, and save that distance and
        // the angle of the ray.
        int min_idx = [redacted]
        float [redacted]
        float

        std::cout << "dist_to_wall: " << dist_to_wall << " dir_to_wall: " << dir_to_wall << std::endl;

        // Compute a vector that points towards the closest obstacle.
        Vector3D robot_to_wall_v;
        [redacted]

        // Create a vector that points up.
        [redacted]

        // Get a vector that is perpendicular to the nearest obstacle.
        Vector3D forward_v = [redacted]

        float vx = [redacted]
        float vy =
        std::cout << "Forward dir - vx: " << vx << " vy: " << vy << std::endl;

        [redacted]

        vx += [redacted]
        vy +=

        [redacted]

        drive(vx, vy, 0);
    }
```