Functions and Structured Programming

Introduction

Structured Programming is a problem-solving strategy and a programming methodology that includes the following two guidelines:

- The flow of control in a program should be as simple as possible.
- The construction of a program should embody top-down design.

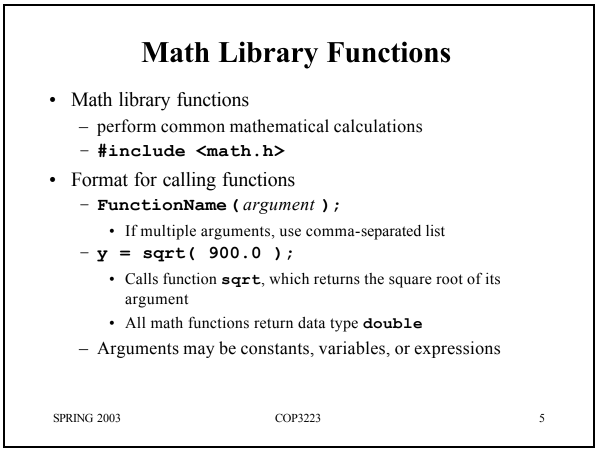
Top-down Design

Top-down design, also referred to as *stepwise refinement*, or *divide and conquer*, consists of repeatedly decomposing a problem into smaller problems. In other words:

- Construct a program from smaller pieces or components
  - These smaller pieces are called modules
- Each piece more manageable than the original program

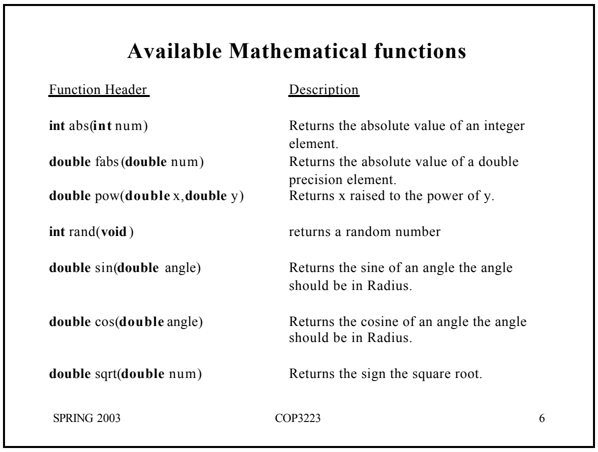
Program Modules in C

- Functions
  - Modules in C
  - Programs combine user-defined functions with library functions
    - C standard library has a wide variety of functions
- Function calls
  - Invoking functions
    - Provide function name and arguments (data)
    - Function performs operations or manipulations
    - Function returns results
  - Function call analogy:
    - Boss asks worker to complete task
      - Worker gets information, does task, returns result
      - Information hiding: boss does not know details



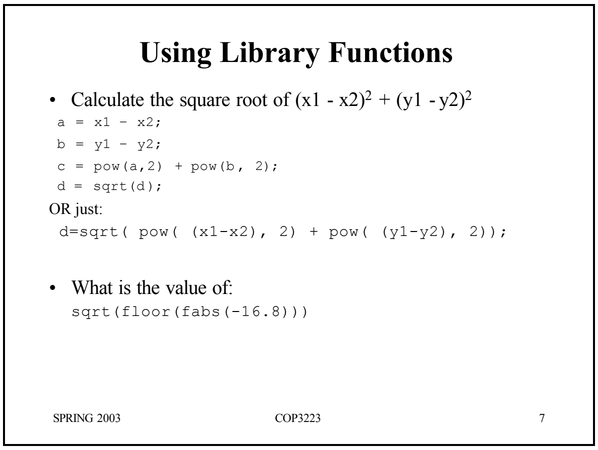
Math Library Functions

- Math library functions
  - perform common mathematical calculations
  - **`#include <math.h>`**
- Format for calling functions
  - **`FunctionName (`** *argument* **`);`**
    - If multiple arguments, use comma-separated list
  - **`y = sqrt( 900.0 );`**
    - Calls function **`sqrt`**, which returns the square root of its argument
    - All math functions return data type **`double`**
  - Arguments may be constants, variables, or expressions



Available Mathematical functions

Function Header	Description
int abs(**int** num)	Returns the absolute value of an integer element.
double fabs(**double** num)	Returns the absolute value of a double precision element.
double pow(**double** x,**double** y)	Returns x raised to the power of y.
int rand(**void**)	returns a random number
double sin(**double** angle)	Returns the sine of an angle the angle should be in Radius.
double cos(**double** angle)	Returns the cosine of an angle the angle should be in Radius.
double sqrt(**double** num)	Returns the sign the square root.



Using Library Functions

- Calculate the square root of $(x1 - x2)^2 + (y1 - y2)^2$

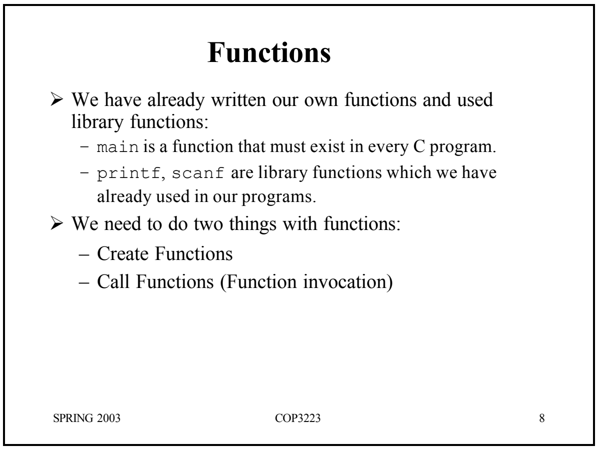
```
a = x1 - x2;
b = y1 - y2;
c = pow(a,2) + pow(b, 2);
d = sqrt(d);
```

OR just:

```
d=sqrt( pow( (x1-x2), 2) + pow( (y1-y2), 2));
```

- What is the value of:

```
sqrt(floor(fabs(-16.8)))
```



Functions

- We have already written our own functions and used library functions:
  - `main` is a function that must exist in every C program.
  - `printf`, `scanf` are library functions which we have already used in our programs.
- We need to do two things with functions:
  - Create Functions
  - Call Functions (Function invocation)

Function Definition

function prototype

A function definition has the following form:

return_type function name (formal parameter list)
{
declarations
statements
}

return_type - the type of value returned by the function
- `void` – indicates that the function returns nothing.

function name – any valid identifier

formal parameter list – comma separated list, describes the number and types of the arguments that get passed into the function when its invoked.

Example

- Let's define a function to compute the cube of a number:

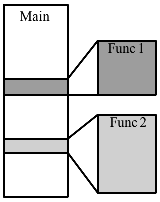
```
int cube ( int num ) {
     int result;

     result = num * num * num;
     return result;
}
```

- This function can be called as:

```
n = cube(5);
```

Function Invocation

- A program is made up of one or more functions, one of them being `main`( ).
- When a program encounters a function, the function is called or invoked.
- After the function does its work, program control is passed back to the calling environment, where program execution continues.



```
#include  <stdio.h>

void prn_message (void);   /* function prototype */

int main (void)
{
     prn_message ( );     /* function invocation */
     return 0;
}

void prn_message(void)  /* function definition */
{
      printf("A message for you:   ");
      printf("Have a nice day!\n");
}
```

```
#include   <stdio.h>
void print_message (int k);   /*function prototype */
int main (void)
{
      int n;
      printf(“There is a message for you.\n”);
      printf(“How many times do you want to see it?  ”);
      scanf(“%d”, &n);
      print_message(n);
      return 0;
}

void print_message (int k)  /* function definition */
{
      int i;
      printf(“\nHere is the message.\n”);
      for (i=0; i < k; ++i)
             printf(“Have a nice day!\n”);
}
```

```
/* An example demonstrating local variables */
#include  <stdio.h>

void func1  (void);

int main  (void)
{
       int i = 5;
       printf(“%d \n”, i);
       func1( );
       printf(“%d \n”,i);
       return 0;
}

void func1  (void)
{
        int i = 5;
        printf(“%d\n”, i);
        i++;
         printf(“%d\n”, i);
}
```

```
5
5
6
5
```

The `return` statement

- When a return statement is executed, program control is immediately passed back to the calling environment.
- If an expression follows the keyword return, the value of the expression is returned to the calling environment as well.
- A return statement has one of the following two forms:
  `return` `;`
  `return` *expression*;

Examples

return ;

return 77;

return ++a;

return (a+b+c);

```
#include  <stdio.h>
int  min (int a, int b);

int main (void)
{
   int j, k, m;

   printf(“Input two integers:     ”);
   scanf(“%d %d”, &j, &k);
   m = min(j,k);
   printf(“\nThe minimum is %d.\n”, m);
   return 0;
}
int min(int a, int b)
{
   if (a < b)
      return a;
   else
      return b;
}
```

```
Input two integers:  5  6
The minimum is 5.

Input two integers:  11  3
The mininum is 3.
```

Parameters

- A function can have zero or more parameters.
- In declaration header:

```
int f (int x, double y, char c);
```

⇧

the *formal parameter list* (parameter variables and their types are declared here)

- In function calling:

```
value = f(age, score, initial);
```

⇧

actual parameter list (cannot tell what their type are from here)

Rules for Parameter Lists

- The number of parameters in the actual and formal parameter lists must be *consistent*
- Parameter association is *positional:* the first *actual* parameter matches the first *formal* parameter, the second matches the second, and so on
- *Actual* parameters and *formal* parameters must be of compatible *data types*
- *Actual* parameters may be a variable, constant, any expression matching the type of the corresponding formal parameter

Invocation and Call-by-Value

- Each argument is evaluated, and its value is used locally in place of the corresponding formal parameter.
- If a variable is passed to a function, the stored value of that variable in the calling environment will not be changed.
- In C, all calls are call-by-value.

```
#include  <stdio.h>
int compute_sum (int n);

int main (void)
{
   int n, sum;

   n = 3;

   printf("%d\n", n);
   sum=compute_sum(n);
   printf("%d\n",n);
   printf("%d\n", sum);
   return 0;
}
```

```
int compute_sum (int n)
{
   int  sum;

   sum = 0;

   for (  ; n > 0; --n)
      sum += n;
   printf("%d\n", n);
   return sum;
}
```

```
3
0
3
6
```

```
/* Finding the maximum of three integers */

#include <stdio.h>

int maximum( int, int, int );   /* function prototype */

int main()
{
   int a, b, c;

   printf( "Enter three integers: " );
   scanf( "%d%d%d", &a, &b, &c );
   printf( "Maximum is: %d\n", maximum( a, b, c ) );

   return 0;
}

/* Function maximum definition */
int maximum( int x, int y, int z )
{
   int max = x;

   if ( y > max )
      max = y;

   if ( z > max )
      max = z;

   return max;
}
```

```
Enter three integers: 22 85 17
Maximum is: 85
```

Function Prototypes

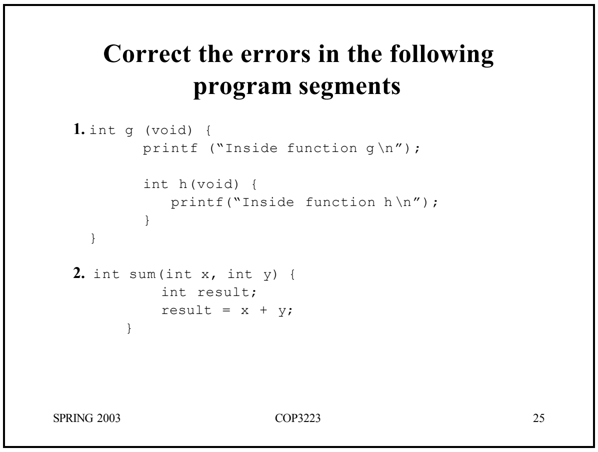
- Function prototype
  - Function name
  - Parameters – what the function takes in
  - Return type – data type function returns (default `int`)
- Used to validate functions
  - Prototype only needed if function definition comes after use in program
- The function with the prototype

  `int maximum( int, int, int );`
  - Takes in 3 `int`s
  - Returns an `int`

Alternative styles for function definition order

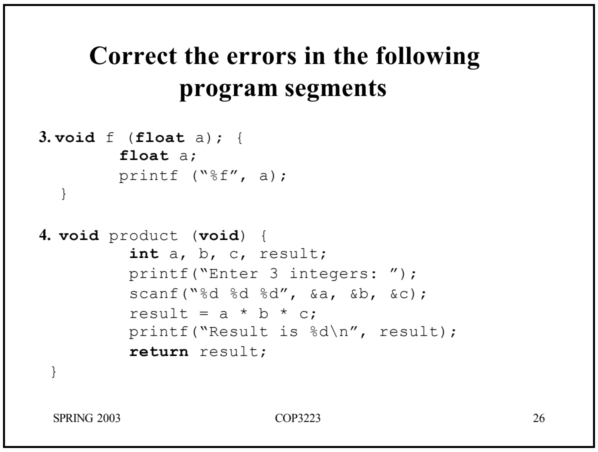
```
#include <stdio.h>

int max(int,int);
int min(int,int);

int main(void)
{
  min(x,y);
  max(u,v);
  ...
}
int max (int a, int b)
{
  ...
}
int min (int a, int b)
{
 ...
}
```

```
#include <stdio.h>
int max (int a, int b)
{
  ...
}

int min (int a, int b)
{
  ...
}

int main(void)
{
  ...
  min(x,y);
  max(u,v);
  ...
}
```



Correct the errors in the following program segments

```
1. int g (void) {
        printf ("Inside function g\n");

        int h(void) {
           printf("Inside function h\n");
        }
  }

2. int sum(int x, int y) {
          int result;
          result = x + y;
      }
```



Correct the errors in the following program segments

```
3. void f (float a); {
        float a;
        printf ("%f", a);
  }

4. void product (void) {
         int a, b, c, result;
         printf("Enter 3 integers: ");
         scanf("%d %d %d", &a, &b, &c);
         result = a * b * c;
         printf("Result is %d\n", result);
         return result;
 }
```