Computer Science I

Functions & Pointers

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Outline

Part I: Introduction

Functions

- A function produces an *output* when given an *input* or *inputs*

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- Functions in code are similar and use familiar "syntax"

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- Familiar functions: `main()`, `printf()`, `sqrt()`

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- A function may "return" a value to the calling function

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- Procedural abstraction: designing and using functions allows you to abstract the details of how a block of code or algorithm works
- Functions *encapsulate* functionality into reusable, abstract code blocks
- Example: how does `sqrt()` work?

Usefulness

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- Problem solving: first question you ask is “is this problem already solved?”

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  - The function's *return* type: the type of data the function returns

Prototype Example

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 *  This function computes the Euclidean distance between
 *  the two points defined by (x1, y1) and (x2, y2)
 */
double euclideanDistance(double x1, double y1, double x2, double y2);
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Syntax and style:

- Documented using doc-style comments (DRY)

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- Identifier: use `lowerCamelCasing`
- Comma delimited list of parameters and their type
- Prototype ends with a semicolon and has no function *body*

Definition Example

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double euclideanDistance(double x1, double y1, double x2, double y2) {

  double temp = sqrt( (x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2) );
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Part II: Modularity

Writing modular code, creating libraries

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- Separation allows you to organize very complex programs with thousands or millions of LOCs
- Programs only "include" the functionality they actually need

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- `stdio.h`, `math.h`
- You can then `#include` your own libraries!

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    produces an *object* file, `distance.o`

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- Add additional distance-related functionality

Part III: Pitfalls & Other Issues

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- Example: `int foo(void);`
- Better practice to omit `void`:
  `int foo();`

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- Example: `abs(int)`, `fabs(double)`, `labs(long)`
- Must take care when naming functions so as not to *pollute the namespace*

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Part IV: How Functions Work

How Functions Work

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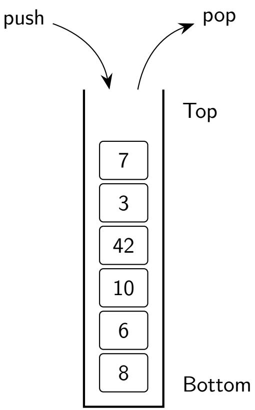

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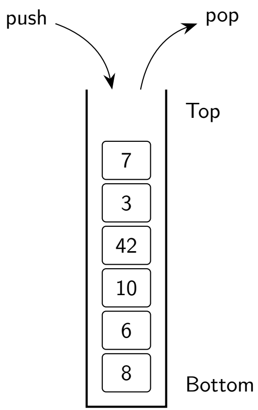

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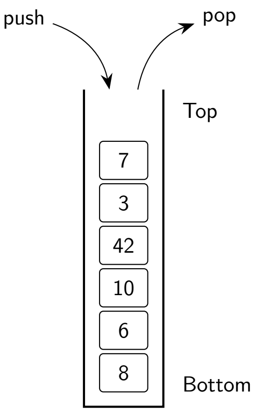

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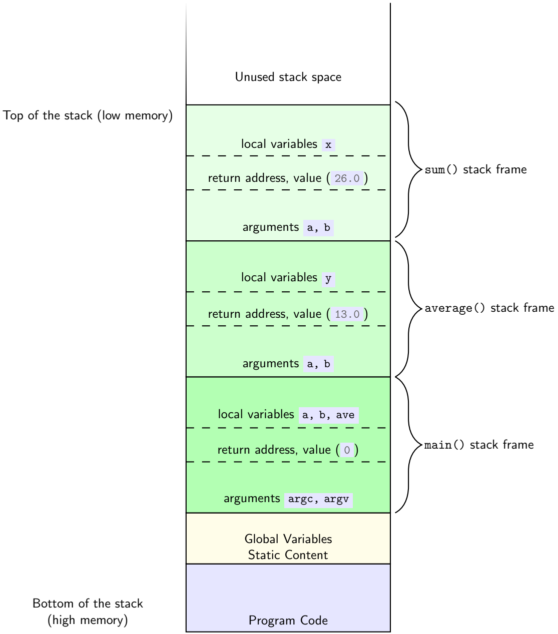
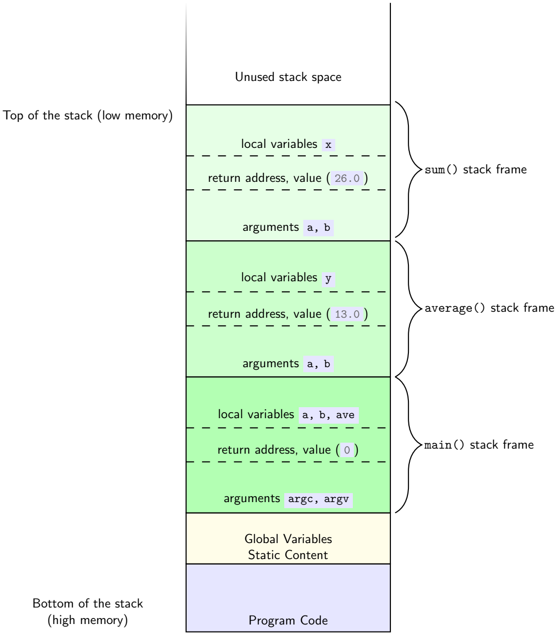
- As functions are called, a new stack frame is created
- Each frame contains: parameters, local variables, etc.
- When a function returns, the frame is popped from the top of the call stack
- Data and variables in each frame is distinct and separate

Program Stack

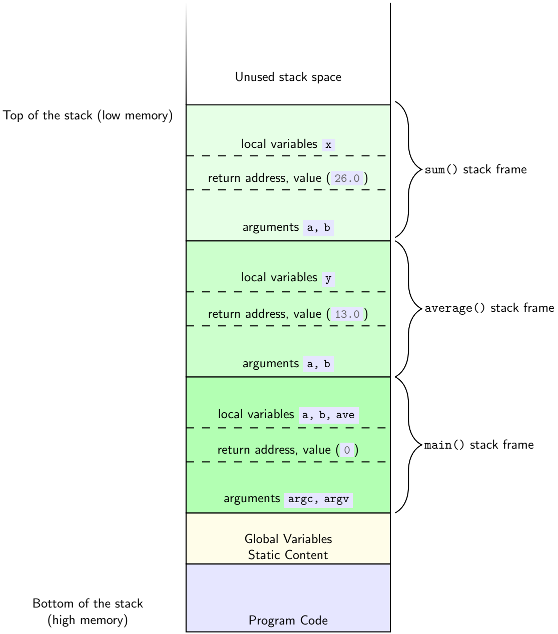

```c
double sum(double a, double b) {
  double x = a + b;
  return x;
}

double average(double a, double b) {
  double y = sum(a, b) / 2.0;
  return y;
}

int main(int argc, char **argv) {
  double a = 10.0, b = 16.0;
  double ave = average(a, b);
  printf("average = %f\n", ave);
  return 0;
}
```

- Stack orientation





- Stack orientation
- Each function has its own stack frame



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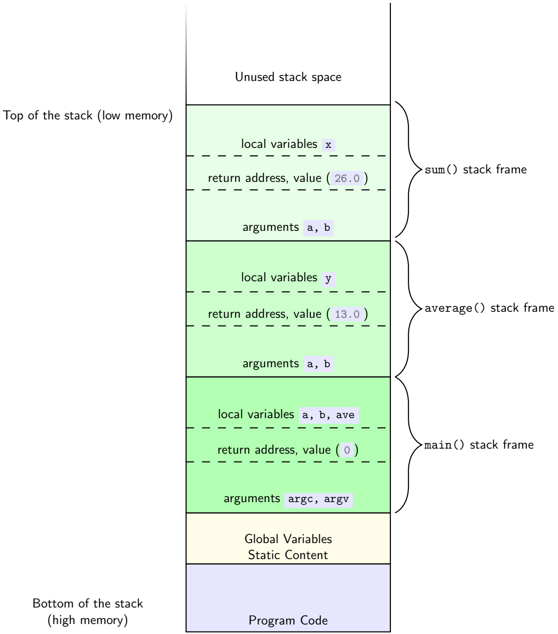

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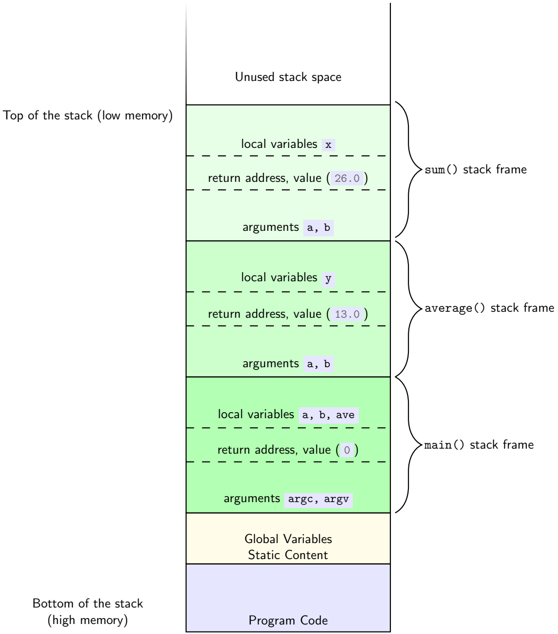

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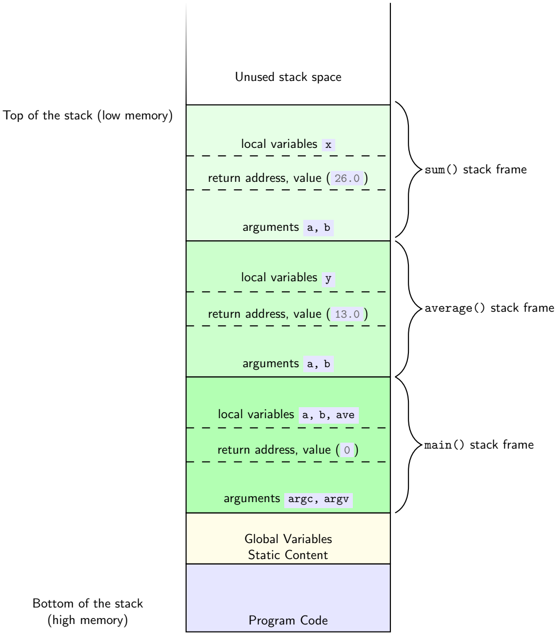

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- The values stored in the variables are copied into variables in a new stack frame
- As functions return, stack frames are removed
- Live demonstration

Demonstration

Consider the following code that attempts to swap two values:

```
void swap(int a, int b) {
  int temp = a;
  a = b;
  b = temp;
  return;
}
```

Part V: Pointers

Memory

- Every piece of data in a computer is stored in memory

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- Memory has both an *address* and *contents*

Address	Contents
0x7fff58310b87	0x01
0x7fff58310b86	0x32
0x7fff58310b85	0x7c
0x7fff58310b84	0xff
0x7fff58310b83	
0x7fff58310b82	
0x7fff58310b81	
0x7fff58310b80	
0x7fff58310b7f	
0x7fff58310b7e	
0x7fff58310b7d	
0x7fff58310b7c	3.14159265359
0x7fff58310b7b	
0x7fff58310b7a	
0x7fff58310b79	
0x7fff58310b78	32,321,231
0x7fff58310b77	
0x7fff58310b76	
0x7fff58310b75	
0x7fff58310b74	1,458,321
.	.

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- You can access memory *addresses* with *pointers*
- A pointer is a memory reference that "points" to some memory address
- Syntax:

```c
//regular variable:
int a = 10;

//an integer pointer variable:
int *ptrToA;
```

Pointers


```
int *ptrToA;
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- `ptrToA` is a pointer variable that can point to a memory location that stores an integer

Pointers


```
int *ptrToA;
```

- `ptrToA` is a pointer variable that can point to a memory location that stores an integer
- An *uninitialized pointer* may point to anything:

```
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- Best practice to initialize pointers
- The `NULL` pointer is a special pointer that indicates "nothing"
- Initialization:

  ```
  int *ptrToA = NULL;
  ```

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Pass By Reference

- Pointer variables can be created for any type of variable.

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double *ptrToB = NULL;
char *ptrToC = NULL;
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Pointers
Other Types

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- Null pointer check

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Using Pointers
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```c
int a = 42;
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ptrToA = &a;
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Using Pointers

Referencing Operator

- Need to be able to make a pointer *point* to something
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int a = 42;
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//make ptrToA point to a:
ptrToA = &a;
```

```
double b = 10.5;
double *ptrToB = NULL;
ptrToB = &b;
```

Pitfalls

- Types of pointer variables and what they point to *need to match*:

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int a = 42;
double *dblPtr = NULL;
dblPtr = &a; //WRONG
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Pitfalls

- Types of pointer variables and what they point to *need to match*:

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- Pointers *must be assigned a valid memory address*

```c
int a = 42;
int *ptrToA = NULL;
ptrToA = a;  //WRONG!!
ptrToA = 10; //SO WRONG!!
```

Using Pointers
Dereferencing Operator

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Using Pointers

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- You can also *change* the contents

```c
*ptrToA = 43;
```

- Pointer declaration:

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int *ptr = NULL;
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Summary

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- Pointer declaration:
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Summary

- Pointer declaration:
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- Why pointers?
- So we can *pass variables by reference*!!

Part VI: Pass By Reference

Pass By Reference

- Recall our swap function:

```c
void swap(int a, int b) {
  int temp = a;
  a = b;
  b = temp;
  return;
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Pass By Reference

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- Failed because `a` and `b` were passed by value
- Values were copied to separate local parameter variables
- Using pointers, we can pass *references* to the variables instead

Pass By Reference

- Parameters become pointer variables instead:

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void swap(int *a, int *b) {
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Pass By Reference

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- Functions can make changes that are *visible* to the calling function
- Consequences:
  - Functions can have *side effects*
  - Functions can "return" multiple values via pass-by-reference variables

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Demonstration:

1. Modify one of our distance functions to utilize pass-by-reference
2. Implement a new function to calculate a line graph:

$$y = mx + b$$

Given $(x_1, y_1), (x_2, y_2)$, compute:

$$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$b = y_1 - mx_1$$