ECE 131 – Programming Fundamentals

Dr. Daryl Lee

University of New Mexico

UNM | Electrical & Computer Engineering

Parameters

- What is the purpose of functions in programming? They allow you to package some useful functionality in a way that can be reused.
- The motivation for including parameter lists in functions is that they allow generic procedures to be developed. I.e., the data that a function will work on does not have to be specified beforehand, but instead can be varied from one function call to the next.
  Ex: `bubblesort()`
- Thus, a function is written so that it operates on the "dummy variables" supplied in the parameter list. These dummy variables are referred to as formal parameters.
- The data supplied when the procedure is actually called are referred to as actual parameters.

Parameters

Consider:

```
void func(int);

main() {
   int x=1;
   func(x);
}

void func(int a) {
   int y;
   y = a * 2;
}
```

The variable `x` is the actual parameter, and it is supplied to `func()`, where it is assigned to the formal parameter a.

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Parameter Passing

There are two mechanisms that can be used to pass the actual parameters to a procedure:

- Pass-by-value – a copy of the actual parameters (i.e., their values) is supplied to the formal parameters. Thus, any modification of these parameters is not reflected outside of the function. That is, a change in value of one of the parameters inside the function is local to that function.
- Pass-by-reference – the formal parameters are bound to the reference values of the actual parameters. This means that a change in the value of a parameter inside a function will actually change the value contained in the variable to which that parameter references. Thus, a change in the value of a parameter inside the function is *not* local to that function.

Important: C only supports pass-by-value.

Parameter Passing

What does the following program print:

```
main() {
   int x=1;
   increment(x);
   printf("1+1 = %d", x);
}

void increment(int a) {
   a = a+1;
}
```

It prints `1+1 = 1`. When the value of `x` is passed to `increment()`, it's assigned to the formal parameter a in increment, and incremented locally, without changing `x`.

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Parameter Passing

Here's how to fix it:

```
main() {
   int x=1;
   x = increment(x);
   printf("1+1 = %d", x);
}

int increment(int a) {
   a = a+1;
   return a;
}
```

It now prints `1+1 = 2`.

Parameter Passing – Arrays

- In C, you do not pass an entire array as a parameter – rather, you pass a “pointer” to the array. I.e., we pass the value of a pointer. (Pointers will be explained fully in Chapter 11)
- As part of the formal parameter, you can provide the dimension of the array.
  Ex: (http://www.youtube.com/watch?v=lyZQPjUT5B4)

```
main() {
 int i, num[10] =
   {3,0,1,8,7,2,5,4,6,9};
 bubblesort(num);
 for (i = 0; i<10; i++)
   printf(" %d ", num[i]);
}
```

```
const int N=10;
void bubblesort(int A[N]) {
  int i, j, temp;
  for (i=0; i<N-1; i++)
    for (j=0; j<N-i; j++)
      if (A[j] > A[j+1]) {
        temp = A[j];
        A[j] = A[j+1];
        A[j+1] = temp;
      }
}
```

Parameter Passing – Arrays

- The problem with the previous implementation is that it will only sort a list of ten numbers.
- In order to make `bubblesort()` more useful, we should pass in the size of the list we wish to sort.
  Ex:

```
main()
{
 int i, num[10] =
   {3,0,1,8,7,2,5,4,6,9};
 int length =
   sizeof(num)/sizeof(num[0]);
 bubblesort(length, num);
 for (i = 0; i<length; i++)
   printf(" %d ", num[i]);
}
```

```
void bubblesort(int sz, int A[sz])
{
  int i, j, temp;
  for (i=0; i<sz-1; i++)
    for (j=0; j<sz-i; j++)
      if (A[j] > A[j+1]) {
        temp = A[j];
        A[j] = A[j+1];
        A[j+1] = temp;
      }
}
```

Parameter Passing – Arrays

- Once again, remember that we can index beyond the bounds of the array, and the C compiler will not complain at compile time – this will either yield erroneous results, or a run-time error.

  Ex: If I change the 3rd line in `bubblesort()` to:

  ```
  for (i=0; i<sz; i++)
  ```

  the code compiles on my machine without warnings/errors, but it produces the wrong results.
  However, if I change it to:

  ```
  for (i=0; i<sz+100; i++)
  ```

  it again compiles without any problems, but I get a "segmentation fault" at run-time.

Parameter Passing – Multidimensional Arrays

- Because C always allocates array elements in contiguous memory locations, once we have the pointer to a one dimensional array, we can just index into it.
- The situation is different for multi-dimensional arrays. In order to index into a multidimensional array, we need know every dimension except for the first.
  E.g., if we wish to pass the array:

  ```
  int ary[5][8]
  ```

  to a function, that function needs to know that every row contains eight integers. I.e., to determine where in memory ary[2][3] is, the following pointer arithmetic is performed: `ary + (2 * 8) + 3`.
  The function knows about the 2 and the 3, they were used when indexing the array, but how does it know about the 8?
  In the function declaration, we need to supply this information:

  ```
  void func(int A[][8]);
  ```

Parameter Passing – Multidimensional Arrays

- The function definition also needs to contain this information:

```
void func(int A[][8]) {
   ...
}
```

- What if we wanted to pass the three-dimensional array

```
float ary[4][6][10];
```

  to a function, what would the function prototype need to look like?

```
void func(float myary[][6][10]);
```

- This is a little ugly, since we hard-coded two of the three array dimensions, which tends to make the code less reusable. One alternative is to use variable sizing, as illustrated earlier.

Parameter Passing – How Does It Actually Work?

- Recall our example of how functions work from Module #2 (next slide).
- Notice that `main()` calls `func1()`, and `func1()` calls `func2()`. Furthermore, the value returned by `func2()` is used in `func1()`, and then value returned by `func1()` is used in `main()`.
- How does the program keep track of all of these values across multiple function calls while program is running?
- Every function call in C creates an activation record. Each time a function is called, the state of the function that made the call is recorded in its activation record, and then stored on the run-time stack for later retrieval.
- Think of a "stack" as being organized like a stack of cafeteria trays. The next one to be removed is the one on top, which must also be the tray that was most recently added.

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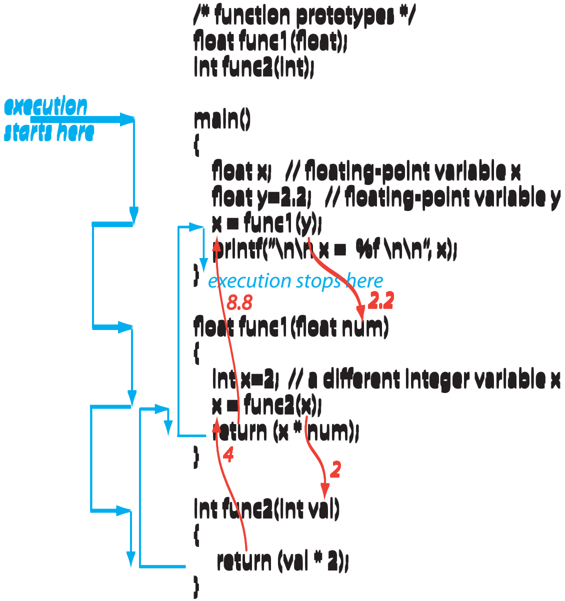
Functions in C



```
/* function prototypes */
float func1(float);
int func2(int);

main()
{
   float x;   // floating-point variable x
   float y=2.2;  // floating-point variable y
   x = func1(y);
   printf("\n\n x =  %f \n\n", x);
}

float func1(float num)
{
   int x=2;  // a different integer variable x
   x = func2(x);
   return (x * num);
}

int func2(int val)
{
    return (val * 2);
}
```

The Run-time Stack

- An activation record contains storage for all local variables declared in the function, as well as either a copy of, or a reference to, the parameters that are being passed to the procedure.
- An activation record must also contain some information that specifies where program execution will resume when the function is completed.
- At the completion of the function, the associated activation record will be removed from the run-time stack, and program control will return to the point specified in the activation record.
- Activation records are managed using a stack (a LIFO data structure). Why? Upon completing execution of a function, control should return to the function that called it — which will be the one most recently stored on the run-time stack.

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The Run-time Stack

Management of the run-time stack in the previous example:

```
activation
  record
    1          main()
    2              func1()
    3                  func2()
    3                      return(4)
    2                  x=4
    2                  return 8.8
    1              x = 8.8
```

Activation record 1 is placed on the stack when `func1()` is called. Then activation record 2 is placed on top of it, when `func2()` is called. When `func2()` completes execution, activation record 2 is popped from the stack, and when it finishes, activation record 1 is popped from the stack. Why a stack? We always want to remove the most recently added activation record.

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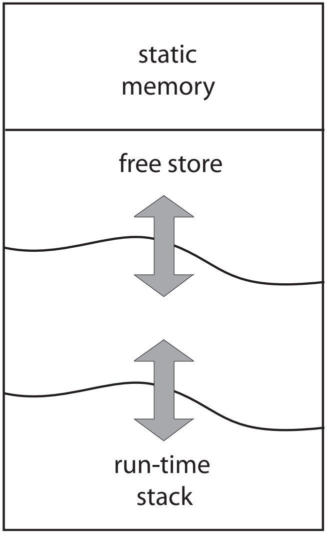
A More Complete C Memory Model

The memory model you should have when programming in C:



- Static Memory – Variables and constants that will persist in memory throughout the execution of the program.
- Free Store – Space set aside for dynamically allocated memory.
- Run-time Stack – Each time a function is called in a program, an activation record is created and stored in computer memory on the run-time stack.