C Function Invocation

The C Programming Language, Chapter 4

Function Terminology

```
int main(int argc, char **argv) {
        int a=3;
        int b=4;
        int c = myfn(a,b+2);
        return 0;
}
```

Caller

Invocation

Return Address

Return Value

```
int myfn(int x, int y) { return x*x + y*y; }
```

Callee

Terminology Definitions

- Caller: Higher level function that invokes a lower level function
- Callee: Lower level function that has been invoked by a higher level function
  - Note: A single function can be both a callee and a caller
- Invocation: The indication in the caller that it want’s to use the callee
- Instance: One specific execution of the callee
- Return Value: The value specified on the “return” statement of the callee
- Return Address: The instruction in the caller that should be executed when the instance of the callee is complete

Instruction processing…

[OS(caller) invokes Main (callee)]
[Main (callee) startup)]
a=3;
b=4;
[Main (caller) invokes myfn(callee)]
x=a, y=b+2;
[myfn (callee) startup]
x*x + y*y
[myfn (callee) return to main]
[main (caller) return from myfn]
c = [return value from myfn]
[main (callee) return to OS]

```
int main(int argc, char **argv) {
        int a=3;
        int b=4;
        int c = myfn(a,b+2);
        return 0;
}

int myfn(int x, int y) { return x*x + y*y; }
```

Function Invocation Details

[OS(caller) invokes Main (callee)]
[Main (callee) startup)]

a=3;
b=4;

- Evaluate arguments
- Copy argument values to parameters
- Preserve Caller's state
- Save return address

[Main (caller) invokes myfn(callee)]
x=a, y=b+2;
[myfn (callee) startup]

- Preserve caller's state
- Create/initialize local variables
- Establish argument accessibility

x*x + y*y

[myfn (callee) return to main]
[main (caller) return from myfn]

c = [return value from myfn]

[main (callee) return to OS]

Caller invoke…

```
int main(int argc, char **argv) {

    int a=3;
    int b=4;
    int c = myfn(a,b+2);
    return 0;
}

int myfn(int x, int y) { return x*x + y*y; }
```

Save Caller's State

Eval. Args… myfn(3,6)

Copy args to parms… x=3, y=6

Save Return Address

Callee startup…

```
int main(int argc, char **argv) {

        int a=3;
        int b=4;
        int c = myfn(a,b);
        return 0;
}

int myfn(int x, int y) { return x*x + y*y; }
```

Save Caller's State

Establish args… x=3, y=6

Create Local Variables

Function Return Details

[OS(caller) invokes Main (callee)]
[Main (callee) startup)]
a=3;
b=4;
[Main (caller) invokes myfn(callee)]
x=a, y=b+2;
[myfn (callee) startup]
x*x + y*y
[myfn (callee) return to main]
[main (caller) return from myfn]
c = [return value from myfn]
[main (callee) return to OS]

- Evaluate return expression
- Save return value
- Free local variables
- Restore caller's state
- Branch to return address

- Restore caller's state
- Free space for arguments/return address
- Use returned value

Callee return…

```
int main(int argc, char **argv) {

    int a=3;
    int b=4;
    int c = myfn(a,b);
    return 0;
}

int myfn(int x, int y) { return x*x + y*y; }
```

Eval Return
3*3+6*6

Save return val : 45

Free Local Variables

Restore Caller's
State

Branch to
Return Address

Caller on return…

```
int main(int argc, char **argv) {

    int a=3;
    int b=4;
    int c = myfn(a,b);
    return 0;
}

int myfn(int x, int y) { return x*x + y*y; }
```

Free Args & return address

Restore Caller's State

Use return value: 46

"Call by Value"

- Convention that says callee works on a copy of the arguments
- Protects callers variables from unexpected "side-effects"

```
int x=1,y=2,z=3;
int myfunc(int a; int b) { a=2*a; return a*b; }
x=myfunc(y,z);
```

- Prevents functions from modifying arguments

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

Update Argument work-arounds

- Use the return value

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

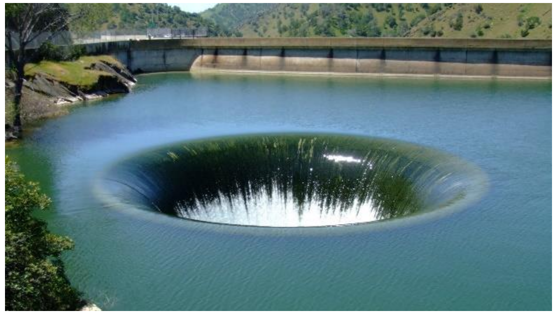
- Pass a pointer to the value

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

Function Variable Scope

- Variables are visible *only* inside the block in which they are declared
  - Block is delimited by curly braces… {   }
  - Variables typically declared inside a function definition
  - Not visible to called functions! (Different from other languages)
- That way, “x” in this function is always different from “x” in the calling function!
- Function variables disappear when the block ends

Example Scope Hole



```
{ int i; int j=7;
  for (i=0; i<3; i++) {
      int j=i+1;
      printf("j=%d\n",j);
  }
  printf("j=%d\n");
}
```

Scope of outside j

Scope of inside j
(Hole for outside j)

j=1
j=2
j=3
j=7

Function Binding in C

- Binding: How much do I need to know in order to code a function
  - Parameter Definitions
  - Return Value Type
  - Functionality
  - Environment (global variables, lower level function availability, etc.)
  - Caller's environment (variable names, etc.)
  - State (status of IO devices, value of caller's variables, etc.)
- High Binding => Low Portability / Re-Use
- Function Variables in C => Lower Binding

Variable Life

- Global Variables (declared outside function):
  - allocated/initialized before “main” is invoked
  - freed after “main” returns
- Local Variables:
  - allocated/initialized when function is invoked
  - freed after function returns

The “Disappearing” return value problem

```
char * myfn(int x) {
        char val[256]; int j;
        for(j=0;j<x && j<256; j++) val[j]=‘x’;
        val[j]=0; return val;
}
int main() {
        char *p=myfn(121);
        printf(“121 xs are: %s\n”,p); // Problem here!
        return 0;
}
```

return value fix

```
char val[256]; // "Global" variable
char * myfn(int x) {
	int j;
	for(j=0;j<x && j<256; j++) val[j]='x';
	val[j]=0; return val;
}
int main() {
	char *p=myfn(121); // p alias for "val"
	printf("121 xs are: %s\n",p); // Works, but dangerous!
	return 0;
}
```

return value fix 2

```
char * myfn(int x) {
	int j;
	char *val=(char *)malloc(x+1); // get memory from OS
	for(j=0;j<x; j++) val[j]='x';
	val[j]=0; return val;
}
int main() {
	char *p=myfn(121);
	printf("121 xs are: %s\n",p);
	free(p); // return memory to OS
	return 0;
}
```