

Lecture 10: function pointers, building large projects, beginning C++, C++ and structs



Project 2C

Worth 4% of your grade

Assignment: You will implement 3 structs and 9 functions. The prototypes for the functions are located in the file `prototypes.h` (available on the website).

The three structs are `Rectangle`, `Circle`, and `Triangle`, and are described below.

The 3 structs refer to 3 different shapes: `Triangle`, `Circle`, and `Rectangle`. For each shape, there are 3 functions: `Initialize`, `GetArea`, and `GetBoundingBox`. You must implement 9 functions total (3*3).

The prototypes for these 9 functions are available in the file `prototypes.h`

There is also a driver program, and correct output for the driver program.



Project 3A

Worth 4% of your grade

Please read this entire prompt!

Assignment: You will begin manipulation of images

- 1) Write a struct to store an image.
- 2) Write a function called ReadImage that reads an image from a file
- 3) Write a function called YellowDiagonal, which puts a yellow diagonal across an image.
- 4) Write a function called WriteImage that writes an image to a file.

Note: I gave you a file (3A_c.c) to start with that has interfaces for the functions.

Note: your program should be run as:

`./proj3A <input image file> <output image file>`



Outline

- Review
- Building Large Projects
- Beginning C++
- C++ & Structs



Outline

- ~~Review~~
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Function Pointers

- Idea:
 - You have a pointer to a function
 - This pointer can change based on circumstance
 - When you call the function pointer, it is like calling a known function



Function Pointer Example

```
128-223-223-72-wireless:cli hank$ cat function_ptr.c
```

```
#include <stdio.h>
```

```
int doubler(int x) { return 2*x; }
```

```
int tripler(int x) { return 3*x; }
```

```
int main()
```

```
{
```

```
    int (*multiplier)(int);
```

```
    multiplier = doubler;
```

```
    printf("Multiplier of 3 = %d\n", multiplier(3));
```

```
    multiplier = tripler;
```

```
    printf("Multiplier of 3 = %d\n", multiplier(3));
```

```
}
```

```
128-223-223-72-wireless:cli hank$ gcc function_ptr.c
```

```
128-223-223-72-wireless:cli hank$ ./a.out
```

```
Multiplier of 3 = 6
```

```
Multiplier of 3 = 9
```



Function Pointer Example #2

```
128-223-223-72-wireless:cli hank$ cat array_fp.c
#include <stdio.h>
void doubler(int *X) { X[0]*=2; X[1]*=2; };
void tripler(int *X) { X[0]*=3; X[1]*=3; };
int main()
{
    void (*multiplier)(int *);
    int A[2] = { 2, 3 };
    multiplier = doubler;
    multiplier(A);
    printf("Multiplier of 3 = %d, %d\n", A[0], A[1]);
    multiplier = tripler;
    multiplier(A);
    printf("Multiplier of 3 = %d, %d\n", A[0], A[1]);
}
128-223-223-72-wireless:cli hank$ gcc array_fp.c
128-223-223-72-wireless:cli hank$ ./a.out
```

Don't be scared of extra '*'s ... they just come about because of pointers in the arguments or return values.



Simple-to-Exotic Function Pointer Declarations

```
void (*foo)(void);
```

```
void (*foo)(int **, char ***);
```

```
char ** (*foo)(int **, void (*)(int));
```

These sometimes come up on interviews.



Function Pointers vs Conditionals

```
128-223-223-72-wireless:cli hank$ cat function_ptr2.c
#include <stdio.h>
int doubler(int x) { return 2*x; }
int tripler(int x) { return 3*x; }
int main()
{
    int (*multiplier)(int);
    int condition = 1;

    if (condition)
        multiplier = doubler;
    else
        multiplier = doubler;

    printf("Multiplier of 3 = %d\n", multiplier(3));
}
```

```
#include <stdio.h>
int doubler(int x) { return 2*x; }
int tripler(int x) { return 3*x; }
int main()
{
    int val;

    if (condition)
        val = doubler(3);
    else
        val = tripler(3);

    printf("Multiplier of 3 = %d\n", val);
}
```

What are the pros and cons of each approach?



Callbacks

- Callbacks: function that is called when a condition is met
 - Commonly used when interfacing between modules that were developed separately.
 - ... libraries use callbacks and developers who use the libraries “register” callbacks.



Callback example

```
128-223-223-72-wireless:callback hank$ cat mylog.h
void RegisterErrorHandler(void (*eh)(char *));
double mylogarithm(double x);
```

```
128-223-223-72-wireless:callback hank$ cat mylog.c
#include <mylog.h>

#include <stdio.h>
#include <stdlib.h>
#include <math.h>

/* NULL is an invalid memory location.
 * Useful for setting to something known, rather than
 * leaving uninitialized */
void (*error_handler)(char *) = NULL;

void RegisterErrorHandler(void (*eh)(char *))
{
    error_handler = eh;
}

void Error(char *msg)
{
    if (error_handler != NULL)
        error_handler(msg);
}

double mylogarithm(double x)
{
    if (x <= 0)
    {
        char msg[1024];
        sprintf(msg, "Logarithm of a negative number: %f !!", x);
        Error(msg);
        return 0;
    }

    return log(x);
}
```



Callback example

```
128-223-223-72-wireless:callback hank$ cat program.c
#include <mylog.h>
#include <stdio.h>

FILE *F1 = NULL;
void HanksErrorHandler(char *msg)
{
    if (F1 == NULL)
    {
        F1 = fopen("error", "w");
    }
    fprintf(F1, "Error: %s\n", msg);
}

int main()
{
    RegisterErrorHandler(HanksErrorHandler);

    mylogarithm(3);
    mylogarithm(0);
    mylogarithm(-2);
    mylogarithm(5);
    if (F1 != NULL)
        fclose(F1);
}
128-223-223-72-wireless:callback hank$
128-223-223-72-wireless:callback hank$ ./program
128-223-223-72-wireless:callback hank$
128-223-223-72-wireless:callback hank$ cat error
Error: Logarithm of a negative number: 0.000000 !!
Error: Logarithm of a negative number: -2.000000 !!
128-223-223-72-wireless:callback hank$
```



Function Pointers

- We are going to use function pointers to accomplish “sub-typing” in Project 2D.



Subtyping



Subtyping

- Type: a data type (int, float, structs)
- Subtype / supertype:
 - Supertype: the abstraction of a type
 - (not specific)
 - Subtype: a concrete implementation of the supertype
 - (specific)

The fancy term for this is “subtype polymorphism”



Subtyping: example

- Supertype: Shape
- Subtypes:
 - Circle
 - Rectangle
 - Triangle



Subtyping works via interfaces

- Must define an interface for supertype/subtypes
 - Interfaces are the functions you can call on the supertype/subtypes
- The set of functions is fixed
 - Every subtype must define all functions



Subtyping

- I write my routines to the supertype interface
- All subtypes can automatically use this code
 - Don't have to modify code when new subtypes are added
- Example:
 - I wrote code about Shapes.
 - I don't care about details of subtypes (Triangle, Rectangle, Circle)
 - When new subtypes are added (Square), my code doesn't change



Project 2D

- You will extend Project 2C
- You will do Subtyping
 - You will make a union of all the structs
 - You will make a struct of function pointers
- This will enable subtyping
- Goal: driver program works on “Shape”s and doesn’t need to know if it is a Circle, Triangle, or Rectangle.



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3 files: prototypes.h, rectangle.c, driver.c

prototypes.h

```
struct Rectangle;  
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
```

rectangle.c

```
struct Rectangle  
{  
    double minX, maxX, minY, maxY;  
};  
  
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4)  
{  
    r->minX = v1;  r->maxX = v2;  r->minY = v3;  r->maxY = v4;  
}
```

driver.c

```
#include <prototypes.h>  
  
int main()  
{  
    struct Rectangle r;  
    InitializeRectangle(r, 0, 1, 0, 1.5);  
}
```



Review on compilation

- `gcc -c`: build an object file (.o), i.e., binary code that can directly run on the architecture
- Then the binary can be generated from the object files.
- Libraries are a mechanism for grouping up a bunch of related object files
 - They are assembled together using a program called an archiver (ar)
- You can also just use object files directly when linking.



Makefiles

- Consists of rules
- Rule syntax:

target: dependency1 dep2 ... depN

<tab>command1

<tab>command2

Quiz: write down a Makefile for a program called proj2B.
Again, the file names are prototypes.h, driver.c, rectangle.c



Makefile for prototypes.h, rectangle.c, driver.c

Makefile

```
proj2B: driver.c rectangle.c prototypes.h  
    gcc -l. -c rectangle.c  
    gcc -l. -c driver.c  
    gcc -o proj2B driver.o rectangle.o
```

Is this a good Makefile?
What's the problem with it?



Makefile for prototypes.h, rectangle.c, driver.c

Makefile

```
proj2B: rectangle.o driver.o  
    gcc -o proj2B driver.o rectangle.o
```

```
driver.o: prototypes.h driver.c  
    gcc -I. -c driver.c
```

```
rectangle.o: prototypes.h rectangle.c  
    gcc -I. -c rectangle.c
```



Definition of Rectangle in rectangle.c

Why is this a problem?

prototypes.h

```
struct Rectangle;  
void IntializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
```

rectangle.c

```
struct Rectangle
```

“gcc -c driver.c” needs to make an object file.
It needs info about Rectangle then, not later.

```
{  
    r->minX = v1;  r->maxX = v2;  r->minY = v3;  r->maxY = v4;  
}
```

driver.c

```
#include <prototypes.h>
```

```
int main()  
{  
    struct Rectangle r;  
    InitializeRectangle(&r, 0, 1, 0, 1.5);  
}
```



The fix is to make sure driver.c has access to the Rectangle struct definition.

Option: "gcc -E"

driver.c

```
{  
    struct Rectangle r;  
    InitializeRectangle(r, 0, 1, 0, 1.5);  
}
```

gcc -E -I.

```
# 1 "driver.c"  
# 1 "<built-in>" 1  
# 1 "<built-in>" 3  
# 162 "<built-in>" 3  
# 1 "<command line>" 1  
# 1 "<built-in>" 2  
# 1 "driver.c" 2  
# 1 "./prototypes.h" 1
```

struct Rectangle;

```
void InitializeRectangle(struct Rectangle *r, double v1, double v2,  
# 2 "driver.c" 2
```

```
int main()  
{  
    struct Rectangle r;  
    InitializeRectangle(r, 0, 1, 0, 1.5);  
}
```

gcc -E shows what the compiler sees after satisfying “preprocessing”, which includes steps like “#include”.

This is it. If the compiler can't figure out how to make object file with this, then it has to give up.



4 files: struct.h, prototypes.h, rectangle.c, driver.c

struct.h

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

prototypes.h

```
#include <struct.h>
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
```

rectangle.c

```
#include <struct.h>
#include <prototypes.h>
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4)
{
    r->minX = v1; r->maxX = v2; r->minY = v3; r->maxY = v4;
}
```

driver.c

```
#include <struct.h>
#include <prototypes.h>
int main()
{
    str
    Ini
}
```

What is the problem with this configuration?



Compilation error

```
C02LN00GFD58:project hank$ make
gcc -I. -c rectangle.c
In file included from rectangle.c:2:
In file included from ./prototypes.h:2:
./struct.h:2:8: error: redefinition of 'Rectangle'
struct Rectangle
    ^
./struct.h:2:8: note: previous definition is here
struct Rectangle
    ^
1 error generated.
make: *** [rectangle.o] Error 1
```



gcc -E rectangle.c

```
C02LN00GFD58:project hank$ gcc -E -I. rectangle.c
```

```
# 1 "rectangle.c"
# 1 "<built-in>" 1
# 1 "<built-in>" 3
# 162 "<built-in>" 3
# 1 "<command line>" 1
# 1 "<built-in>" 2
# 1 "rectangle.c" 2
# 1 "./struct.h" 1
```

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

```
# 2 "rectangle.c" 2
# 1 "./prototypes.h" 1
```

```
# 1 "./struct.h" 1
```

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

```
# 3 "./prototypes.h" 2
```

```
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
# 3 "rectangle.c" 2
```

```
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4)
{
    r->minX = v1;
    r->maxX = v2;
    r->minY = v3;
    r->maxY = v4;
}
```



How to fix?

- Solution #1: don't include it twice
 - → Turns out, that is hard
- Solution #2: need more infrastructure – macros
 - (This motivates the next ten slides)

Preprocessor

- Preprocessor:
 - takes an input program
 - produces another program (which is then compiled)
- C has a separate language for preprocessing
 - Different syntax than C
 - Uses macros (“#”)

macro (“macroinstruction”): rule for replacing input characters with output characters



Preprocessor Phases

- Resolve `#includes`
 - (we understand `#include` phase)
- Conditional compilation (`#ifdef`)
- Macro replacement
- Special macros



#define compilation

```
C02LN00GFD58:330 hank$ cat defines.c
#define RV 2

int main()
{
    return RV;
}
C02LN00GFD58:330 hank$ gcc defines.c
C02LN00GFD58:330 hank$ ./a.out
C02LN00GFD58:330 hank$ echo $?
2
```

This is an example of macro replacement.



#define via gcc command-line option

```
C02LN00GFD58:330 hank$ cat defines.c
int main()
{
    return RV;
}
C02LN00GFD58:330 hank$ gcc -DRV=4 defines.c
C02LN00GFD58:330 hank$ ./a.out
C02LN00GFD58:330 hank$ echo $?
4
```



Conflicting -D and #define

```
C02LN00GFD58:330 hank$ cat defines.c
```

```
#define RV 2
```

```
int main()
```

```
{
```

```
    return RV;
```

```
}
```

```
C02LN00GFD58:330 hank$ gcc -DRV=4 defines.c
```

```
defines.c:1:9: warning: 'RV' macro redefined
```

```
#define RV 2
```

^

```
<command line>:1:9: note: previous definition is here
```

```
#define RV 4
```

^

```
1 warning generated.
```

```
C02LN00GFD58:330 hank$ ./a.out
```

```
C02LN00GFD58:330 hank$ echo $?
```

```
2
```



Conditional compilation

```
C02LN00GFD58:330 hank$ cat conditional.c
#define USE_OPTION 1

int main()
{
    DoMainCode();
#ifdef USE_OPTION
    UseOption();
#endif
    DoCleanupCode();
}
```



Conditional compilation controlled via compiler flags

```
C02LN00GFD58:330 hank$ cat conditional_printf.c
#include <stdio.h>

int main()
{
#ifdef DO_PRINTF
    printf("I am doing PRINTF!!\n");
#endif
}
C02LN00GFD58:330 hank$ gcc conditional_printf.c
C02LN00GFD58:330 hank$ ./a.out
C02LN00GFD58:330 hank$ gcc -DDO_PRINTF conditional_printf.c
C02LN00GFD58:330 hank$ ./a.out
I am doing PRINTF!!
```

This is how configure/cmake controls the compilation.



4 files: struct.h, prototypes.h, rectangle.c, driver.c

struct.h

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

prototypes.h

```
#include <struct.h>
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
```

rectangle.c

```
#include <struct.h>
#include <prototypes.h>
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4)
{
    r->minX = v1; r->maxX = v2; r->minY = v3; r->maxY = v4;
}
```

driver.c

```
#include <struct.h>
#include <prototypes.h>
int main()
{
    str
    Ini
}
```

What is the problem with this configuration?



Compilation error

```
C02LN00GFD58:project hank$ make
gcc -I. -c rectangle.c
In file included from rectangle.c:2:
In file included from ./prototypes.h:2:
./struct.h:2:8: error: redefinition of 'Rectangle'
struct Rectangle
    ^
./struct.h:2:8: note: previous definition is here
struct Rectangle
    ^
1 error generated.
make: *** [rectangle.o] Error 1
```



gcc -E rectangle.c

```
C02LN00GFD58:project hank$ gcc -E -I. rectangle.c
```

```
# 1 "rectangle.c"
# 1 "<built-in>" 1
# 1 "<built-in>" 3
# 162 "<built-in>" 3
# 1 "<command line>" 1
# 1 "<built-in>" 2
# 1 "rectangle.c" 2
# 1 "./struct.h" 1
```

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

```
# 2 "rectangle.c" 2
# 1 "./prototypes.h" 1
```

```
# 1 "./struct.h" 1
```

```
struct Rectangle
{
    double minX, maxX, minY, maxY;
};
```

```
# 3 "./prototypes.h" 2
```

```
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4);
# 3 "rectangle.c" 2
```

```
void InitializeRectangle(struct Rectangle *r, double v1, double v2, double v3, double v4)
{
    r->minX = v1;
    r->maxX = v2;
    r->minY = v3;
    r->maxY = v4;
}
```



#ifndef / #define to the rescue

struct.h

```
#ifndef RECTANGLE_330
#define RECTANGLE_330

struct Rectangle
{
    double minX, maxX, minY, maxY;
};

#endif
```

Why does this work?

This problem comes up a lot with big projects, and especially with C++.



There is more to macros...

- Macros are powerful & can be used to generate custom code.
 - Beyond what we will do here.
- Two special macros that are useful:
 - `__FILE__` and `__LINE__`

```
C02LN00GFD58:330 hank$ cat macro.c
```

```
#include <stdio.h>
```

```
int  
{  
    printf("This print happens on line %d of file %s\n", __LINE__, __FILE__);  
    printf("But this print happens on line %d\n", __LINE__);  
}
```

```
C02LN00GFD58:330 hank$ gcc macro.c
```

```
C02LN00GFD58:330 hank$ ./a.out
```

```
This print happens on line 5 of file macro.c
```

```
But this print happens on line 6
```

(Do an example with `__LINE__`, `__FILE__`)



Outline

- Review
- Building Large Projects
- **Beginning C++**
- C++ & Structs



Relationship between C and C++

- C++ adds new features to C
 - Increment operator!
- For the most part, C++ is a superset of C
 - A few invalid C++ programs that are valid C programs
- Early C++ “compilers” just converted programs to C



A new compiler: g++

- g++ is the GNU C++ compiler
 - Flags are the same
 - Compiles C programs as well
 - (except those that aren't valid C++ programs)

.c vs .C

- Unix is case sensitive
 - (So are C and C++)
- Conventions:
 - .c: C file
 - .C: C++ file
 - .cxx: C++ file
 - .cpp: C++ file (this is pretty rare)

Gnu compiler will sometimes assume the language based on the extension ... CLANG won't.



Variable declaration (1/2)

- You can declare variables anywhere with C++!

```
void line_C(double X1, double X2, double Y1, double Y2)
{
    double slope;
    double intercept;

    slope      = (Y2-Y1)/(X2-X1);
    intercept = Y1-slope*X1;
}
```

```
void line_CPP(double X1, double X2, double Y1, double Y2)
{
    double slope      = (Y2-Y1)/(X2-X1);
    double intercept = Y1-slope*X1;
}
```



Variable declaration (2/2)

- You can declare variables anywhere with C++!

```
int C_fun(void)
```

Why is this bad?

```
C02LN00GFD58:L10 hank$ g++ t.C
```

```
t.C:16:17: error: invalid '+= ' at end of declaration; did you mean '='?
```

```
    int sum += i;
```

```
        ^~
```

```
        =
```

```
t.C:18:12: error: use of undeclared identifier 'sum'
```

```
    return sum;
```

```
        ^
```

```
2 errors generated.
```

What compiler error
would you get?

```
int CPP_fun(void)
```

```
{
```

```
    int sum = 0;
```

```
    for (int i = 0 ; i < 10 ; i++)
```

```
    {
```

```
        sum += i;
```

```
    }
```

```
    return sum;
```

```
}
```



C-style Comments

```
/* Here is a single line comment */
```

```
/*  
    Here is a multi-line comment */
```

```
/*  
 * Here is a  
 * multi-line comment  
 * that makes it clearer  
 * that each line is a  
 * comment  
 * ... because of the *'s  
 */
```



C++-style comments

```
// this is a comment
```

```
/* this is still a comment */
```

```
// this is a  
// multi-line C++ comment
```

When you type “//”, the rest of the line is a comment, whether you want it to be or not.



Valid C program that is not a valid C++ program

- We have now learned enough to spot one (the?) valid C program that is not a valid C++ program
 - (lectured on this earlier)

```
int main()
{
    int y = 2;
    int x = 3 /* 2 */y;
}
```



Problem with C...

```
C02LN00GFD58:330 hank$ cat doubler.c
float doubler(float f) { return 2*f; }
C02LN00GFD58:330 hank$ gcc -c doubler.c
C02LN00GFD58:330 hank$ cat doubler_example.c
#include <stdio.h>

int doubler(int);

int main()
{
    printf("Doubler of 10 is %d\n", doubler(10));
}
C02LN00GFD58:330 hank$ gcc -c doubler_example.c
C02LN00GFD58:330 hank$ gcc -o doubler_example doubler.o doubler_example.o
C02LN00GFD58:330 hank$ ./doubler_example
Doubler of 10 is 2
_
```



Problem with C...

```
C02LN00GFD58:330 hank$ nm doubler.o
000000000000000048 s EH_frame0
000000000000000000 T _doubler ←
000000000000000060 S _doubler.eh
C02LN00GFD58:330 hank$ nm doubler
doubler.c          doubler_example    doubler_example.o
doubler.o          doubler_example.c  doubler_user.o
C02LN00GFD58:330 hank$ nm doubler_example.o
000000000000000068 s EH_frame0
000000000000000032 s L_.str
                   U _doubler ←
000000000000000000 T _main
000000000000000080 S _main.eh
                   U _printf
```

No checking of type...



Problem is fixed with C++...

```
C02LN00GFD58:330 hank$ cat doubler.c
float doubler(float f) { return 2*f; }
C02LN00GFD58:330 hank$ g++ -c doubler.c
clang: warning: treating 'c' input as 'c++' when in C++ mode, this behavior is deprecated
C02LN00GFD58:330 hank$ cat doubler_example.c
#include <stdio.h>

int doubler(int);

int main()
{
    printf("Doubler of 10 is %d\n", doubler(10));
}
C02LN00GFD58:330 hank$ g++ -c doubler_example.c
clang: warning: treating 'c' input as 'c++' when in C++ mode, this behavior is deprecated
C02LN00GFD58:330 hank$ g++ -o doubler_example doubler_example.o doubler.o
Undefined symbols for architecture x86_64:
  "doubler(int)", referenced from:
      _main in doubler_example.o
ld: symbol(s) not found for architecture x86_64
clang: error: linker command failed with exit code 1 (use -v to see invocation)
C02LN00GFD58:330 hank$
```



Problem is fixed with C++...

```
C02LN00GFD58:330 hank$ nm doubler.o
000000000000000048 s EH_frame0
000000000000000000 T __Z7doublerf ←
000000000000000060 S __Z7doublerf.eh
C02LN00GFD58:330 hank$ nm doubler_example.o
000000000000000068 s EH_frame0
000000000000000032 s L_.str
U __Z7doubleri ←
000000000000000000 T _main
000000000000000080 S _main.eh
U _printf
C02LN00GFD58:330 hank$

C02LN00GFD58:330 hank$ nm doubler.o
000000000000000048 s EH_frame0
000000000000000000 T _doubler
000000000000000060 S _doubler.eh
C02LN00GFD58:330 hank$ nm doubler
doubler.c doubler_example
example.c doubler_example
EH_frame0
_printf
```

This will affect you with C++. Before you got unresolved symbols when you forgot to define the function. Now you will get it when the arguments don't match up. Is this good?

Mangling

- Mangling refers to combining information about arguments and “mangling” it with function name.
 - Way of ensuring that you don’t mix up functions.
 - Return type not mangled, though
- Causes problems with compiler mismatches
 - C++ compilers haven’t standardized.
 - Can’t take library from icpc and combine it with g++.




C++ will let you overload functions with different types

```
C02LN00GFD58:330 hank$ cat t.c
float doubler(float f) { return 2*f; }
int doubler(int f) { return 2*f; }
C02LN00GFD58:330 hank$ gcc -c t.c
t.c:2:5: error: conflicting types for 'doubler'
int doubler(int f) { return 2*f; }
    ^
t.c:1:7: note: previous definition is here
float doubler(float f) { return 2*f; }
    ^
1 error generated.
C02LN00GFD58:330 hank$ g++ -c t.C
C02LN00GFD58:330 hank$ █
```




C++ also gives you access to mangling via “namespaces”

```
C02LN00GFD58:330 hank$ cat cis330.C
#include <stdio.h>

namespace CIS330 
{
    int GetNumberOfStudents(void) { return 56; };
}

namespace CIS610
{
    int GetNumberOfStudents(void) { return 9; };
}

int main()
{
    printf("Number of students in 330 is %d, but in 610 was %d\n",
 CIS330::GetNumberOfStudents(),
        CIS610::GetNumberOfStudents());
}

C02LN00GED58:330 hank$ g++ cis330.C
```

Functions or variables within a namespace are accessed with “::”
“::” is called “scope resolution operator”



C++ also gives you access to mangling via “namespaces”

```
C02LN00GFD58:330 hank$ cat cis330.C
```

The “using” keyword makes all functions and variables from a namespace available without needing “::”.
And you can still access other namespaces.

```
namespace CIS610
{
    int GetNumberOfStudents(void) { return 9; };
}

using namespace CIS330;

int main()
{
    printf("Number of students in 330 is %d, but in 610 was %d\n",
        GetNumberOfStudents(),
        CIS610::GetNumberOfStudents());
}

C02LN00GFD58:330 hank$ g++ cis330.C
C02LN00GFD58:330 hank$ ./a.out
Number of students in 330 is 56, but in 610 was 9
C02LN00GFD58:330 hank$
```

References

- A reference is a simplified version of a pointer.
- Key differences:
 - You cannot do pointer manipulations
 - A reference is always valid
 - a pointer is not always valid
- Accomplished with & (ampersand)
 - &: address of variable (C-style, still valid)
 - &: reference to a variable (C++-style, also now valid)

You have to figure out how '&' is being used based on context.



Examples of References

```
C02LN00GFD58:330 hank$ cat ref.C
#include <stdio.h>

void ref_doubler(int &x) { x = 2*x; };

int main()
{
    int x1 = 2;
    ref_doubler(x1);
    printf("Val is %d\n", x1);
}
C02LN00GFD58:330 hank$ g++ ref.C
C02LN00GFD58:330 hank$ ./a.out
Val is 4
```



References vs Pointers vs Call-By-Value

```
C02LN00GFD58:330 hank$ cat reference.C
#include <stdio.h>

void ref_doubler(int &x) { x = 2*x; };
void ptr_doubler(int *x) { *x = 2**x; };
void val_doubler(int x)  { x = 2*x; };

int main()
{
    int x1 = 2, x2 = 2, x3 = 2;
    ref_doubler(x1);
    ptr_doubler(&x2);
    val_doubler(x3);
    printf("Vals are %d, %d, %d\n", x1, x2, x3);
}
```

ref_doubler and ptr_doubler are both examples of call-by-reference.
val_doubler is an example of call-by-value.



References

- Simplified version of a pointer.
- Key differences:
 - You cannot manipulate it
 - Meaning: you are given a reference to exactly one instance ... you can't do pointer arithmetic to skip forward in an array to find another object
 - A reference is always valid
 - No equivalent of a NULL pointer ... must be a valid instance



Different Misc C++ Topic: initialization during declaration using parentheses

```
C02LN00GFD58:330 hank$ cat decl_paren.C
#include <stdio.h>

int main()
{
    int x(3);
    printf("X is %d\n", x);
}
C02LN00GFD58:330 hank$ g++ decl_paren.C
C02LN00GFD58:330 hank$ ./a.out
X is 3
```

This isn't that useful for simple types, but it will be useful when we start dealing with objects.



Outline

- Review
- Building Large Projects
- Beginning C++
- C++ & Structs



Learning classes via structs

- structs and classes are closely related in C++
- I will lecture today on changes on how “structs in C++” are different than “structs in C”
- ... at the end of the lecture, I will describe how classes and structs in C++ differ.



3 Big changes to structs in C++

- 1) You can associate “methods” (functions) with structs



Methods vs Functions

- Methods and Functions are both regions of code that are called by name (“routines”)
- With functions:
 - the data it operates on (i.e., arguments) are explicitly passed
 - the data it generates (i.e., return value) is explicitly passed
 - stand-alone / no association with an object
- With methods:
 - associated with an object & can work on object’s data
 - still opportunity for explicit arguments and return value

(left) function is separate from struct
(right) function (method) is part of struct

```
C02LN00GFD58:330 hank$ cat function.c
typedef struct
{
    int i;
} Integer;

int doubler(int x) { return 2*x; };

int main()
{
    Integer i;
    i.i = 3;
    i.i = doubler(i.i);
}
```

```
typedef struct
{
    int i;

    void doubler(void) { i = 2*i; };
} Integer;

int main()
{
    Integer i;
    i.i = 3;
    i.doubler();
}
```

(left) arguments and return value are explicit
(right) arguments and return value are not necessary, since they
are associated with the object

Tally Counter



3 Methods:
Increment Count
Get Count
Reset

Methods & Tally Counter

- Methods and Functions are both regions of code that are called by name (“routines”)
- With functions:
 - the data it operates on (i.e., arguments) are explicitly passed
 - the data it generates (i.e., return value) is explicitly passed
 - stand-alone / no association with an object
- With methods:
 - associated with an object & can work on object’s data
 - still opportunity for explicit arguments and return value





C-style implementation of TallyCounter

```
C02LN00GFD58:TC hank$ cat tallycounter_c.c
#include <stdio.h>

typedef struct
{
    int count;
} TallyCounter;

void ResetTallyCounter(TallyCounter *tc) { tc->count = 0; }
int  GetCountFromTallyCounter(TallyCounter *tc) { return tc->count; }
void TallyCounterIncrementCount(TallyCounter *tc) { tc->count++; }

int main()
{
    TallyCounter tc;
    tc.count = 0;
    TallyCounterIncrementCount(&tc);
    TallyCounterIncrementCount(&tc);
    TallyCounterIncrementCount(&tc);
    TallyCounterIncrementCount(&tc);
    printf("Count is %d\n", GetCountFromTallyCounter(&tc));
}
C02LN00GFD58:TC hank$ gcc tallycounter_c.c
C02LN00GFD58:TC hank$ ./a.out
Count is 4
```

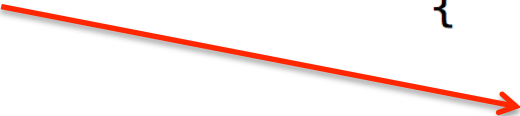


C++-style implementation of TallyCounter

```
C02LN00GFD58:330 hank$ cat tallycounter.C  
#include <stdio.h>
```

```
typedef struct  
{  
    int    count;  
  
    void    Reset() { count = 0; };  
    int     GetCount() { return count; };  
    void    IncrementCount() { count++; };  
} TallyCounter;
```

```
int main()  
{  
    TallyCounter tc;  
    tc.count = 0;  
    tc.IncrementCount();  
    tc.IncrementCount();  
    tc.IncrementCount();  
    tc.IncrementCount();  
    printf("Count is %d\n", tc.GetCount());  
}
```




```
C02LN00GFD58:330 hank$ g++ tallycounter.C  
C02LN00GFD58:330 hank$ ./a.out  
Count is 4
```



```
typedef struct
{
    int    count;

    void    Initialize() { count = 0; };
    void    Reset() { count = 0; };
    int     GetCount() { return count; };
    void    IncrementCount() { count++; };
} TallyCounter;

int main()
{
    TallyCounter tc;
    tc.Initialize();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    printf("Count is %d\n", tc.GetCount());
}
```

A red arrow originates from the right side of the slide and points to the `tc.Initialize();` line in the `main` function.



Constructors

- Constructor: method for constructing object.
 - Called automatically
- There are several flavors of constructors:
 - Parameterized constructors
 - Default constructors
 - Copy constructors
 - Conversion constructors

I will discuss these flavors
in upcoming slides



```
typedef struct
{
    int    count;

    void    Initialize() { count = 0; };
    void    Reset() { count = 0; };
    int     GetCount() { return count; };
    void    IncrementCount() { count++; };
} TallyCounter;

int main()
{
    TallyCounter tc;
    tc.Initialize();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    printf("Count is %d\n", tc.GetCount());
}
```

```
#include <stdio.h>

struct TallyCounter
{
    int    count;

    TallyCounter(void) { count = 0; };
    void    Reset() { count = 0; };
    int     GetCount() { return count; };
    void    IncrementCount() { count++; };
};

int main()
{
    TallyCounter tc;
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    tc.IncrementCount();
    printf("Count is %d\n", tc.GetCount());
}
```

Note the typedef went away ... not needed with C++.

(This is the flavor called “default constructor”)



```
C02LN00GFD58:330 hank$ cat tallycounterV4.C
```

```
#include <stdio.h>
```

```
struct TallyCounter
```

```
{
```

```
    int    count;
```

```
        TallyCounter(void) { count = 0; };
```

```
        TallyCounter(int c) { count = c; };
```

```
void    Reset() { count = 0; };
```

```
int     GetCount() { return count; };
```

```
void    IncrementCount() { count++; };
```

```
};
```

```
int main()
```

```
{
```

```
    TallyCounter tc(10);
```

```
    tc.IncrementCount();
```

```
    tc.IncrementCount();
```

```
    tc.IncrementCount();
```

```
    tc.IncrementCount();
```

```
    printf("Count is %d\n", tc.GetCount());
```

```
}
```

```
C02LN00GFD58:330 hank$ g++ tallycounterV4.C
```

```
C02LN00GFD58:330 hank$ ./a.out
```

```
Count is 14
```

Argument can be passed to
constructor.

(This is the flavor called
“parameterized constructor”)



More traditional file organization

- struct definition is in .h file
 - #ifndef / #define
- method definitions in .C file
- driver file includes headers for all structs it needs

More traditional file organization

```
C02LN00GFD58:TC hank$ cat tallycounter.h
#ifndef TALLY_COUNTER_H
#define TALLY_COUNTER_H

struct TallyCounter
{
    int    count;

    TallyCounter(void);
    TallyCounter(int c);

    void    Reset();
    int     GetCount();
    void    IncrementCount();
};

#endif
```

```
C02LN00GFD58:TC hank$ cat main.C
```

```
#include <stdio.h>
```

```
#incl
```

```
int ma
{
```

```
Ta
tc
tc
tc
tc
tc
```

```
printf("Count is %d\n", tc.GetCount());
```

```
}
```

```
C02LN00GFD58:TC hank$ cat Makefile
main: main.o tallycounter.o
    g++ -o main main.o tallycounter.o

.C.o: $<
    g++ -I. -c $<
```

```
C02LN00GFD58:TC hank$ cat tallycounter.C
#include <TallyCounter.h>
```

```
TallyCounter::TallyCounter(void)
{
    count = 0;
}
```

```
TallyCounter::TallyCounter(int c)
{
    count = c;
}
```

```
void
TallyCounter::Reset()
{
    count = 0;
}
```

Methods can be defined outside the struct definition.
They use C++'s namespace concept, which is
automatically in place.
(e.g., TallyCounter::IncrementCount)

```
count++;
```

```
}
```

“this”: pointer to current object

- From within any struct's method, you can refer to the current object using “this”

```
TallyCounter::TallyCounter(int c)
{
    count = c;
}
```

<----->

```
TallyCounter::TallyCounter(int c)
{
    this->count = c;
}
```

Copy Constructor

- Copy constructor: a constructor that takes an instance as an argument
 - It is a way of making a new instance of an object that is identical to an existing one.

```
struct TallyCounter
{
    int    count;

    TallyCounter(void);
    TallyCounter(int c);
    TallyCounter(TallyCounter &);

    void    Reset();
    int     GetCount();
    void    IncrementCount();
};
```

```
TallyCounter::TallyCounter(TallyCounter &c)
{
    count = c.count;
}
```

Constructor Types

```
struct TallyCounter
{
    int    count;

    TallyCounter(void);
    TallyCounter(int c);
    TallyCounter(TallyCounter &);

    void Reset();
    int GetCount();
    void IncrementCount();
};
```

Default constructor

Parameterized
constructor

Copy constructor



Example of 3 Constructors

```
C02LN00GFD58:TC hank$ cat main.C
#include <stdio.h>
#include <TallyCounter.h>

int main()
{
    TallyCounter tc;          /* Default constructor */
    tc.IncrementCount();

    TallyCounter tc2(10);     /* Parameterized constructor */
    tc2.IncrementCount(); tc2.IncrementCount();

    TallyCounter tc3(tc);     /* copy constructor */
    tc3.IncrementCount(); tc3.IncrementCount(); tc3.IncrementCount();

    printf("Counts are %d, %d, %d\n", tc.GetCount(),
          tc2.GetCount(), tc3.GetCount());
}
C02LN00GFD58:TC hank$ ./main
????????????????
```



Conversion Constructor

```
struct ImperialDistance  
{  
    double miles;  
};
```

```
struct MetricDistance  
{  
    double kilometers;  
  
    MetricDistance() { kilometers = 0; };  
    MetricDistance(ImperialDistance &id)  
        { kilometers = id.miles*1.609; };  
};
```



3 big changes to structs in C++

- 1) You can associate “methods” (functions) with structs
- 2) You can control access to data members and methods

Access Control

- New keywords: public and private
 - public: accessible outside the struct
 - private: accessible only inside the struct
 - Also “protected” ... we will talk about that later

```
struct TallyCounter
{
    private:
        int    count;

    public:
        TallyCounter(void);
        TallyCounter(int c);
        TallyCounter(TallyCounter &);

        void    Reset();
        int     GetCount();
        void     IncrementCount();
};
```

Everything following is private. Only will change when new access control keyword is encountered.

Everything following is now public. Only will change when new access control keyword is encountered.



public / private

```
struct TallyCounter
{
    public:
        TallyCounter(void);
        TallyCounter(int c);
        TallyCounter(TallyCounter &);

    private:
        int    count;

    public:
        void    Reset();
        int     GetCount();
        void    IncrementCount();
};
```

You can issue public and private as many times as you wish...



The compiler prevents violations of access controls.

```
128-223-223-72-wireless:TC hank$ cat main.C
```

```
#include <stdio.h>
```

```
#include <TallyCounter.h>
```

```
int main()
```

```
{
```

```
    TallyCounter tc;
```

```
    tc.count = 10;
```

```
}
```

```
128-223-223-72-wireless:TC hank$ make
```

```
g++ -I. -c main.C
```

```
main.C:7:8: error: 'count' is a private member of 'TallyCounter'
```

```
    tc.count = 10;
```

^

```
./TallyCounter.h:12:12: note: declared private here
```

```
    int    count;
```

^

```
1 error generated.
```

```
make: *** [main.o] Error 1
```



The friend keyword can override access controls.

```
struct TallyCounter
{
    friend    int main();

    public:
        TallyCounter(void);
        TallyCounter(int c);
        TallyCounter(TallyCounter &);

    private:
        int    count;
```

This will compile, since main now has access to the private data member “count”.

- Note that the struct declares who its friends are, not vice-versa
 - You can’t declare yourself a friend and start accessing data members.
- friend is used most often to allow objects to access other objects.

class vs struct

- class is new keyword in C++
- classes are very similar to structs
 - the only differences are in access control
 - primary difference: struct has public access by default, class has private access by default
- Almost all C++ developers use classes and not structs
 - C++ developers tend to use structs when they want to collect data types together (i.e., C-style usage)
 - C++ developers use classes for objects ... which is most of the time

You should use classes!
Even though there isn't much difference ...



3 big changes to structs in C++

- 1) You can associate “methods” (functions) with structs
- 2) You can control access to data members and methods
- 3) Inheritance

We will discuss inheritance next week.



Bonus Topics

Backgrounding

- “&”: tell shell to run a job in the background
 - Background means that the shell acts as normal, but the command you invoke is running at the same time.
- “sleep 60” vs “sleep 60 &”

When would backgrounding be useful?



Suspending Jobs

- You can suspend a job that is running
Press “Ctrl-Z”
- The OS will then stop job from running and not schedule it to run.
- You can then:
 - make the job run in the background.
 - Type “bg”
 - make the job run in the foreground.
 - Type “fg”
 - like you never suspended it at all!!



Web pages

- `ssh -l <user name> ix.cs.uoregon.edu`
- `cd public_html`
- put something in `index.html`
- → it will show up as

<http://ix.cs.uoregon.edu/~<username>>



Web pages

- You can also exchange files this way
 - `scp file.pdf <username>@ix.cs.uoregon.edu:~/public_html`
 - point people to `http://ix.cs.uoregon.edu/~<username>/file.pdf`

Note that `~/public_html/dir1` shows up as
<http://ix.cs.uoregon.edu/~<username>/dir1>

(“~/dir1” is not accessible via web)