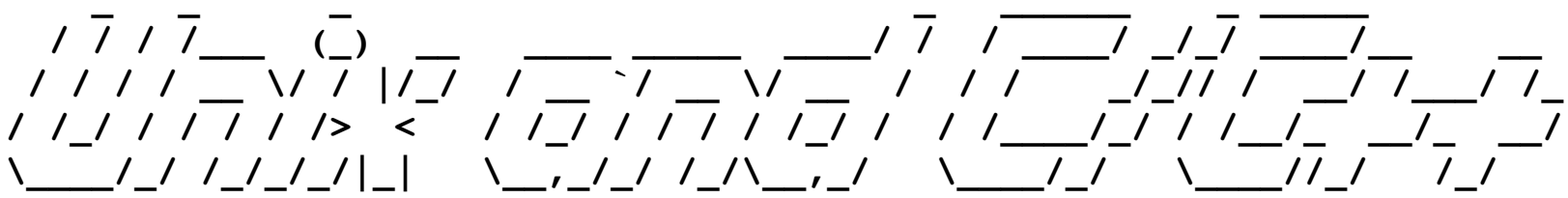
UNIVERSITY OF OREGON

CIS 330:



Lecture 10:
C++ and structs
lots of random stuff

May 4th, 2016

Hank Childs, University of Oregon

Announcements

- OH on Fri 5/6: only 1-1:30 (not 12:30-1:30)
- Weekend OH: decided on Friday

Random Topics

Random Topics #1

```
fawcett:Dropbox childs$ cat t.c
#include <stdio.h>

struct arr
{
    int width;
    int height;
};

int main()
{
    struct arr y;
    FILE *f_in = fopen("hank", "r");
    fscanf(f_in, "%d\n", &(y.width));
    fscanf(f_in, "%d\n", &y.height);
    printf("X is [%d, %d]\n", y.width, y.height);
}
fawcett:Dropbox childs$ cat hank
5
65
fawcett:Dropbox childs$ gcc t.c
fawcett:Dropbox childs$ ./a.out
X is [5, 65]
```

Operator Precedence

Precedence	Operator	Description	Associativity
1	++ -- () [] . -> (*type*){*list*}	Suffix/postfix increment and decrement Function call Array subscripting Structure and union member access Structure and union member access through pointer Compound literal(C99)	Left-to-right
2	++ -- + - ! ~ (*type*) * & sizeof _Alignof	Prefix increment and decrement Unary plus and minus Logical NOT and bitwise NOT Type cast Indirection (dereference) Address-of Size-of Alignment requirement(C11)	Right-to-left
3	* / %	Multiplication, division, and remainder	Left-to-right
4	+ -	Addition and subtraction	
5	<< >>	Bitwise left shift and right shift	
6	< <= > >=	For relational operators < and ≤ respectively For relational operators > and ≥ respectively	
7	== !=	For relational = and ≠ respectively	
8	&	Bitwise AND	
9	^	Bitwise XOR (exclusive or)	
10	|	Bitwise OR (inclusive or)	
11	&&	Logical AND	
12	||	Logical OR	
13[note 1]	?:	Ternary conditional[note 2]	Right-to-Left
14	= += -= *= /= %= <<= >>= &= ^= |=	Simple assignment Assignment by sum and difference Assignment by product, quotient, and remainder Assignment by bitwise left shift and right shift Assignment by bitwise AND, XOR, and OR	
15	,	Comma	Left-to-right

Source: http://en.cppreference.com/w/c/language/operator_precedence

Random Topics #2

Actions

performance of different fread options?

It seems like there are maybe three different ways to use fread:

option 1: fread(location, size_of_element, number_of_elements, file)

option 2: fread(location, size_of_element * number_of_elements, 1, file)

option 3: loop over i < number_of_elements: fread(location + i, size_of_element, 1, file)

You might want to use different options depending on the context, but supposing it didn't matter, I was wondering which would be the best?

I figured option 3 would be the slowest because of all the function calls. I wrote a little program and got running times: option 2 < option 1 << option 3

Does anyone know why option 2 is the fastest? If you're interested, the test program I wrote is at: http://ix.cs.uoregon.edu/~hampton2/330/fread_test/

This isn't the most important thing in the world ... just goofing around :)

DRAM vs NV-RAM

- DRAM: Dynamic Random Access Memory
  - stores data
  - each bit in separate capacitor within integrated circuit
  - loses charge over time and must be refreshed
  - → volatile memory
- NV-RAM: Non-Volatile Random Access Memory
  - stores data
  - information unaffected by power cycle
  - examples: Read-Only Memory (ROM), flash, hard drive, floppy drive, …

Amazon.com…

Seagate Expansion 5TB Desktop External Hard Drive USB 3.0 (STEB5000100)

by Seagate

$133.99 ~~$169.99~~ Prime

Get it by **Friday, Nov 20**

More Buying Choices
$133.99 new (68 offers)
$117.24 used (1 offer)

1,394

Electronics Gift Guide See more

Trade-in eligible for an Amazon gift card

Electronics: See all 94 items

Crucial Ballistix Sport 16GB Kit (8GBx2) DDR3 1600 MT/s (PC3-12800) UDIMM Memory BLS2KIT8G3D1609DS1S00/ BLS2CP8G3D1609DS1S00

by Crucial

$74.99 ~~$159.99~~ Prime

Get it by **Thursday, Nov 19**

More Buying Choices
$69.95 new (73 offers)

1,443

Product Description
... is a *16GB* kit consisting ... computers that take DDR3 UDIMM *memory* ...

Electronics: See all 454,298 items

Corsair Vengeance 16GB (2x8GB) DDR3 1600 MHz (PC3 12800) Desktop Memory (CMZ16GX3M2A1600C10)

by Corsair

$83.90 ~~$118.70~~ Prime

Get it by **Thursday, Nov 19**

More Buying Choices
$72.50 new (101 offers)
$74.99 used (3 offers)

912

Product Features
XMP *Memory* Profile for simple, safe overclocking

Electronics: See all 454,298 items

Crucial 16GB Kit (8GBx2) DDR3/DDR3L-1600 MHz (PC3-12800) CL11 204-Pin SODIMM Memory for Mac CT2K8G3S160BM / CT2C8G3S160BM

by Crucial

$72.99 ~~$165.99~~ Prime

Get it by **Thursday, Nov 19**

More Buying Choices
$71.29 new (99 offers)
$62.00 used (8 offers)

3,247

Product Description
... CT2K8G3S160BM is a *16GB* kit consisting of (2) 8GB DDR3L (DDR3 low ...

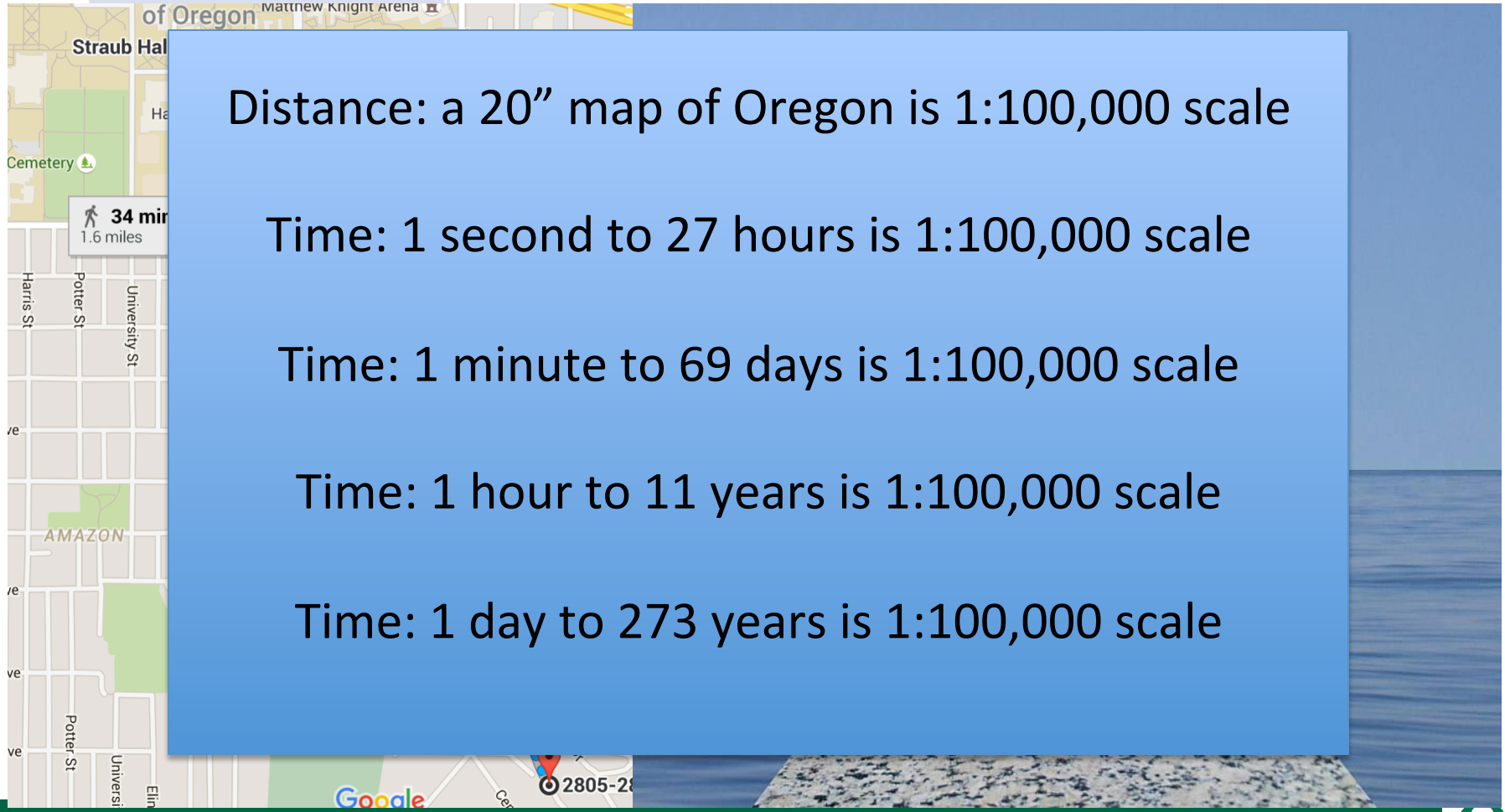
Electronics: See all 454,298 items

Relationship to File Systems

- File Systems could be implemented in DRAM.
- However, almost exclusively on NV-RAM
  - Most often hard drives
- Therefore, properties and benefits of file systems are often associated with properties and benefits of NV-RAM.

DRAM vs NV-RAM properties

Property	DRAM	NV-RAM



Distance: a 20” map of Oregon is 1:100,000 scale

Time: 1 second to 27 hours is 1:100,000 scale

Time: 1 minute to 69 days is 1:100,000 scale

Time: 1 hour to 11 years is 1:100,000 scale

Time: 1 day to 273 years is 1:100,000 scale

Random Topics #3

diff command embedded in Makefile does not work on ix machine

```
zhibin@ix-trusty: ~/cis330/3A 95$ make
gcc -o a 3A_c.c
./a 3A_input.pnm my_output.pnm
make: *** [my_output.pnm] Error 64
zhibin@ix-trusty: ~/cis330/3A 96$ make
diff my_output.pnm 3A_output.pnm
```

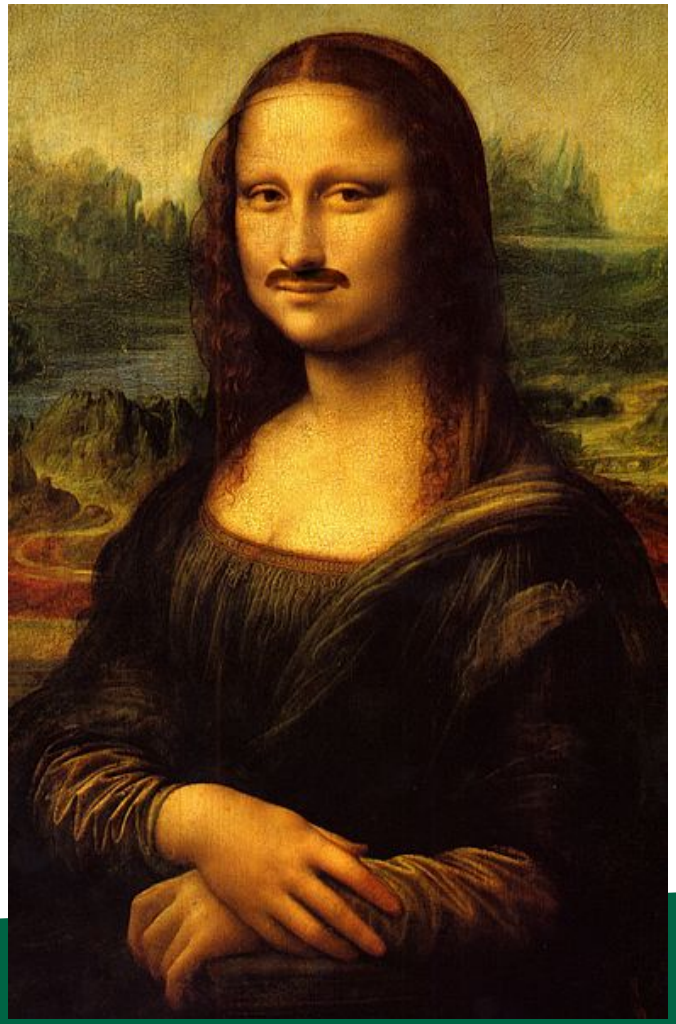
However, same Makefile works perfectly fine on my local machine.
Any thoughts?

Thanks in advance.

Random Topics #4

Why Can't I Modify the Input in Yellow Diagonal

- Imagine I handed you the Mona Lisa with you and asked you to produce a version with a moustache…
- Would you?:
  - make a reproduction and add the moustache to the reproduction
  - vandalize the original



With Respect to 3B…

How to Make a Reproduction

```
struct name *
ToLowerGood(struct name *input)
{
    struct name *rv = malloc(sizeof(struct name));
    int nchars = strlen(input->buffer);
    rv->buffer = malloc(sizeof(char)*nchars + 1);
    for (int i = 0 ; i < nchars ; i++)
    {
        char c = input->buffer[i];
        if (c >= 'A' && c <= 'Z')
            c = 'a' + (c-'A');
        rv->buffer[i] = c;
    }
    rv->buffer[nchars] = '\0';

    return rv;
}
```

```
struct name *
ToLowerBad(struct name *input)
{
    int nchars = strlen(input->buffer);
    for (int i = 0 ; i < nchars ; i++)
    {
        char c = input->buffer[i];
        if (c >= 'A' && c <= 'Z')
            c = 'a' + (c-'A');
        input->buffer[i] = c;
    }

    return input;
}
```

```
')+1);

    /* goal: hank childs */

    printf("N2's buffer is %s\n", n2->buffer);
    printf("N1's buffer is %s\n", n1.buffer);
}
```

Review

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

"gcc –c driver.c" needs to make an object file.
It needs info about Rectangle then, not later.

driver.c

```
#include <prototypes.h>

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

ion: “gcc –E”

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

r.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 IntializeRectangle(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++.

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.

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
0000000000000048 s EH_frame0
0000000000000000 T _doubler
0000000000000060 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
0000000000000068 s EH_frame0
0000000000000032 s L_.str
                 U _doubler
0000000000000000 T _main
0000000000000080 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
0000000000000048 s EH_frame0
0000000000000000 T __Z7doublerf
0000000000000060 S __Z7doublerf.eh
C02LN00GFD58:330 hank$ nm doubler_example.o
0000000000000068 s EH_frame0
0000000000000032 s L_.str
                 U __Z7doubleri
0000000000000000 T _main
0000000000000080 S _main.eh
                 U _printf
C02LN00GFD58:330 hank$
```

```
C02LN00GFD58:330 hank$ nm doubler.o
0000000000000048 s EH_frame0
0000000000000000 T _doubler
0000000000000060 S _doubler.eh
C02LN00GFD58:330 hank$ nm doubler
doubler.c          doubler_example    d
                   _example.c         d
                   doubler_examp
                   e0
                   r
                   h
                 U _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 combing information about arguments and “mangling” it with function name.
  - Way of ensuring that you don’t mix up functions.
  - Why not return type too?
- 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());
}
C02LN00GFD58:330 hank$ g++ cis330.C
C02LN00GFD58:330 hank$ ./a.out
Number of students in 330 is 56, but in 610 was 9
```

Functions or variables within a namespace are accessed with “::”

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.

Learning classes via structs

- structs and classes are closely related in C++
- I lectured Friday on changes on how “structs in C++” are different than “structs in C”
- Soon 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());
}
```

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();
     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 Makefile
main: main.o tallycounter.o
        g++ -o main main.o tallycounter.o

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

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

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

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

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

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

#include <stdio.h>

#incl

int ma
{
    T
    t
    t
    t
    tc.
    printf("Count is %d\n", tc.GetCount());
}
```

```
    count++;
}
```

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

New Stuff

“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

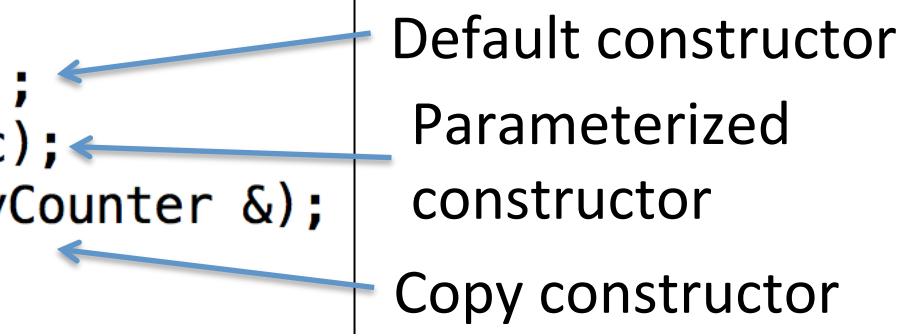
- Copy constructor: a constructor that takes an instance as an argument
  - It is a way of making a new instance of an object that is identical to an existing one.

```
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();
};
```



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

Simple inheritance example

```
struct A
{
    int x;
};

struct B : A
{
    int y;
};

int main()
{
    B b;
    b.x = 3;
    b.y = 4;
}
```

- Terminology
  - B inherits from A
  - A is a base type for B
  - B is a derived type of A
- Noteworthy
  - ":" (during struct definition) → inherits from
    - Everything from A is accessible in B
      - (b.x is valid!!)

Object sizes

```
128-223-223-72-wireless:330 hank$ cat simple_inheritance.C
#include <stdio.h>

struct A
{
    int x;
};

struct B : A
{
    int y;
};

int main()
{
    B b;
    b.x = 3;
    b.y = 4;
    printf("Size of A = %lu, size of B = %lu\n", sizeof(A), sizeof(B));
}
128-223-223-72-wireless:330 hank$ g++ simple_inheritance.C
128-223-223-72-wireless:330 hank$ ./a.out
Size of A = 4, size of B = 8
```

Inheritance + TallyCounter

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

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

  private:
    int    count;

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

struct FancyTallyCounter : TallyCounter
{
    void   DecrementCount() { count--; }
}
```

FancyTallyCounter inherits all of TallyCounter, and adds a new method: DecrementCount

Virtual functions

- Virtual function: function defined in the base type, but can be re-defined in derived type.
- When you call a virtual function, you get the version defined by the derived type

Virtual functions: example

```
128-223-223-72-wireless:330 hank$ cat virtual.C
#include <stdio.h>

struct SimpleID
{
   int id;
   virtual int GetIdentifier() { return id; };
};

struct ComplexID : SimpleID
{
   int extraId;
   virtual int GetIdentifier() { return extraId*128+id; };
};

int main()
{
   ComplexID cid;
   cid.id = 3;
   cid.extraId = 3;
   printf("ID = %d\n", cid.GetIdentifier());
}
128-223-223-72-wireless:330 hank$ g++ virtual.C
128-223-223-72-wireless:330 hank$ ./a.out
ID = 387
```

Virtual functions: example

```
128-223-223-72-wireless:330 hank$ cat virtual2.C
#include <stdio.h>

struct SimpleID
{
   int id;
   virtual int GetIdentifier() { return id; };
};

struct ComplexID : SimpleID
{
   int extraId;
   virtual int GetIdentifier() { return extraId*128+id; };
};

struct C3 : ComplexID
{
   int extraExtraId;
};

int main()
{
   C3 cid;
   cid.id = 3;
   cid.extraId = 3;
   cid.extraExtraId = 4;
   printf("ID = %d\n", cid.GetIdentifier());
}
128-223-223-72-wireless:330 hank$ g++ virtual2.C
128-223-223-72-wireless:330 hank$ ./a.out
```

You get the method furthest down in the inheritance hierarchy

Virtual functions: example

```
128-223-223-72-wireless:330 hank$ cat virtual3.C
#include <stdio.h>

struct SimpleID
{
   int id;
   virtual int GetIdentifier() { return id; };
};

struct ComplexID : SimpleID
{
   int extraId;
   virtual int GetIdentifier() { return extraId*128+id; };
};

struct C3 : ComplexID
{
   int extraExtraId;
};

int main()
{
   C3 cid;
   cid.id = 3;
   cid.extraId = 3;
   cid.extraExtraId = 4;
   printf("ID = %d, %d\n", cid.SimpleID::GetIdentifier(), cid.GetIdentifier());
}
128-223-223-72-wireless:330 hank$ g++ virtual3.C
128-223-223-72-wireless:330 hank$ ./a.out
ID = 3, 387
```

You can specify the method you want to call by specifying it explicitly

Access controls and inheritance

```
C02LN00GFD58:330 hank$ cat inheritance.C
struct A { int x; };
struct B : A { int y; };
struct C : public A { int y; };
struct D : private A { int y; };

int main()
{
    C c;
    c.x = 2;
    D d;
    d.x = 2;
}
```

B and C are the same. public is the default inheritance for structs

Public inheritance: derived types gets access to base type's data members and methods

Private inheritance: derived types don't get access.

One more access control word: protected

- Protected means:
  - It cannot be accessed outside the object
    - Modulo “friend”
  - But it can be accessed by derived types
    - (assuming public inheritance)

Public, private, protected

	Accessed by derived types*	Accessed outside object
Public	Yes	Yes
Protected	Yes	No
Private	No	No

* = with public inheritance

More on virtual functions upcoming

- "Is A"
- Multiple inheritance
- Virtual function table
- Examples
  - (Shape)

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)

Unix and Windows difference

- Unix:
  - "\n": goes to next line, and sets cursor to far left
- Windows:
  - "\n": goes to next line (cursor does not go to left)
  - "\m": sets cursor to far left

- Text files written in Windows often don't run well on Unix, and vice-versa
  - There are more differences than just newlines

vi: "set ff=unix" solves this