Lecture 3:
Permissions and More Memory Stuff
(Finish Lecture 2)
Running out of memory (stack)

```c
int endless_fun()
{
    endless_fun();
}

int main()
{
    endless_fun();
}
```

---

stack overflow: when the stack runs into the heap.
There is no protection for stack overflows.
(Checking for it would require coordination with the heap’s memory manager on every function calls.)
Running out of memory (heap)

```c
int *heaps_o_fun()
{
    int *heap_A = malloc(sizeof(int)*1000000000);
    return heap_A;
}

int main()
{
    int *stack_A;
    stack_A = heaps_o_fun();
}
```

If the heap memory manager doesn’t have room to make an allocation, then malloc returns NULL .... a more graceful error scenario.
## Stack vs Heap: Pros and Cons

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<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Memory Fragmentation

• Memory fragmentation: the memory allocated on the heap is spread out of the memory space, rather than being concentrated in a certain address space.
Memory Fragmentation

```c
int *bar()
{
    int *heap_varA;
    heap_varA = malloc(sizeof(int)*2);
    heap_varA[0] = 2;
    heap_varA[1] = 2;
    return heap_varA;
}

int main()
{
    int i;
    int stack_varA[50];
    for (i = 0 ; i < 50 ; i++)
        stack_varA[i] = bar();
    for (i = 0 ; i < 25 ; i++)
        free(stack_varA[i*2]);
}
```

Negative aspects of fragmentation?
(1) can’t make big allocations
(2) losing cache coherency
Fragmentation and Big Allocations

Even if there is lots of memory available, the memory manager can only accept your request if there is a big enough contiguous chunk.
# Stack vs Heap: Pros and Cons

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Memory Errors

• Array bounds read
  
  int main()
  { 
    int var;
    int arr[3] = { 0, 1, 2 };
    var=arr[3];
  }

• Array bounds write

  int main()
  { 
    int var = 2;
    int arr[3];
    arr[3]=var;
  }
Now Start Lecture 3
My goal is to arrange topics such that more work can be put earlier in the course.
Accessing a Unix environment

- Rm 100, Deschutes
- Remote logins (ssh, scp)
- Windows options
  - Cygwin / MSYS
  - Virtual machines

Who has home access to a Unix environment?

Who has Windows only and wants to pursue Cygwin/VM?
Quiz

• What is the output of this sequence?

Semi-colon: issue the first command, then the second right afterwards
Output from first command will be on one line, with second command on the next line.
Unix systems

• Four basic use cases
  – Personal use machines
  – Servers
  – Embedded
  – Compute clusters

In many of these scenarios, there is a system administrator who makes an “image” of the OS that they “clone” for each machine.

Are there more? (this is off the top of my head)

I have used Unix actively since 1994, but only did system administration 2005-2009 when I had a Linux box in my home.
Outline

• Permissions
• Project 1B Overview
• More on memory / arrays / pointers
Outline

• Permissions
• Project 1B Overview
• More on memory / arrays / pointers
Permissions: System Calls

• System calls: a request from a program to the OS to do something on its behalf
  – ... including accessing files and directories

• System calls:
  – Typically exposed through functions in C library
  – Unix utilities (cd, ls, touch) are programs that call these functions

Permissions in Unix are enforced via system calls.
Permissions: Unix Groups

• Groups are a mechanism for saying that a subset of Unix users are related
  – In 2014, we had a “330_S14” unix group on ix
  – Members:
    • Me
    • 2 GTFs

The commands for creating a group tend to vary, and are often done by a system administrator

CIS uses “groupctl”
Permissions

• Permissions are properties associated with files and directories
  – System calls have built-in checks to permissions
    • Only succeed if proper permissions are in place

• Three classes of permissions:
  – User: access for whoever owns the file
    • You can prevent yourself from accessing a file!
      – (But you can always change it back)
  – Group: allow a Unix group to access a file
  – Other: allow anyone on the system to access a file
Three types of permissions

- Read
- Write
- Execute (see next slide)
Executable files

• An executable file: a file that you can invoke from the command line
  – Scripts
  – Binary programs

• The concept of whether a file is executable is linked with file permissions
There are 9 file permission attributes

• Can user read?
• Can user write?
• Can user execute?
• Can group read?
• Can group write?
• Can group execute?
• Can other read?
• Can other write?
• Can other execute?

A bunch of bits ... we could represent this with binary

User = “owner”
Other = “not owner, not group”
Translating R/W/E permissions to binary

<table>
<thead>
<tr>
<th>#</th>
<th>Permission</th>
<th>rwx</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>full</td>
<td>111</td>
</tr>
<tr>
<td>6</td>
<td>read and write</td>
<td>110</td>
</tr>
<tr>
<td>5</td>
<td>read and execute</td>
<td>101</td>
</tr>
<tr>
<td>4</td>
<td>read only</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>write and execute</td>
<td>011</td>
</tr>
<tr>
<td>2</td>
<td>write only</td>
<td>010</td>
</tr>
<tr>
<td>1</td>
<td>execute only</td>
<td>001</td>
</tr>
<tr>
<td>0</td>
<td>none</td>
<td>000</td>
</tr>
</tbody>
</table>

Which of these modes make sense? Which don’t?

We can have separate values (0-7) for user, group, and other.
Unix command: chmod

• chmod: change file mode

• chmod 750 <filename>
  – User gets 7 (rwx)
  – Group gets 5 (rx)
  – Other gets 0 (no access)

Lots of options to chmod
(usage shown here is most common)
Manpage for chmod

- “man chmod”

CHMOD(1) BSD General Commands Manual

NAME
chmod -- change file modes or Access Control Lists

SYNOPSIS
chmod [-fv] [R [-H | -L | -P]] mode file ...
chmod [-fv] [R [-H | -L | -P]] [-a | +a | =a] ACE file ...
chmod [-fhv] [R [-H | -L | -P]] [-E] file ...
chmod [-fhv] [R [-H | -L | -P]] [-C] file ...
chmod [-fhv] [R [-H | -L | -P]] [-N] file ...

DESCRIPTION
The chmod utility modifies the file mode bits of the listed files as specified by the mode operand. It may also be used to modify the Access Control Lists (ACLs) associated with the listed files.

The generic options are as follows:

-f Do not display a diagnostic message if chmod could not modify the mode for file.
Unix commands for groups

• chgrp: changes the group for a file or directory
  – chgrp <group> <filename>

• groups: lists groups you are in
`ls -l`

- Long listing of files

```
Last login: Thu Apr  3 08:09:23 on ttys007
C02LN00GFD58:~ hank$ mkdir CIS330
C02LN00GFD58:~ hank$ cd CIS330
C02LN00GFD58:CIS330 hank$ touch a
C02LN00GFD58:CIS330 hank$ ls -l
```

```
total 0
-rw-r--r-- 1 hank  staff  0 Apr  3 08:14 a
```

How to interpret this?

- Permissions
- Links (*)
- Owner
- Group
- File size
- Date of last change
- Filename
Permissions and Directories

• You can only enter a directory if you have “execute” permissions to the directory

• Quiz: a directory has permissions “400”. What can you do with this directory?

   Answer: it depends on what permissions a system call requires.
Directories with read, but no execute

```
Last login: Thu Apr  3 08:14:33 on ttys007
C02LN00GFD58:~ hank$ mkdir CIS330
C02LN00GFD58:~ hank$ touch CIS330/a
C02LN00GFD58:~ hank$ chmod 400 CIS330
C02LN00GFD58:~ hank$ ls CIS330
a
C02LN00GFD58:~ hank$ cd CIS330
-bash: cd: CIS330: Permission denied
C02LN00GFD58:~ hank$ cat CIS330/a
cat: CIS330/a: Permission denied
```
Outline

• Permissions
• Project 1B Overview
• More on memory / arrays / pointers
Unix scripts

• Scripts
  – Use an editor (vi/emacs/other) to create a file that contains a bunch of Unix commands
  – Give the file execute permissions
  – Run it like you would any program!!
Unix scripts

• Arguments
  – Assume you have a script named “myscript”
  – If you invoke it as “myscript foo bar”
  – Then
    • $# == 2
    • $1 == foo
    • $2 == bar
Project 1B

• Summary: write a script that will create a specific directory structure, with files in the directories, and specific permissions.
CIS 330: Project #1B
Assigned: April 7th, 2017
Due April 12th, 2017
(which means submitted by 6am on April 13th, 2017)
Worth 2% of your grade

Assignment: Create a script that will create a directory structure, and files within that directory structure, all with the specified file permissions. The script should be named “proj1b”. (A consistent name will help with grading.)

Note: you are only allowed to use the following commands: mkdir, touch, cd, chmod, mv, cp, rm, rmdir. (You do not need to use all of these commands to successfully complete the assignment.)
Project 1B

The directory structure should be:
Outline

• Permissions
• Project 1B Overview
• More on memory / arrays / pointers
Memory Segments

- text (fixed size)
- data (fixed size)
- stack
- free
- heap

Source: http://www.cs.uwm.edu/classes/cs315/Bacon/
C: must manage your own memory

• This is a big change from other programs
• You keep track of memory
  – Allocation
  – How much there is / indexing memory
  – Deallocation
malloc

- malloc: command for allocating memory

```c
#include <stdlib.h>

void *
calloc(size_t count, size_t size);

void
free(void *ptr);

void *
malloc(size_t size);

void *
realloc(void *ptr, size_t size);

void *
reallocf(void *ptr, size_t size);

void *
valloc(size_t size);
```

### DESCRIPTION

The `malloc()`, `calloc()`, `valloc()`, `realloc()`, and `reallocf()` functions allocate memory. The allocated memory is aligned such that it can be used for any data type, including AltiVec- and SSE-related types. The `free()` function frees allocations that were created via the preceding allocation functions.

The `malloc()` function allocates `size` bytes of memory and returns a pointer to the allocated memory.
#include <stdlib.h>
int main()
{
    int stack_varA;
    int stack_varB[2];
    int *heap_varA;
    int *heap_varB;
    heap_varA = malloc(sizeof(int));
    heap_varB = malloc(sizeof(int)*2);
    free(heap_varA);
    free(heap_varB);
}

Automatic allocation on the stack. (Deallocation occurs when out of scope.)

Explicit allocation from the heap. (Deallocation occurs with “free” call.)
sizeof

- **sizeof**: gets size of type
- **Usually:**
  - `sizeof(int) == 4`
  - `sizeof(float) == 4`
  - `sizeof(double) == 8`
  - `sizeof(unsigned char) == 1`
  - `sizeof(char) == 1`
  - `sizeof(int *) == sizeof(double *) == sizeof(char *) == 8`
- array of 10 ints → `malloc(10 * sizeof(int))`
Hexadecimal

• Binary: 2 values
• Decimal: 10 values
• Hexadecimal: 16 values
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
• 0x: prefix for hexadecimal
• 0x10 = 16
• 0x101 = 257
Memory Addresses

• Every location in memory has an address associated with it
• Locations in memory are represented in hexadecimal

Memory addresses descend in the stack, ascend in the heap.
Pointers

• Pointers store locations in memory
Pointers

• Pointers store locations in memory

• “&”: unary operator that gives the address of a variable.

```c
int x;
int *yp = &x;
```
Pointers

• Pointers store locations in memory

```c
#include <stdio.h>

int main()
{
    int x, y;
    printf("The location of x is %p and the location of y is %p\n", &x, &y);
}
```

The location of x is 0x7fff56d26bcc and the location of y is 0x7fff56d26bc8

`printf` prints pointers with “%p”
NULL pointer

- NULL: defined by compiler to be a location that is not valid.
  - Typically 0x00000000
- You can use NULL to initialize pointers, and also to check to see whether a pointer is set already.

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

int main()
{
    int *ptr = NULL;
    while (1)
    {
        char c;
        c = getchar();
        if (c == 'A')
        {
            if (ptr == NULL)
            {
                printf("Allocating!\n");
                ptr = malloc(100*sizeof(int));
            }
            else
                printf("Already allocated\n");
        }
    }
}
```

IBM team I worked on used 0xDEADBEEF, not NULL
‘*’ operator

• Let “ptr” be a pointer
• Then “*ptr” returns value in the address that ptr points to.
• * = “dereference operator”

```c
#include <stdio.h>

int main()
{
    int x = 3;
    int *y = &x;
    int z = *y;
    printf("x = %d, z = %d\n", x, z);
}
```

```
C02LN00GFD58:330 hank$ cat ptr.c
C02LN00GFD58:330 hank$ gcc ptr.c
C02LN00GFD58:330 hank$ ./a.out
x = 3, z = 3
```
Behavior of dereference

• When you dereference, you get the value at that moment.
  – Whatever happens afterwards won’t have effect.

```c
int main()
{
    int x = 3;
    int *y = &x;
    int z = *y;
    x = 4;
    printf("x = %d, y = %d, z = %d\n", x, *y, z);
}
```

```
C02LN00GFD58:330 hank$ cat ptr2.c
#include <stdio.h>
int main()
{
    int x = 3;
    int *y = &x;
    int z = *y;
    x = 4;
    printf("x = %d, y = %d, z = %d\n", x, *y, z);
}
C02LN00GFD58:330 hank$ gcc ptr2.c
C02LN00GFD58:330 hank$ ./a.out
x = 4, y = 4, z = 3
```
Pointer Arithmetic

- You can combine pointers and integers to get new pointer locations

```c
#include <stdio.h>

int main()
{
    int x = 3;
    int *y = &x;
    int *z = y+1;
    char a = 'A';
    char *b = &a;
    char *c = b+1;
    printf("x = %d, y = %p, z = %p\n", x, y, z);
    printf("a = %c, b = %p, c = %p\n", a, b, c);
}
```

```
$ gcc ptr_arith.c
$ ./a.out
x = 3, y = 0x7fff5d397bcc, z = 0x7fff5d397bd0
a = A, b = 0x7fff5d397bb7, c = 0x7fff5d397bb8
```
Arrays

• Arrays: container that has multiple elements of identical type, all stored in contiguous memory

int A[10];

→ 10 integers, stored in 40 consecutive bytes (assuming sizeof(int) == 4)

Arrays are just pointers. You can use arrays and pointers interchangeably.
The [ ] operator

- [ ] is a way of dereferencing memory
  - Recall that ‘*’ is the dereference operator

- A[0] <= => *A
- A[5] <= => *(A+5);
More array relationships

```c
int A[10];
int *B;

B=&(A[0]) \rightarrow B = A
B=&(A[5]) \rightarrow B = A+5
```
Pointers to pointers

- Remember: pointer points to a location in memory
  - We’ve been considering cases where locations in memory are arrays of integers
  - But locations in memory could be pointer themselves
Simple pointers to pointers example

```c
#include <stdlib.h>

int main()
{
    int **X = malloc(sizeof(int *)*4);
    X[0] = malloc(sizeof(int)*6);
    X[1] = malloc(sizeof(int)*4);
    X[2] = malloc(sizeof(int)*8);
    X[3] = malloc(sizeof(int)*10);
}
```

```
C02LN00GFD58:330 hank$ cat ptrptr.c
#include <stdlib.h>

int main()
{
    int **X = malloc(sizeof(int *)*4);
    X[0] = malloc(sizeof(int)*6);
    X[1] = malloc(sizeof(int)*4);
    X[2] = malloc(sizeof(int)*8);
    X[3] = malloc(sizeof(int)*10);
}
```

```
C02LN00GFD58:330 hank$ gcc ptrptr.c
C02LN00GFD58:330 hank$ ./a.out
```
What's the difference between these two programs?

Answer: X is on the heap on the left, and on the stack on the right. But they are both pointers-to-pointers.
What's the difference between these two programs?

Answer: program on left makes one allocation for each pointer, program on right makes one allocation for whole program & each pointer points at locations within that allocation.
Call by value / call by reference

• Refers to how parameters are passed to a function.
  – Call by value: send the value of the variable as a function parameter
    • Side effects in that function don’t affect the variable in the calling function
  – Call by reference: send a reference (pointer) as a function parameter
    • Side effects in that function affect the variable in the calling function
Call by Value

```c
#include <stdio.h>

void foo(int x) {
    x = x+1;
}

int main() {
    int x = 2;
    foo(x);
    printf("X is %d\n", x);
}
```

```
C02LN00GFD58:330 hank$ cat cbv.c
C02LN00GFD58:330 hank$ gcc cbv.c
C02LN00GFD58:330 hank$ ./a.out
X is 2
```
Call by value

```c
int doubler(int A)
{
    int stack_varA;
    stack_varA = 2*A;
    return stack_varA;
}

int main()
{
    int stack_varC;
    int stack_varD = 3;
    stack_varC = doubler(stack_varD);
}
```

Return copies into location specified by calling function

```
A (= 3)  
<info for how to get back to main>
```

```
<Location for RV>
```

```
stack_varA
```
Call by reference

```c
#include <stdio.h>

void foo(int *x)
{
    *x = *x+1;
}

int main()
{
    int x = 2;
    foo(&x);
    printf("X is %d\n", x);
}
```

```bash
hank$ cat cbr.c
```

```bash
hank$ gcc cbr.c
```

```bash
hank$ ./a.out
```

```bash
X is 3
```
Call by reference

```c
int doubler(int *A)
{
    int stack_varA;
    stack_varA = 2*A;
    return stack_varA;
}

int main()
{
    int stack_varC;
    int stack_varD = 3;  &
    stack_varC = doubler(&stack_varD);
}
```

Return copies into location specified by calling function
Memory Errors

- Free memory read / free memory write

```c
int main()
{
    int *var = malloc(sizeof(int)*2);
    var[0] = 0;
    var[1] = 2;
    free(var);
    var[0] = var[1];
}
```

When does this happen in real-world scenarios?
Memory Errors

• Freeing unallocated memory

```c
int main()
{
    int *var = malloc(sizeof(int)*2);
    var[0] = 0;
    var[1] = 2;
    free(var);
    free(var);
}
```

When does this happen in real-world scenarios?

Vocabulary: “dangling pointer”: pointer that points to memory that has already been freed.
Memory Errors

• Freeing non-heap memory

```c
int main()
{
    int var[2]
    var[0] = 0;
    var[1] = 2;
    free(var);
}
```

When does this happen in real-world scenarios?
Memory Errors

• NULL pointer read / write
  
```c
int main()
{
    char *str = NULL;
    printf(str);
    str[0] = 'H';
}
```

• NULL is never a valid location to read from or write to, and accessing them results in a “segmentation fault”
  – .... remember those memory segments?

When does this happen in real-world scenarios?
Memory Errors

- Uninitialized memory read

```c
int main()
{
    int *arr = malloc(sizeof(int)*10);
    int V2=arr[3];
}
```

When does this happen in real-world scenarios?