15-213/18-243 Recitation #5

February 22, 2010

Today

- Announcements
- Buflab and Stack Review
- Structs
- Optimization Basics
- Memory Hierarchy and Caching

Announcements

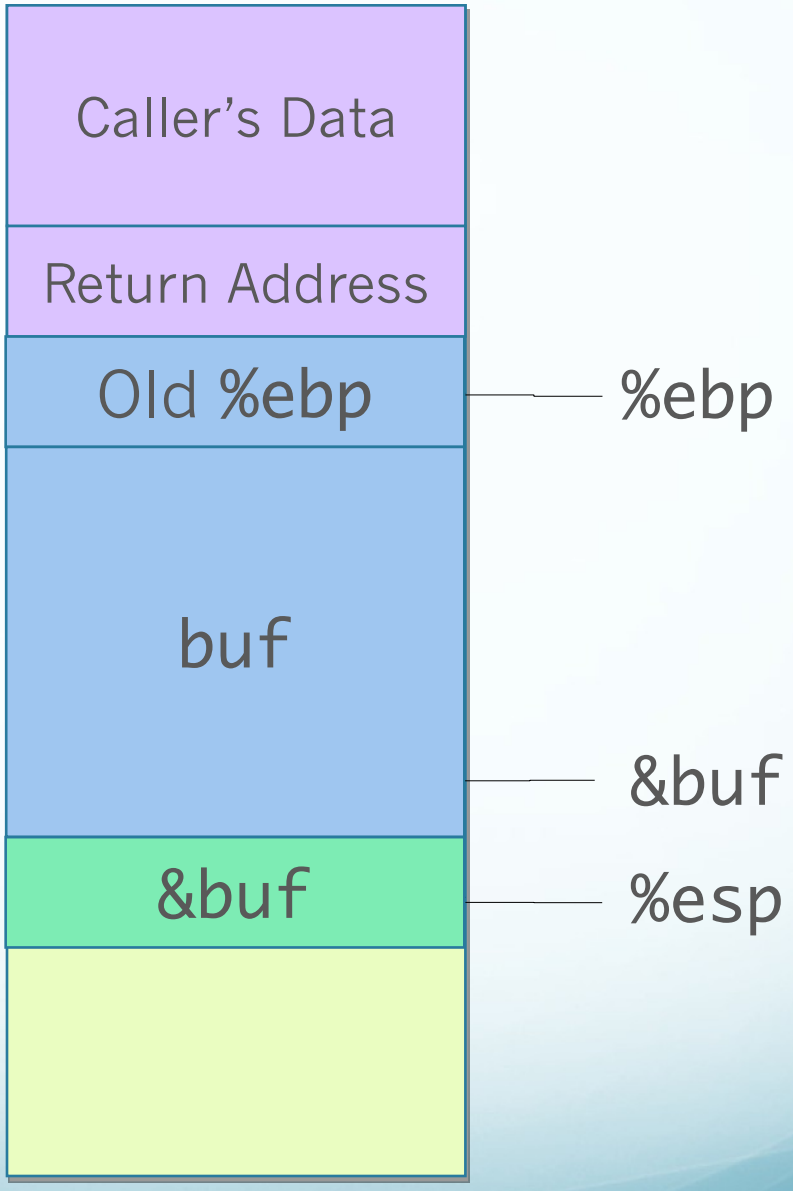
- Datalab can be picked up at the ECE Course Hub, which is on the D level of Hammerschlag.
- Buflab due this Thursday, 2/25
- Exam 1 in class next Tuesday, 3/02

Buflab

x86 Stack Frame

- Consider when this function from Buflab is about to call Gets().

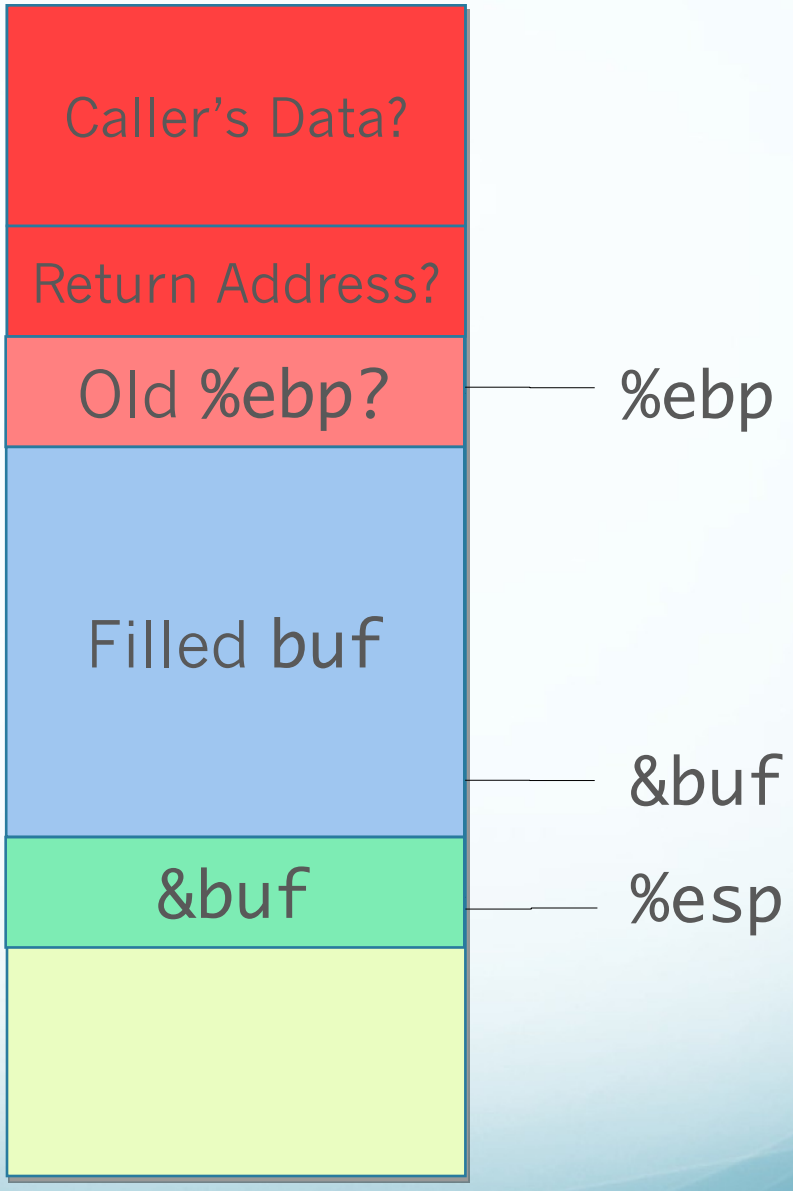
```
int getbuf()
{
    char buf[32];
    Gets(buf);
    return 1;
}
```



x86 Stack Frame

- What happens if we overflow buf?

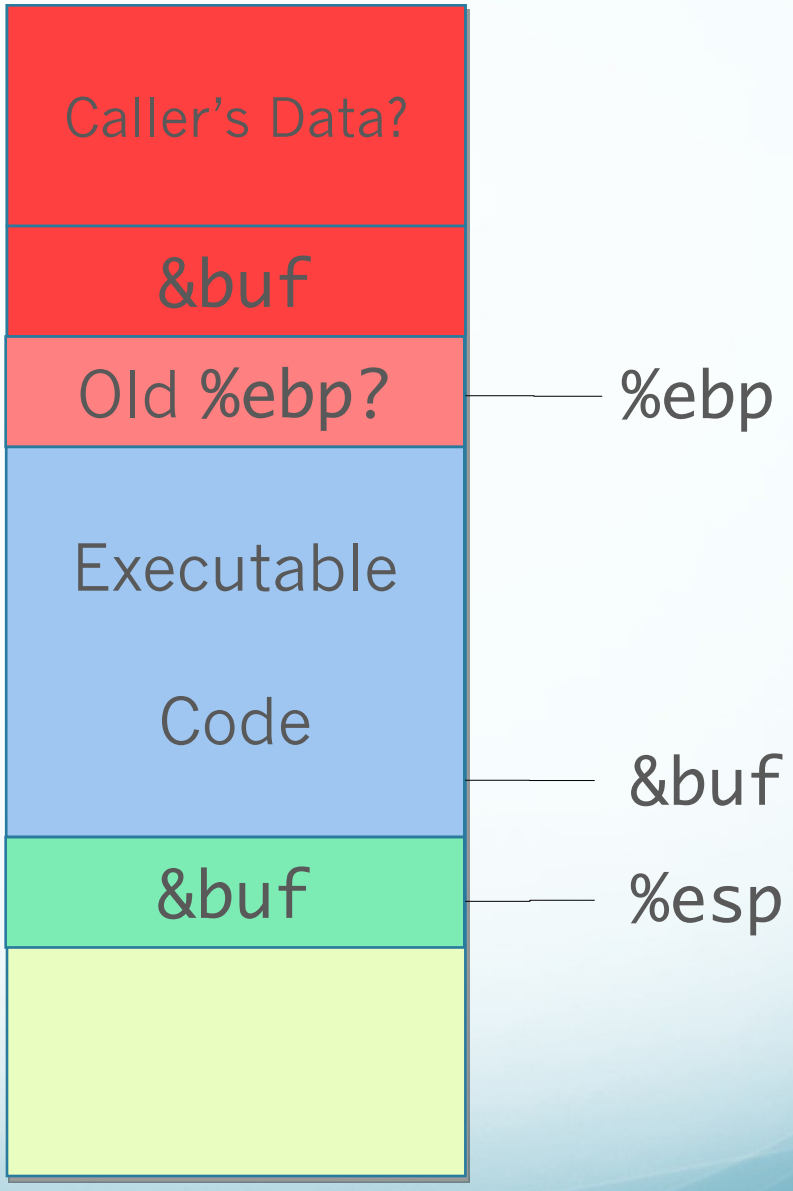
```
int getbuf()
{
    char buf[32];
    Gets(buf);
    return 1;
}
```



x86 Stack Frame

- What if we set the return address to &buf?
- What if we don't know what &buf is?

```
int getbuf()
{
    char buf[32];
    Gets(buf);
    return 1;
}
```



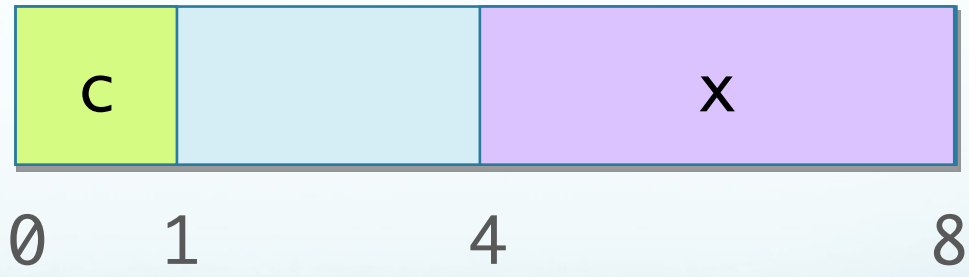
Questions?

Structs

Structs

- Allow you to declare a contiguous block of memory which can include various data types.
- Types are subject to alignment rules (Why?).

```
struct node
{
  char c;
  int x;
}
```



Old Exam Question

- Show the memory layout of the following struct on a 64-bit (x86_64) machine.
- Reorder the fields to have a more optimal packing.

```
struct foo
{
   char a[9];
   short b[3];
   float c;
   char d;
   int e;
   char *f;
   short g;
}
```

Old Exam Question

- Show the memory layout of the following struct on a 64-bit (x86_64) machine.
- Reorder the fields to have a more optimal packing.

```
struct foo
{                               Answers:
   char a[9];                   AAAAAAAAAxB1B2B3
   short b[3];                  CCCCDxxxEEEExxxx
   float c;                     FFFFFFFFGGxxxxxx
   char d;
   int e;                       FFFFFFFFCCCCEEEE
   char *f;                     B1B2B3GGAAAAAAAA
   short g;                     ADxxxxxx
}
```

Questions?

Optimization

Common Sub Expression Elimination

```
void func(int a, int b, char data[])
{
  for(int i=0; i<10; i++)
    if(data[i] < 'z' && data[i] != '\n')
      data[i]++;
}
```

- You could declare `char c = data[i]` before the `if` statement to avoid recalculating and re-accessing `data[i]`.

Code Hoisting

```
void func(int a, int b, char data[])
{
  for(int i=0; i<10; i++)
     data[a*b+i] = 'A';
}
```

- You can calculate `a*b` outside the loop instead of every iteration.
- This also applies to loop limits, i.e. if we had `i<(a+b)`

Loop Unrolling

- A technique to reduce loop overhead.
- When accessing array elements, why not go two or more at a time?
- This results in fewer iterations, which means fewer jumps and condition checking.
- However, it adds code bloat.
- All that extra code may not fit in the instruction cache.

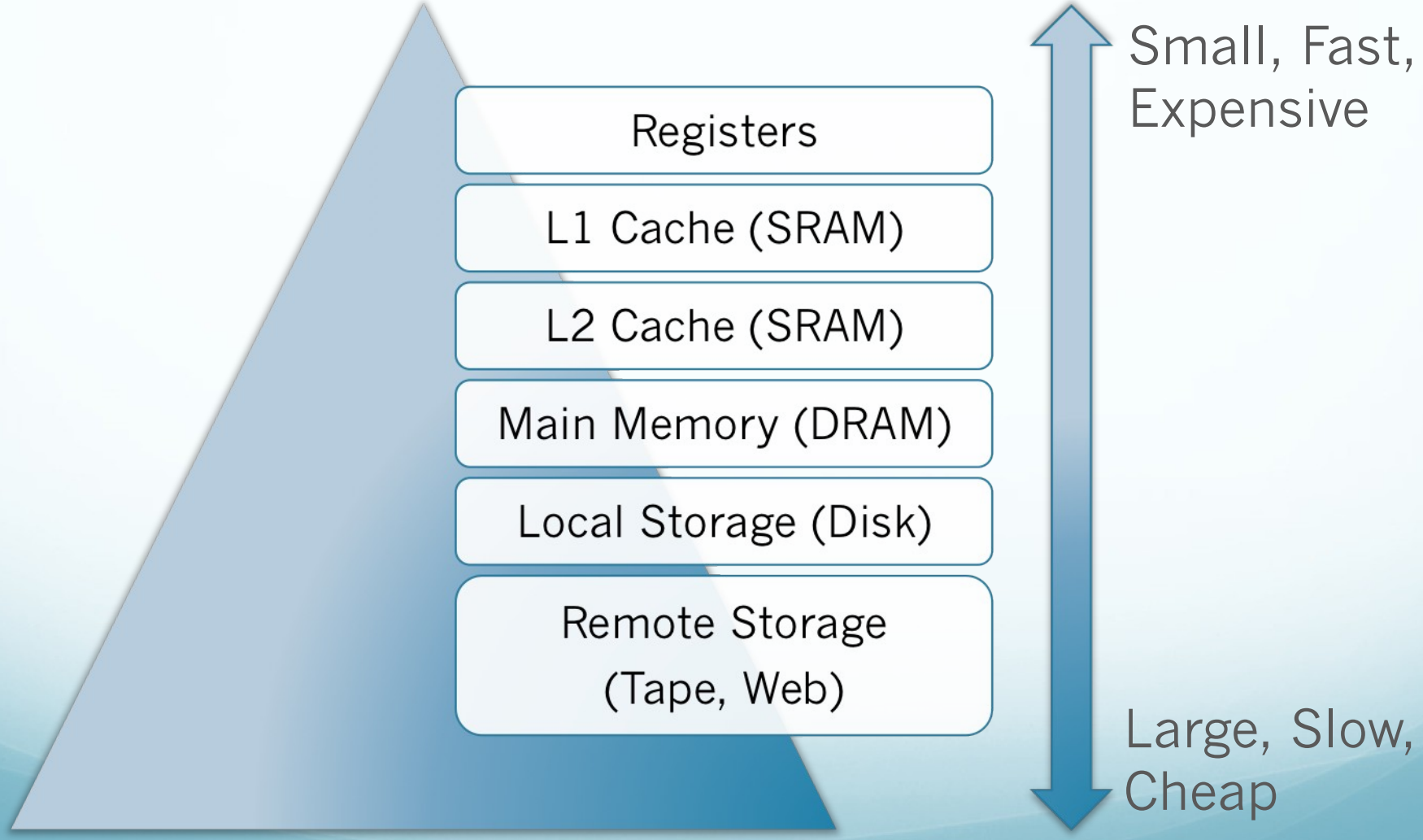
Optimization Blockers

- As good as compilers can be at optimizing, sometimes we can help it do better.
- Function calls can add a lot of overhead.
  - You move function code into the main procedure at the cost of lower modularity and added code bloat.
  - The `inline` keyword or preprocessor macros can have the compiler do this for you.
- Memory aliasing
  - The compiler doesn't know if more than one pointer is accessing the same memory location.
  - Use a temporary variable to do a calculation and store the result in memory when you're done.

Questions?

A Gentle Introduction to Caching

Memory Hierarchy



Caching Introduction

- When memory is accessed, it tends to be accessed again within a short amount of time.
- Instead of accessing slow memory twice, stash a copy in a faster memory.
- Cache “Hit” when memory being accessed is cached, Cache “Miss” otherwise.
- Hit/Miss rate is the ratio of cache hits/misses to total memory accesses, respectively.

Cache Types

- Direct Mapped
  - Data at each memory address is loaded into a specific cache block.
  - Hardware is simple, but you can end up lots of collisions if multiple variables vie for the same block.
- *n*-Way Associative
  - Data at each memory address can be loaded into one of *n* cache blocks.
  - Fewer collisions, but how do you figure out which cache block to fill, or which block has your data?

Review

- Buflab Thursday, Exam 1 next week.
- Stack Review
- Structs
- Optimization Basics
- Memory Hierarchy and Caching
  - Plenty more on these in lecture this week.
- Questions?