15-213 Recitation 6 - 2/26/01

Outline

- Linking
- Exam Review
  - Topics Covered
  - Your Questions

Reminders

- EXAM 1: Tomorrow
  - DH 2210
  - Review Session
    - Tonight, Wean 7500
    - 6:30 PM

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Office Hours:

Wednesday 1:30 – 2:30

Wean 3108

Linking

- Process of patching binaries with correct addresses of symbols unknown at compile time
- Enables use of multiple source files and shared libraries

Linking: Example

a.c

```
#include <stdio.h>

int i = 0;

int main(int argc, char *argv[])
{
  increment_i();
  printf("i: %d\n", i);
}
```

Linking: Example

b.c

```
extern int i;

void increment_i() { i++; }
```

Linking: Example

Compilation

```
gcc –c –o a.o a.c
gcc –c –o b.o b.c
```

- Generate unlinked binary

```
gcc –o prog a.c b.c
```

- Generate executable

```
objdump –D a.o b.o > ab.bdis
```

- Disassemble unlinked binaries

```
objdump –D prog > prog.bdis
```

- Disassemble executable

Linking: Example

ab.bdis

```
00000000 <main>:
   0:   55                      push   %ebp
   1:   89 e5                   mov    %esp,%ebp
   3:   83 ec 08                sub    $0x8,%esp
   6:   e8 fc ff ff ff          call   7 <main+0x7>
   b:   83 c4 f8                add    $0xfffffff8,%esp
   e:   a1 00 00 00 00          mov    0x0,%eax
  13:   50                      push   %eax
  14:   68 00 00 00 00          push   $0x0
  19:   e8 fc ff ff ff          call   1a <main+0x1a>
  1e:   83 c4 10                add    $0x10,%esp
  21:   89 ec                   mov    %ebp,%esp
  23:   5d                      pop    %ebp
  24:   c3                      ret
```

Which bytes of the above will the linker have to change?

Linking: Example

ab.bdis (cont'd)

```
00000000 <increment_i>:
   0:   55                      push   %ebp
   1:   89 e5                   mov    %esp,%ebp
   3:   ff 05 00 00 00 00       incl   0x0
   9:   89 ec                   mov    %ebp,%esp
   b:   5d                      pop    %ebp
   c:   c3                      ret
```

Which bytes of the above will the linker have to change?

Linking: Example

prog.bdis

```
080483e4 <main>:
 80483e4:       55                      push   %ebp
 80483e5:       89 e5                   mov    %esp,%ebp
 80483e7:       83 ec 08                sub    $0x8,%esp
 80483ea:       e8 1d 00 00 00          call   804840c <increment_i>
 80483ef:       83 c4 f8                add    $0xfffffff8,%esp
 80483f2:       a1 8c 94 04 08          mov    0x804948c,%eax
 80483f7:       50                      push   %eax
 80483f8:       68 78 84 04 08          push   $0x8048478
 80483fd:       e8 06 ff ff ff          call   8048308 <_init+0x70>
 8048402:       83 c4 10                add    $0x10,%esp
 8048405:       89 ec                   mov    %ebp,%esp
 8048407:       5d                      pop    %ebp
 8048408:       c3                      ret
```

Linking: Example

prog.bdis (cont'd)

```
0804840c <increment_i>:
 804840c:       55                      push   %ebp
 804840d:       89 e5                   mov    %esp,%ebp
 804840f:       ff 05 8c 94 04 08       incl   0x804948c
 8048415:       89 ec                   mov    %ebp,%esp
 8048417:       5d                      pop    %ebp
 8048418:       c3                      ret
```

Exam Review: Topics Covered

- Bits and Bytes
  - Memory Organization
  - Endian-ness
  - Bit-wise Operations
- Integer Representation
  - Two's Complement, Unsigned
  - Arithmetic Operations
- Machine Level Programming
  - Assembly (lots of it)
  - Stack Discipline
  - Jump Tables

Exam Review: Topics Covered

- Structured Data
  - Arrays
  - `structs` and `unions`
- Floating Point
- Linking