Machine-Level Programming II: Control - loops

These slides adapted from materials provided by the textbook

Machine-Level Programming II: Control

- Control: Condition codes
- Conditional branches
- **Loops**
- Switch Statements

"Do-While" Loop Example

C Code

```
long
pcount_do(unsigned long x)
{
  long result = 0;
  do {
    result += x & 0x1;
    x >>= 1;
  } while (x);
  return result;
}
```

Goto Version

```
long
pcount_goto(unsigned long x)
{
  long result = 0;
 loop:
  result += x & 0x1;
  x >>= 1;
  if(x) goto loop;
  return result;
}
```

- Count number of 1's in argument `x` ("popcount")
- Use conditional branch to either continue looping or to exit loop

"Do-While" Loop Compilation

Goto Version

```
long pcount_goto(unsigned long x)
{
  long result = 0;
 loop:
  result += x & 0x1;
  x >>= 1;
  if(x) goto loop;
  return result;
}
```

Register	Use(s)
%rdi	Argument x
%rax	result

```
   movl    $0, %eax    #  result = 0
.L2:                   # loop:
   movq    %rdi, %rdx
   andl    $1, %edx    #  t = x & 0x1
   addq    %rdx, %rax  #  result += t
   shrq    %rdi        #  x >>= 1
   jne     .L2         #  if (x) goto loop
   rep; ret
```

General "Do-While" Translation

C Code

```
do
   Body
   while (Test);
```

Goto Version

```
loop:
   Body
   if (Test)
      goto loop
```

- **Body:**

```
{
    Statement1;
    Statement2;
      …
    Statementn;
}
```

General "While" Translation #1

- **"Jump-to-middle" translation**
- **Used with –Og**

While version

```
while (Test)
  Body
```

Goto Version

```
  goto test;
loop:
  Body
test:
  if (Test)
    goto loop;
done:
```

While Loop Example #1

C Code

```
long
pcount_while(unsigned long x)
{
  long result = 0;
  while (x) {
    result += x & 0x1;
    x >>= 1;
  }
  return result;
}
```

Jump to Middle

```
long
pcount_goto_jtm(unsigned long x)
{
  long result = 0;
  goto test;
 loop:
  result += x & 0x1;
  x >>= 1;
 test:
  if(x) goto loop;
  return result;
}
```

- Compare to do-while version of function
- Initial goto starts loop at test

General "While" Translation #2

While version

```
while (Test)
  Body
```

Do-While Version

```
  if (!Test)
    goto done;
  do
    Body
    while(Test);
done:
```

Goto Version

```
  if (!Test)
    goto done;
loop:
  Body
  if (Test)
    goto loop;
done:
```

- **"Do-while" conversion**
- **Used with –O1**

While Loop Example #2

C Code

```
Long
pcount_while(unsigned long x)
{
  long result = 0;
  while (x) {
    result += x & 0x1;
    x >>= 1;
  }
  return result;
}
```

Do-While Version

```
Long
pcount_goto_dw(unsigned long x)
{
  long result = 0;
  if (!x) goto done;
 loop:
  result += x & 0x1;
  x >>= 1;
  if(x) goto loop;
 done:
  return result;
}
```

- Compare to do-while version of function
- Initial conditional guards entrance to loop

"For" Loop Form

General Form

```
for (Init; Test; Update) Body
```

```
#define WSIZE 8*sizeof(int)
long
pcount_for(unsigned long x)
{
  size_t i;
  long result = 0;
  for (i = 0; i < WSIZE; i++)
  {
    unsigned bit =
       (x >> i) & 0x1;
    result += bit;
  }
  return result;
}
```

Init

```
i = 0
```

Test

```
i < WSIZE
```

Update

```
i++
```

Body

```
{
  unsigned bit =
      (x >> i) & 0x1;
  result += bit;
}
```

"For" Loop → While Loop

For Version

```
for (Init; Test; Update)
    Body
```

While Version

```
Init;
while (Test) {
    Body
    Update;
}
```

For-While Conversion

Init

```
i = 0
```

Test

```
i < WSIZE
```

Update

```
i++
```

Body

```
{
  unsigned bit =
     (x >> i) & 0x1;
  result += bit;
}
```

```
Long
pcount_for_while(unsigned long x)
{
  size_t i;
  long result = 0;
  i = 0;
  while (i < WSIZE)
  {
    unsigned bit =
       (x >> i) & 0x1;
    result += bit;
    i++;
  }
  return result;
}
```

"For" Loop Do-While Conversion

C Code

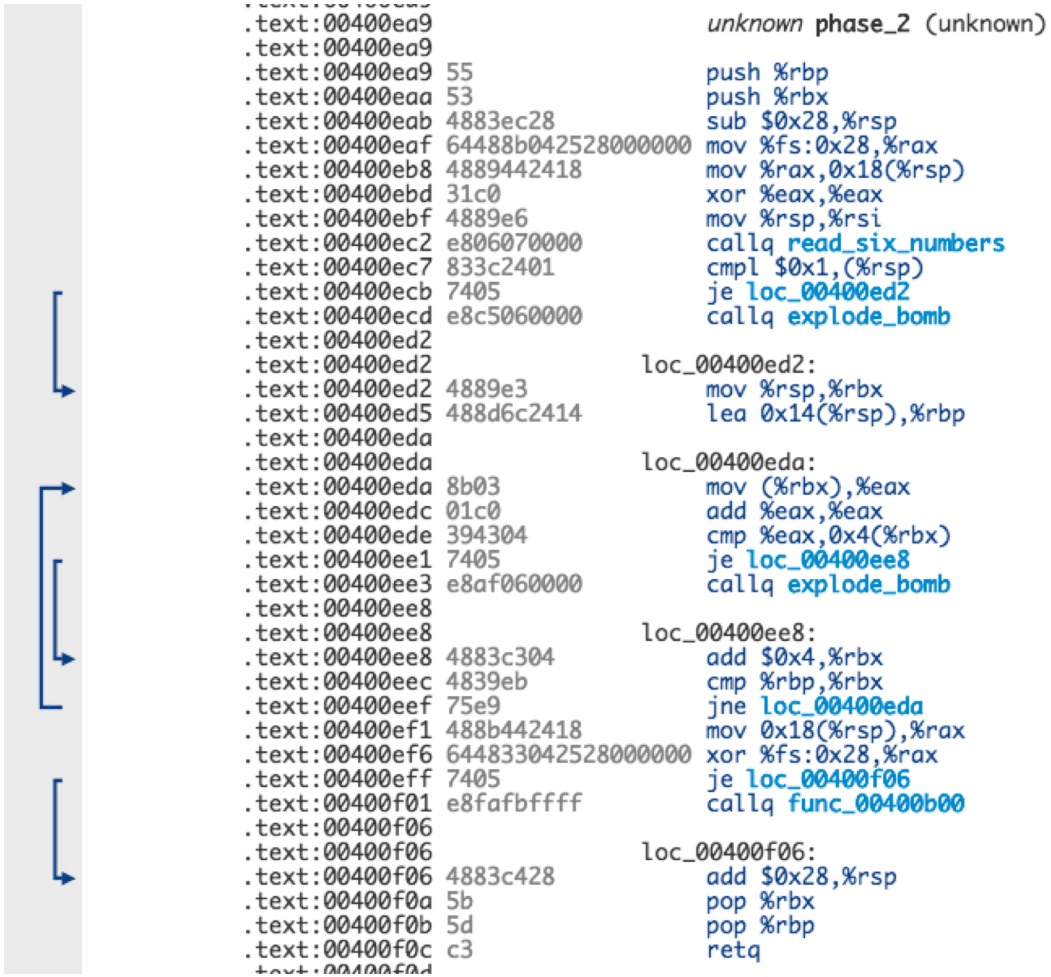
```
long
pcount_for(unsigned long x)
{
  size_t i;
  long result = 0;
  for (i = 0; i < WSIZE; i++)
  {
    unsigned bit =
      (x >> i) & 0x1;
    result += bit;
  }
  return result;
}
```

Goto Version

```
Long
pcount_for_godw(unsigned long x)
{
  size_t i;
  long result = 0;
  i = 0;                          Init
  if (!(i < WSIZE))               ! Test
    goto done;
 loop:
  {
    unsigned bit =
      (x >> i) & 0x1;             Body
    result += bit;
  }
  i++;                            Update
  if (i < WSIZE)                  Test
    goto loop;
 done:
  return result;
}
```

- **Initial test can be optimized away**

Reverse Engineering Assembly



When translating assembly to C, it's useful to draw arrows to "spot the if/loop"

Forward branches are if/then/else

Backwards are loops

Even easier with https://onlinediassembler.com