CS 33

Introduction to C
Part 6

The String Library

```
#include <string.h>

char *strcpy(char *dest, char *src);
  // copy src to dest, returns ptr to dest
char *strncpy(char *dest, char *src, int n);
  // copy at most n bytes from src to dest
int strlen(char *s);
  // return the length of s (not counting the null)
int strcmp(char *s1, char *s2);
  // returns -1, 0, or 1 depending on whether s1 is
  // less than, the same as, or greater than s2
int strncmp(char *s1, char *s2, int n);
  // do the same, but for at most n bytes
```


The String Library (more)

```
size_t strspn(const char *s, const char *accept);
      // returns length of initial portion of s
      // consisting entirely of bytes from accept

size_t strcspn(const char *s, const char *reject);
      // returns length of initial portion of s
      // consisting entirely of bytes not from
      // reject
```

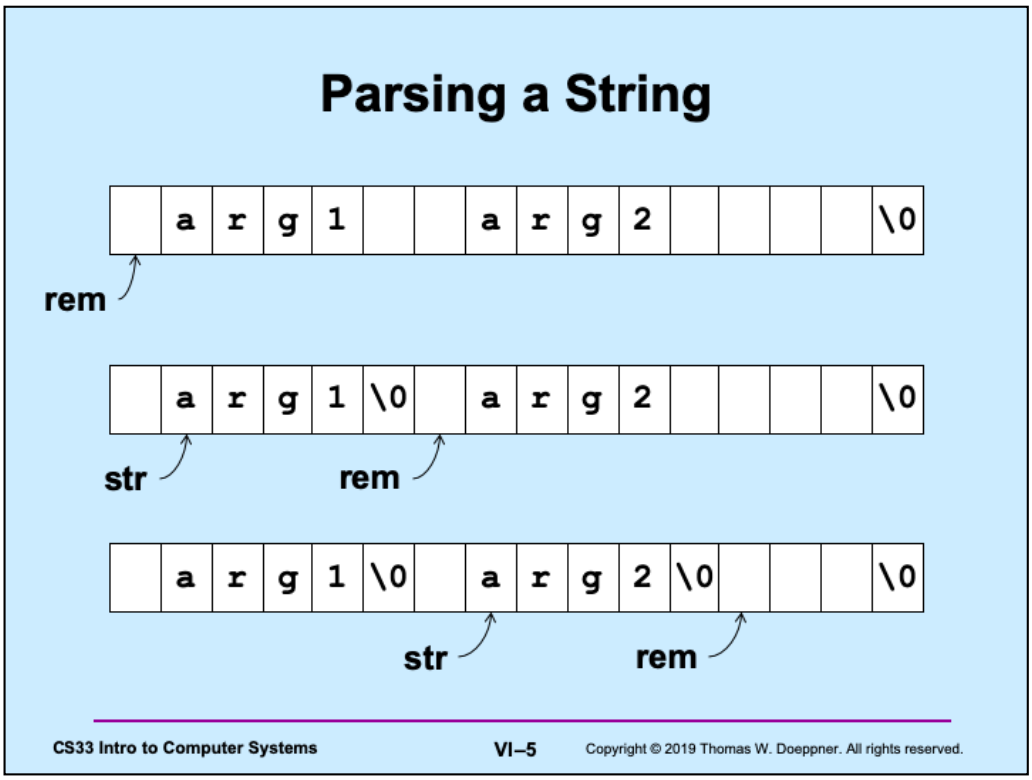

These will be useful in upcoming assignments.

Quiz 1

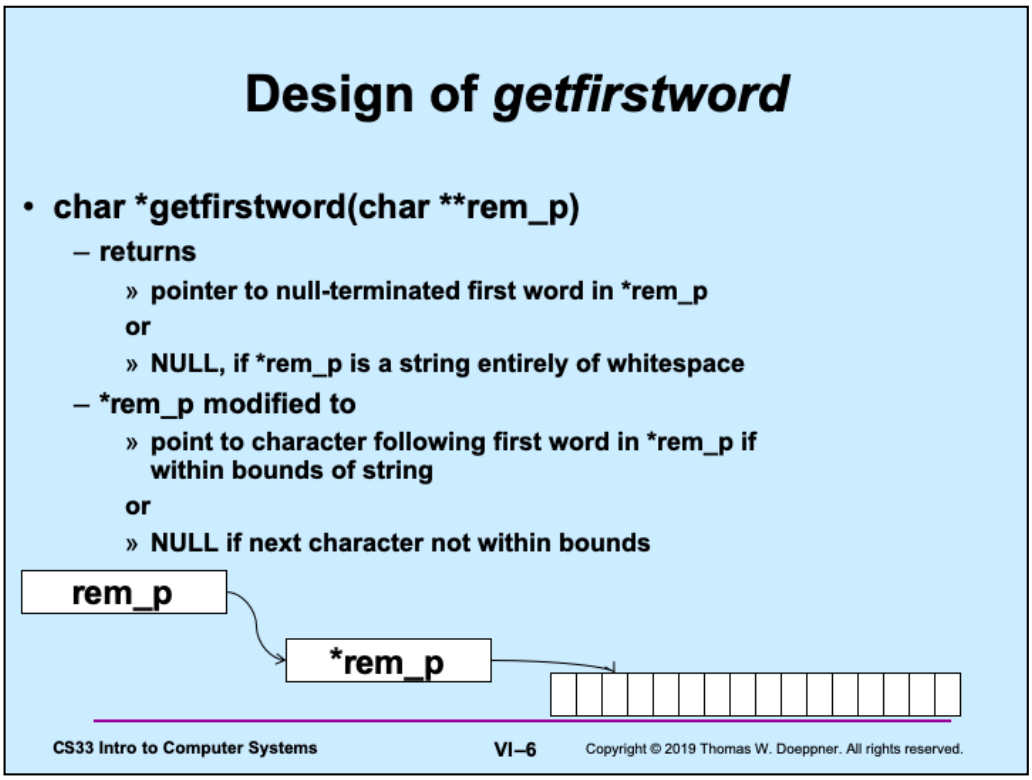
```
#include <stdio.h>
#include <string.h>

int main() {
  char s1[] = "Hello World!\n";
  char *s2;
  strcpy(s2, s1);
  printf("%s", s2);
  return 0;
}
```

This code:

a) **is a great example of well written C code**
b) **has syntax problems**
c) **might seg fault**



Suppose we have a string of characters (perhaps typed into the command line of a shell). We'd like to parse this string to pull out individual words (to be used as arguments to a command); these words are separated by one or more characters of white space. Starting with a pointer to this string (*rem*), we call a function that null-terminates the first word and returns a pointer to that word (*str*), and updates *rem* to point to the remainder of the string. We call it again to get the second word, etc.



Note that the argument is a char **. Thus we are passing *getfirstword* a pointer to a variable that points to the string. This allows us to change this variable inside of *getfirstword* so that it points to a different location in the string.

Using *getfirstword*

```
int main() {
  char line[] = "  arg0   arg1 arg2   arg3   ";
  char *rem = line;
  char *str;
  while ((str = getfirstword(&rem)) != NULL) {
    printf("%s\n", str);
  }
  return 0;
}
```

Output:
arg0
arg1
arg2
arg3

Code

```
char *getfirstword(char **rem_p) {
  char *str = *rem_p;
  if (str == NULL)
    return NULL;
  int len = strlen(str);
  int wslen =
    strspn(str, " \t\n");
      // initial whitespace
  if (wslen == len) {
    // string is all whitespace
    return NULL;
  }
  str = &str[wslen];
    // skip over whitespace
  len -= wslen;
  int wlen =
    strcspn(str, " \t\n");
      // length of first word
  if (wlen < len) {
    // word ends before end of
    // string: terminate
    // it with null
    str[wlen] = '\0';
    *rem_p = &str[wlen+1];
  } else {
    // no more words
    *rem_p = NULL;
  }
  return str;
}
```

Numeric Conversions

```
short a;
int b;
float c;

b = a;    /* always works */
a = b;    /* sometimes works */
c = b;    /* sort of works */
b = c;    /* sometimes works */
```


Assigning a short to an int will always work, since all possible values of a short can be represented by an int. The reverse doesn't always work, since there are many more values an int can take on than can be represented by a short.

A float can represent an int in the sense that the smallest and largest ints fall well within the range of the smallest (most negative) and largest floats. However, floats have few significant digits than do ints and thus, when converting from an int to a float, there may well be a loss of precision.

When converting from a float to an int there will not be any loss of precision, but large floats and small (most negative) floats cannot be represented by ints.

Implicit Conversions (1)

```
float x, y=2.0;
int i=1, j=2;

x = i/j + y;
  /* what's the value of x? */
```


x's value will be 2, since the result of the (integer) division of i by j will be 0.

Implicit Conversions (2)

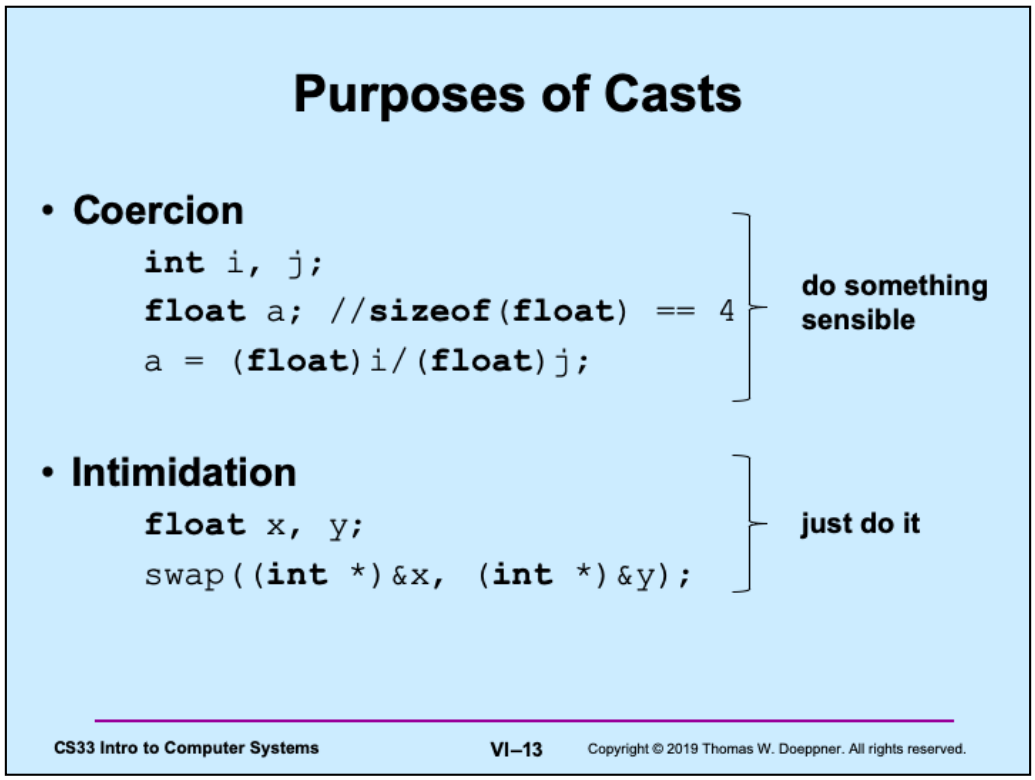
```
float x, y=2.0;
int i=1, j=2;
float a, b;

a = i;
b = j;
x = a/b + y;
  /* now what's the value of x? */
```


Here the values of i and j are converted to float before being assigned to a and b, thus the value assigned to x is 2.5.

Explicit Conversions: Casts

```
float x, y=2.0;
int i=1, j=2;

x = (float)i/(float)j + y;
  /* and now what's the value of x? */
```


Here we do the int-to-float conversion explicitly; x's value will be 2.5.



"Coercion" is a commonly accepted term for one use of casts. "Intimidation" is not. The concept is more commonly known as a "sidecast". Coercion means to convert something of one datatype to another. Intimidation (or sidecasting) means to treat an instance one datatype as being another datatype without doing any conversion of the actual data.

Quiz 2

- **Will this work?**

```
double x, y; //sizeof(double) == 8

...
swap((int *)&x, (int *)&y);
```

a) **yes**
b) **no**

Nothing, and More …

- ***void*** **means, literally, nothing:**

```
void NotMuch(void) {
   printf("I return nothing\n");
}
```

- **What does *void* * mean?**
  - **it's a pointer to anything you feel like**
    - » **a generic pointer**

The void * type is an exception to the rule that the type of the target of a pointer must be known.

Rules

- **Use with other pointers**

```
int *x;
void *y;
x = y; /* legal */
y = x; /* legal */
```

- **Dereferencing**

```
void *z;
func(*z); /* illegal!*/
func(*(int *)z); /* legal */
```


Dereferencing a pointer must result in a value with a useful type. “void” is not a useful type.

Swap, Revisited

```
void swap(int *i, int *j) {
  int tmp;
  tmp = *j; *j = *i; *i = tmp;
}
/* can we make this generic? */
```


Can we write a version of *swap* that handles a variety of data types?

An Application: Generic Swap

```
void gswap (void *p1, void *p2,
     int size) {
  int i;
  for (i=0; i < size; i++) {
     char tmp;
     tmp = ((char *)p1)[i];
     ((char *)p1)[i] = ((char *)p2)[i];
     ((char *)p2)[i] = tmp;
  }
}
```


Note that there is a function in the C library that one may use to copy arbitrary amounts of data — it's called *memcpy*. To see its documentation, use the Linux command "man memcpy".

Using Generic Swap

```
short a=1, b=2;
gswap(&a, &b, sizeof(short));

int x=6, y=7;
gswap(&x, &y, sizeof(int));

int A[] = {1, 2, 3}, B[] = {7, 8, 9};
gswap(A, B, sizeof(A));
```

Fun with Functions (1)

```
void ArrayDouble(int A[], int len) {
  int i;
  for (i=0; i<len; i++)
      A[i] = 2*A[i];
}
```


Fun with Functions (2)

```
void ArrayBop(int A[],
     int len,
     int (*func)(int)) {
  int i;
  for (i=0; i<len; i++)
     A[i] = (*func)(A[i]);
}
```

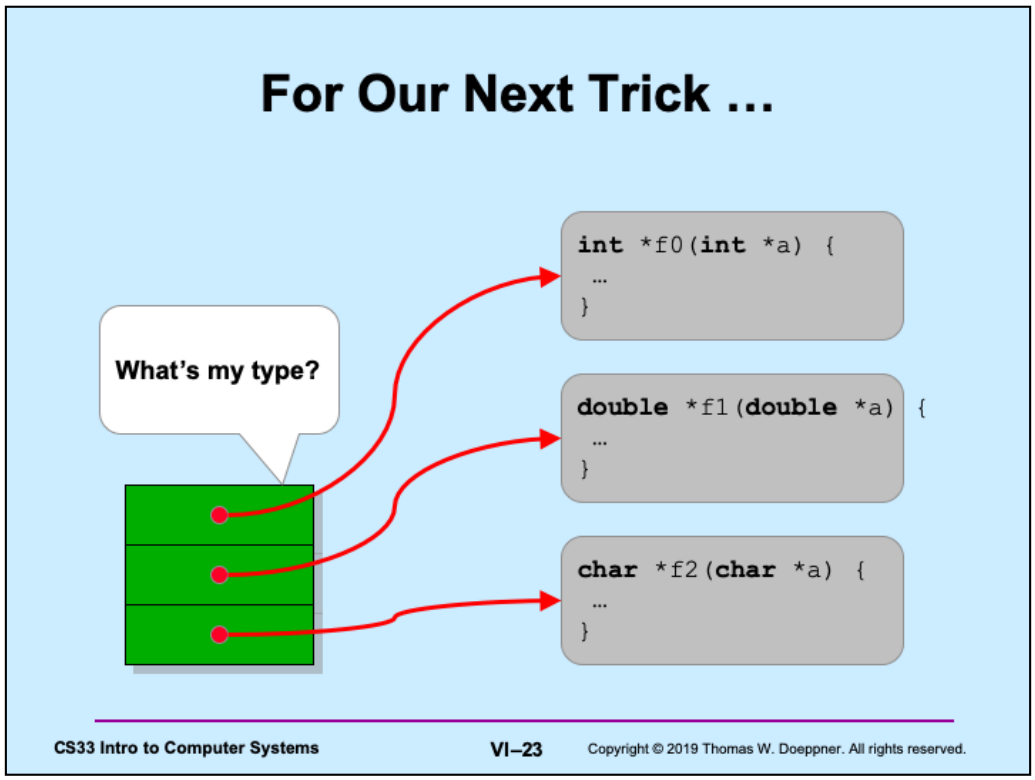

Here *func* is declared to be a pointer to a function that takes an *int* as an argument and returns an *int*.

What's the difference between a pointer to a function and a function? A pointer to a function is, of course, the address of the function. The function itself is the code comprising the function. Thus, strictly speaking, if *func* is the name assigned to a function, *func* really represents the address of the function. You might think that we should invoke the function by saying "**func*", but it's understood that this is what we mean when we say "*func*". Thus when one calls *ArrayBop*, one supplies the name of the desired function as the third argument, without prepending "&".

Fun with Functions (3)

```
int triple(int arg) {
  return 3*arg;
}

int main() {
  int A[20];
  … /* initialize A */
  ArrayBop(A, 20, triple);
  return 0;
}
```

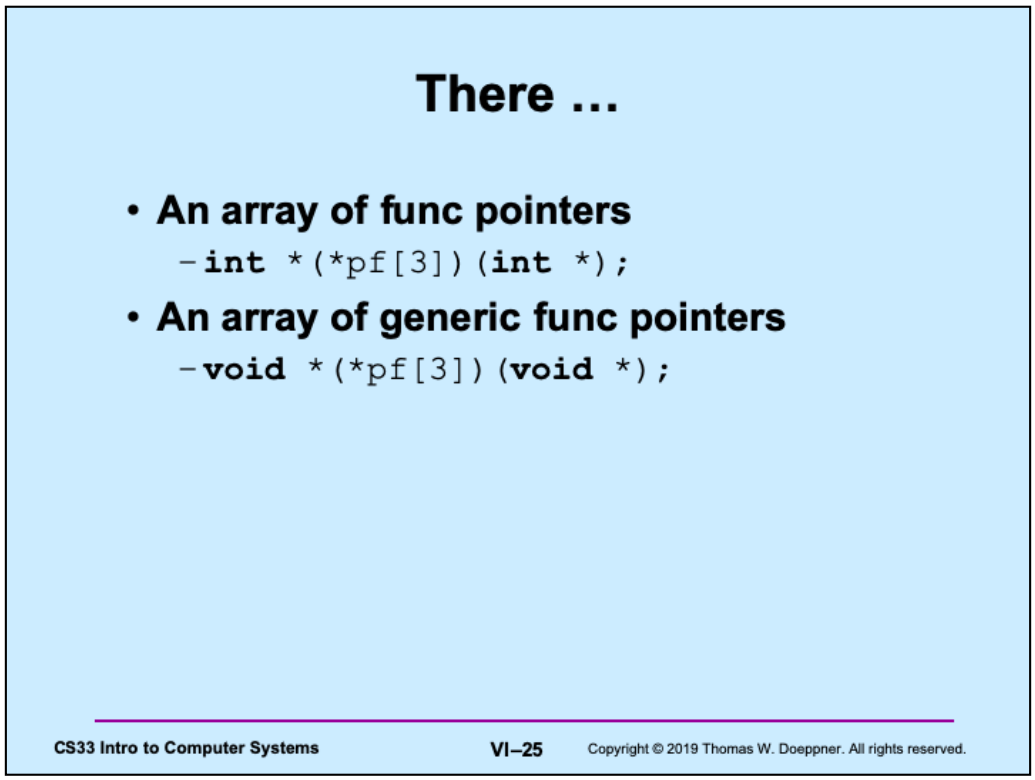

Here we define another function that takes a single *int* and returns an *int*, and pass it to *ArrayBop*.



What we want to come up with is an array, each of whose elements is a function that takes a single pointer argument and returns a pointer value. However, the type of what the pointer points to might be different for each element. What is the type of the resulting array?

Working Our Way There …

- An array of 3 ints
  - `int A[3];`
- An array of 3 int *s
  - `int *A[3];`
- A func returning an int *, taking an int *
  - `int *f(int *);`
- A pointer to such a func
  - `int *(*pf)(int *);`



Note that we can't make the function pointers so generic that they may have differing numbers of arguments.

Using It

```
int *f0(int *a) { *a += 1; return a; }
double *f1(double *a) { *a += 1; return a; }
char *f2(char *a) { *a += 1; return a; }
int main() {
  int x = 1;
  int *p;
  void *(*pf[3])(void *);
  pf[0] = (void *(*)(void *))f0;
  pf[1] = (void *(*)(void *))f1;
  pf[2] = (void *(*)(void *))f2;
  p = pf[0](&x);
  printf("%d\n", *p);
  return 0;
}
```

```
$ ./funcptr
2
$
```

Casts, Yet Again

- They tell the C compiler:
  "Shut up, I know what I'm doing!"
- Sometimes true

```
pf[0] = (void *(*)(void *))f0;
```

- Sometimes false

```
long f = 7;
(void(*)(int))f(2);
```

Laziness …

- Why type the declaration

```
void *(*f)(void *, void *);
```

- You could, instead, type

```
MyType f;
```

- (If, of course, you can somehow define *MyType* to mean the right thing)

typedef

- **Allows one to create new names for existing types**

```
typedef int *IntP_t;
```

```
IntP_t x;
```

- **means the same as**

```
int *x;
```

More typedefs

```
typedef struct complex {
  float real;
  float imag;
} complex_t;

complex_t i, *ip;
```


A standard convention for C is that names of datatypes end with "_t". Note that it's not necessary to give the struct a name (we could have omitted the "complex" following "struct").

And ...

```
typedef void *(*MyFunc_t)(void *, void *);

MyFunc_t f;

// you must do its definition the long way

void *f(void *a1, void *a2) {
  …
}
```


Quiz 3

- **What's A?**

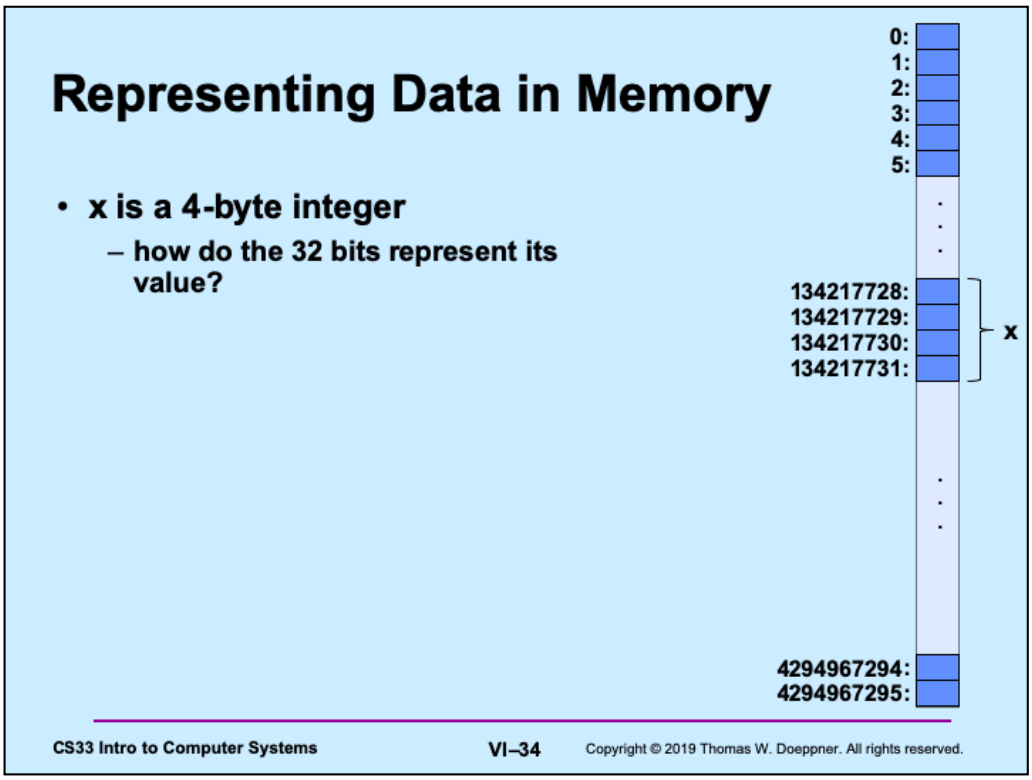
```
typedef double X_t[M];
X_t A[N];
```

a) an array of N doubles
b) an MxN array of doubles
c) an NxM array of doubles
d) a syntax error

CS 33

Data Representation

Part 1



In the diagram, x is an int occupying bytes 134217728, 134217729, 134217730, and 134217731. Its address is 134217728; its size is 4 (bytes).

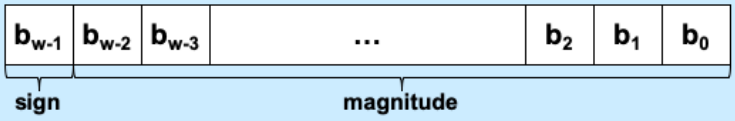
Unsigned Integers

$$\text{value} = \sum_{i=0}^{w-1} b_i \cdot 2^i$$

If a computer word is to be interpreted as an unsigned integer, we can do so as shown in the slide, where w is the number of bits in the word.

Signed Integers

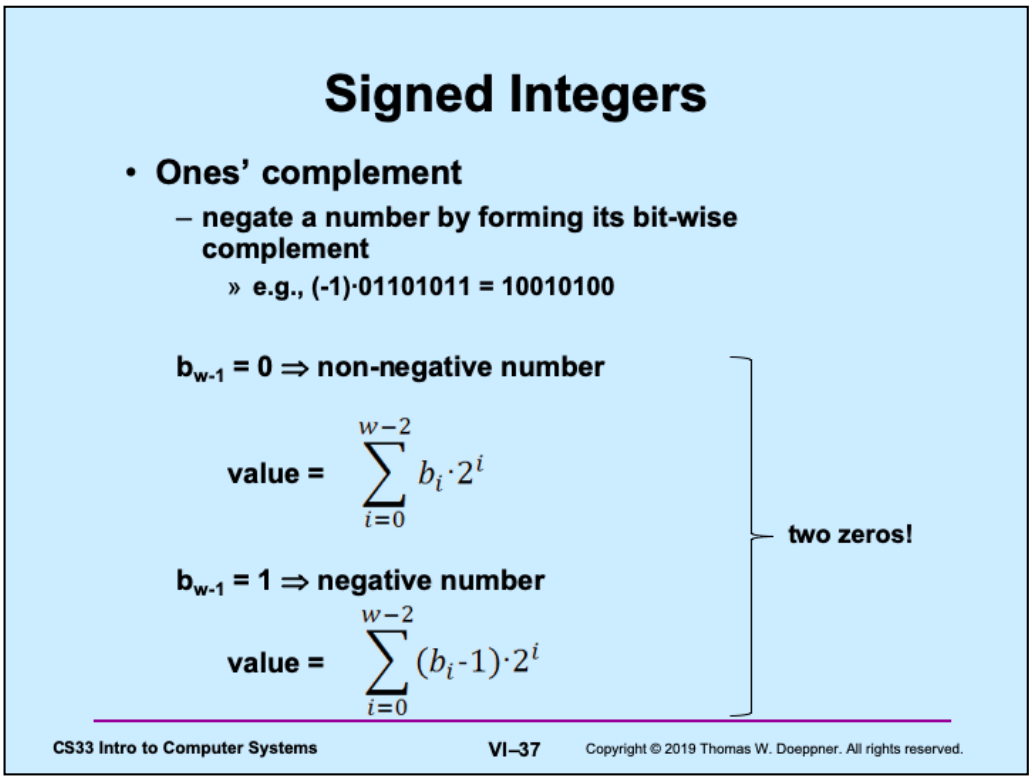
- **Sign-magnitude**



$$\text{value} = (-1)^{b_{w-1}} \cdot \sum_{i=0}^{w-2} b_i \cdot 2^i$$

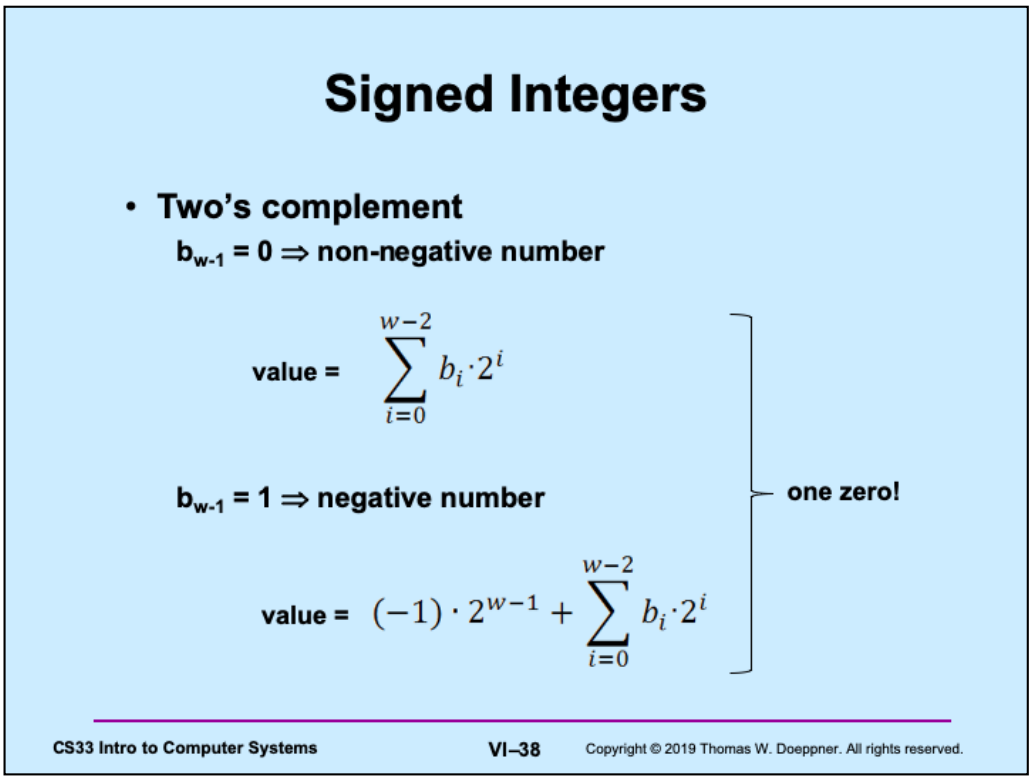
- two representations of zero!
  - computer must have two sets of instructions
    - one for signed arithmetic, one for unsigned

We might also want to interpret the contents of a computer word as a signed integer. There are a few options for how to do this. One straightforward approach is shown in the slide, where we use the high-order (leftmost) bit as the "sign bit": 0 means positive and 1 means negative. However, this has the somewhat weird result that there are two representations of zero. This further means that the computer would have to have two implementations of arithmetic instructions: one for signed arithmetic, the other for unsigned arithmetic.



In ones' complement, a number is positive if its leftmost bit is zero negative otherwise. We negate a number by complementing *all* its bits. Thus if the leftmost bit is zero, a one in position i of the remaining bits contributes a value of 2^i and a zero contributes nothing. But if the leftmost bit is one, a zero in position i contributes a value of -2^i and a one contributes nothing.

Note that the most-significant bit serves as the sign bit. But, as with sign-magnitude, the computer would need two sets of instructions: one for signed arithmetic and one for unsigned.



There's only one zero!

Two's complement is used on pretty much all of today's computers to represent signed integers.

Note that the high-order (most-significant) bit represents -2^{w-1}. All the other bits represent positive numbers.

Example

- **w = 4**

0000: 0	1000: -8
0001: 1	1001: -7
0010: 2	1010: -6
0011: 3	1011: -5
0100: 4	1100: -4
0101: 5	1101: -3
0110: 6	1110: -2
0111: 7	1111: -1