CS2351
Data Structures

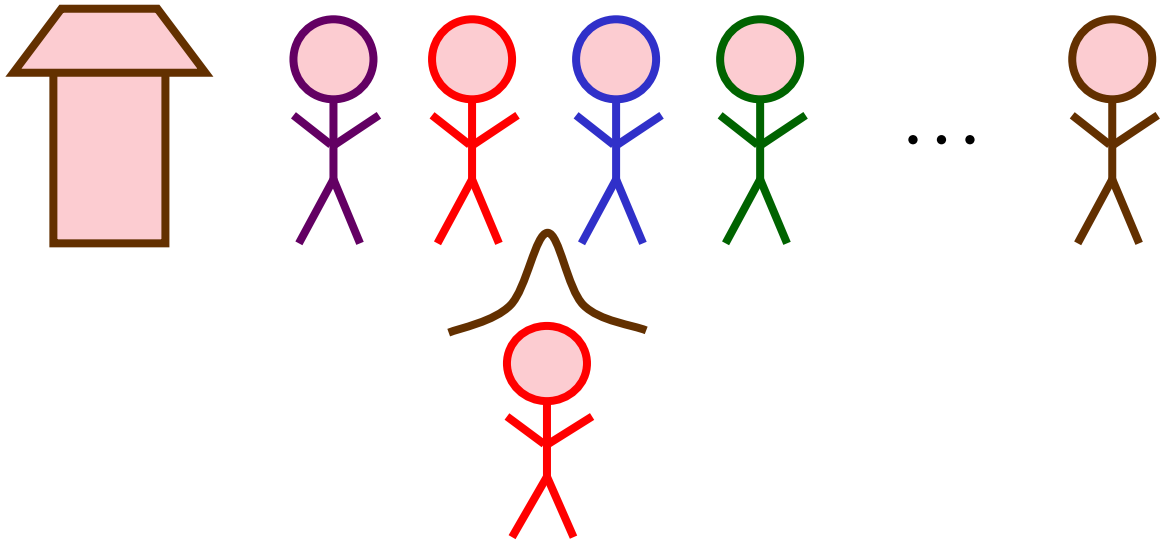
Lecture 7:
A Brief Review of Pointers in C

About this lecture

- Pointer is a useful object that allows us to access different places in our memory
- We will review the basic use of pointer
- Usage: Many data structures are dynamic, and their shapes change from time to time
  - The use of pointers allows us to change the shapes, in a very flexible way

Example: A Dynamic List

- Suppose we have some people, who are waiting in a line to buy Disneyland tickets



- But from time to time, these people may bring in friends to line after them …

Example: A Dynamic List

- To maintain the ordering of the people in the line, we can obviously use an array
- However, there will be problems …
  - "Insertion after" requires $O(n)$ time in the worst case
- Later, we will study dynamic list
  - "Insertion after" can be done in $O(1)$ time

What are Pointers ?

- Consider an array A with 10 integers

- We can access each entry of A by specifying its location (Ex: A[3], A[9])
- Also, we can get or modify the content of an entry (Ex: y = A[3]; A[9] = 113;)

What are Pointers ?

- In fact, our memory is just a long array

- Like a normal array, each entry has a location (or an address), and contains space for storing data
- To access an entry in our memory, we can use a pointer to specify its location

What are Pointers ?

- In C, we declare a pointer using the following syntax :

```
int  *ptr ;
```

- The above line declares a variable ptr, which is used to point at a location in the memory for storing an integer
- Similarly, we can also do something like :

```
char  *cptr ;
```

Pointers in Action

- Once we have declared a pointer, we can do something like :

```
ptr = 0;
```

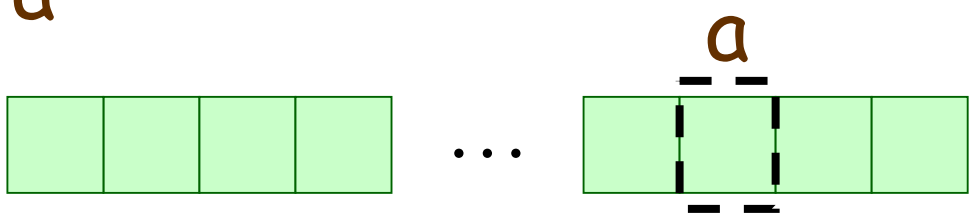
- The above line tells ptr to point to the location 0 in the memory
- This doesn't seem very useful, since there is no particular reason why we want to access location 0 in the memory …

Pointers in Action

- As mentioned, our memory is an array
- Each variable that we declare occupies a certain location in the memory
- Ex : When we declare

```
int a ;
```

then a certain part of memory will be used by a



Pointers in Action

- In C, the location of a in the memory can be obtained by &a
- Then we can write something like :

```
ptr = &a ;
```

which tells ptr to point to the location of a in the memory

Pointers in Action

- In C, when a pointer ptr points to a location in the memory, we can get the value stored in that location by *ptr

```
int a, b, *ptr ;
ptr = &a ;
a = 5 ;
printf("value pointed by p: %d\n", *ptr);
a = 8 ;
printf("value pointed by p: %d\n", *ptr);
```

In C, *p is called dereferencing of a pointer ptr

Pointers in Action

- In C, we can also get or modify the content in the location pointed by a pointer ptr
- The syntax is as follows :

```
  b    = *ptr ;
 *ptr = 15 ;
```

- The first line changes the content of b to the content pointed by ptr
- The second line changes the content pointed by ptr to be 15

Pointers in Action

- What will happen in the following code ?

```
int a, *ptr ;
ptr = &a ;
a = 5 ;
printf("value pointed by p: %d\n", *ptr);
*ptr = 15 ;
printf("value pointed by p: %d\n", *ptr);
printf("value stored by a:  %d\n",  a);
```

Pointers in Action

- What will happen in the following code ?

```
int a, b, *ptr ;
a = 5 ;  b = 3 ;
ptr = &a ;  *ptr = 21 ;
ptr = &b ;  *ptr = 15 ;
printf("value stored by a: %d\n", a);
printf("value stored by b: %d\n", b);
```

Remarks

- Although *ptr usually refers the content of the location pointed by ptr, an exception is during declaration
- The statement :

```
int *ptr = 0 ;
```

is exactly the same as

```
int *ptr ;
ptr = 0 ;
```

Address of Variable

- In C, each variable has a location in the memory for storing its content
- It is true even for a pointer variable !!
- What will happen ?

```
int a, *ptr = 0 ;
printf("the value of ptr: %x\n", ptr);
printf("address of ptr:   %x\n", &ptr);
ptr = &a ;
printf("the value of ptr: %x\n", ptr);
printf("address of ptr:   %x\n", &ptr);
```

Address of Variable

- Each entry in an array also has an address
- What will happen in the following code ?

```
int a[10] ;
printf("address of a[0]: %x\n", &(a[0]));
printf("address of a[1]: %x\n", &(a[1]));
```

- In fact, the array name is a "constant pointer" to the location of its first entry

```
printf("the value of a: %x\n", a);
```

Pointer Arithmetic

- The entries of an array in C occupies contiguous locations in the memory
- When a pointer points to a certain entry in an array, we can increment the pointer to point to the next entry

```
int a[10], *ptr ;
ptr = a ;          // same as ptr = &(a[0]);
ptr++ ;            // ptr now points at a[1]
ptr = ptr + 1;     // ptr now points at a[2]
```

Pointer Arithmetic

- In fact, we can do more :

```
int a[10], *ptr ;
ptr = a ;          // same as ptr = &(a[0]);
ptr = ptr + 3;  // ptr now points at a[3]
printf("a[7] = %d\n", *(ptr + 4));
// note: ptr still points at a[3]
```

- Similarly, we can decrement a pointer to point back to the previous entry

Remarks

- When we add 1 to ptr, the actual value stored ptr may not be increased by 1
  - Reason : this operation is for a change in the memory location, and the change depends on the type of thing pointed by ptr

```
int a[10], *ptr = a ;
printf("value of ptr:     %x\n", ptr);
printf("value of ptr + 1: %x\n", ptr + 1);
```

Note: In a 32-bit machine, the change is 4, since each integer occupies 4 bytes in the memory

Segmentation Fault

- A pointer allows us to access freely any location in the memory
- However, some part of the memory is forbidden (ex: it may be running our OS)
- When we try to touch the content in a forbidden area, segmentation fault occurs

```
int *ptr = 0 ;
printf("value of ptr:          %x\n",  ptr);
printf("value pointed by ptr: %d\n", *ptr);
```

Casting and Bus Error

- In C, we are allowed to perform "casting" to view a variable as a different type from its declared type

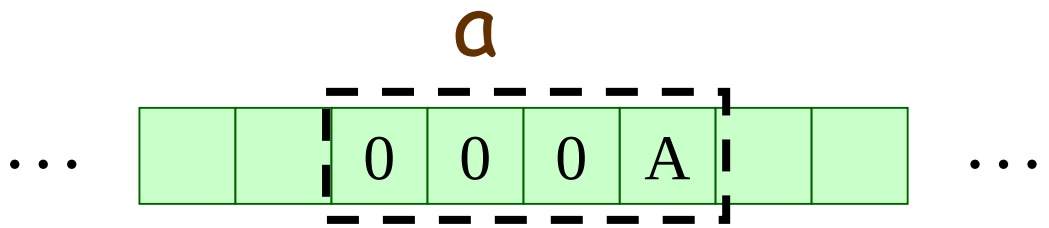
```
char a;
int b ;
a = 'A';
b = (int) a ;   // casting a as int type
printf("value of b: %d\n", b);
```

Casting and Bus Error

- We can also cast pointers

```
char a[4]; int *ptr ;
a[0] = a[1] = a[2] = '\0', a[3]= 'A';
ptr = (int *) a ;
printf("value pointed by ptr: %d\n", *ptr);
```

- The above is like :



Casting and Bus Error

- However, we need to be very careful …
- What will happen in the following code ?

```
char a[4]; int *ptr ;
a[0] = 0, a[1] = 0, a[2]= 0, a[3]= 65;
ptr = (int *) &(a[1]) ;
printf("value pointed by ptr: %d\n", *ptr);
```

- A bus error occurs, because we try to deference an integer pointer at a location that is impossible for storing an integer