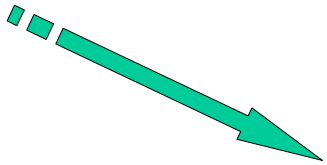
Lecture 10



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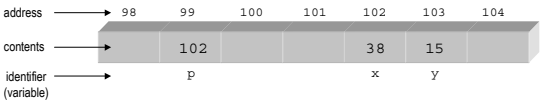
Basics of Pointers

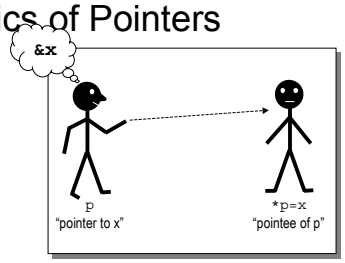
- Pointers are a very important part of C
- In C we need them for many tasks
  e.g. arrays, functions, strings etc
- People tend to find pointers hard to grasp at first!
- First lets go back and look at how variable are stored in memory

Basics of Pointers



- Each cell is numbered with a sequential address
- We can also refer to them by name
- The contents of each is a collection of 0s & 1s which can be interpreted in different ways
- Since an address is a number, it too can be stored in memory
- Here cell 99 contains 102 which is the address of X
- We can say that "p points to x"

Basics of Pointers



- A pointer is a variable that holds the address of another variable
  - We can say that p is a pointer to x
  - We could also say that x is the "pointee" of p

Declaring Pointer Variables

- We have seen declarations such as int x, y which means "x and y are variables of type int"
- We can also declare pointers to all data types e.g.

```
int* p;      p is a pointer to an int variable
float* zz;   zz is a pointer to a float
```

- Note that here '*' means pointer and NOT multiplication. Like many operators in C their usage depends upon the context

Address of Operator &

- Since pointer values are really addresses, we need a way to find the address of a variable.
- This is done by the & operator.
- So `&x` is the "address of x",102 in our example.
- This can then be assigned to p using

```
p=&x;
```

In Summary

```
int x,y;  /* declares 2 int variables */
int* p;   /* pointer to an int */

p=&x;     /* p now points to x */
*p=13;    /* x is now 13 */
```

- The last line means “set the value of the thing pointed to by p to 13”
- Since x is what p points to this is equivalent to saying `x=13;`
- NOTE: `p=13;` sets p to point at address 13, quite different and dangerous

pointer1.c

```
/* Example: basics of pointers, & and * operators */

#include <stdio.h>

main()
{
  int i = 57, j = 19;   /* declare two ints */
  int *ptr;             /* and a pointer to an int */

  ptr = NULL;           /* constant defined in <stdio.h> as 0
                           Means "not pointing to anything" */

  printf("ptr = %p\n", ptr);

  ptr = &i;             /* set ptr to the address of i.
                           i.e. ptr is a pointer to i,
                           and i is the "pointee" of ptr */

  printf("ptr = %p\n", ptr);

  /* We now have two ways of accessing the same variable: */

  printf("*i = %i, j = %i, *ptr = %i\n", i, j, *ptr);

  *ptr *= 2;            /* same as i = 2 * i; */
  (*ptr)--;             /* same as i--; */

  printf("*i = %i, j = %i, *ptr = %i\n", i, j, *ptr);

  ptr = &j;             /* ptr now points at j */

  printf("*i = %i, j = %i, *ptr = %i\n", i, j, *ptr);

  *ptr *= 2;            /* same as j = 2 * j; */
  (*ptr)--;             /* same as j--; */

  printf("*i = %i, j = %i, *ptr = %i\n\n", i, j, *ptr);

  /* Relationships among the variables: */

  printf("&ptr (the address of ptr) is\t%p\n\n", &ptr);
  printf("ptr (the contents of address %p) is\n%p\n\n", &ptr, ptr);
  printf("*ptr (the contents of address %p) is\n%i\n\n", ptr, *ptr);
  printf("&(*ptr) (the address of *ptr) is\n%p\n\n", &(*ptr));
  printf("&j (the address of j) is\n%p\n\n", &j);
  printf("*&j (the contents of address %p) is\n%i\n\n", &j, j);
  printf("*(&j) (the contents of address %p) is\n%i\n", &j, *(&j));
}
```

Basics of Pointers

- Note that the * and & are complementary
- So *(&x) is x
  &(*p) is p

  (Parentheses arent actually needed, evaluation is R to L)

- Weve already seen an example of &, in our use of scanf

  `scanf(“%i”, &x);  /* input a value for x */`
- `&x` is a pointer to `x` and could be rewritten as

  ```
  int*p=&x;
  scanf(“%i”,p);
  ```

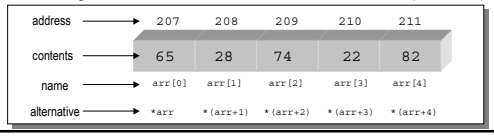
scanfptr.c

```
/* Example: scanf and pointers */

#include <stdio.h>

main()
{
  float number;
  float *number_p;

  number_p = &number;  /* number_p points to number */

  /* One way to do it: */

  puts("Enter a floating point number:");
  scanf("%f", &number);
  printf("You entered %G.\n\n", number);

  /* Another way to do the same thing: */

  puts("Enter a floating point number:");
  scanf("%f", number_p);
  printf("You entered %G.\n", *number_p);
}
```

Arrays and Pointers

- Last time we looked at arrays. Now a secret is revealed

  ARRAYS ARE REALLY POINTERS
- Thus the declaration `int arr[5]={65,28,74,22,82};`
  - reserves storage for 5 ints (here 207 to 211)
  - gives them values as in the list
  - creates a pointer to int called arr
  - gives it the value of the address of the first int (here 207)



Arrays and Pointers

- Because arr is actually an address (type `int*`) we can assign its value to a pointer (of type `int*`)

  ```
  int *ptr;
  ptr=arr;
  ```
  or `ptr=&arr[0];` `/* same thing*/`
- We can refer to the 3rd `int` as `arr[2]` or `*(arr+2)` or `*(ptr+2)` or `ptr[2]`
- We can now see why array indexes always start from zero, they are the offset from the nominal address of the array i.e. its first element

```c
/* BUG ZONE!!!
   Example: some common pointer errors */

#include <stdio.h>

main()
{
  int i = 57;
  float ztran4;
  int track[] = {1, 2, 3, 4, 5, 6}, stick[2][2];
  int *nsave;

  /* Let's try using *nsave as an int variable, and set it to 38 */

  *nsave = 38;  /* BUG */

  nsave = NULL;
  *nsave = 38;  /* BUG */

  nsave = 38;   /* BUG */

  &nsave = 38;  /* BUG */

  nsave = &i;
  *nsave = 38;

  nsave = &ztran4;  /* BUG */

  nsave = track;  /* nsave points at track[0] */

  /* Increase track[0] by 1: */
  *nsave++;  /* BUG */

  /* Now point at stick: */
  nsave = stick;       /* BUG */
  nsave = &stick;      /* BUG */
  nsave = stick[0][0]; /* BUG */
  nsave = *stick;      /* BUG */
  nsave = **stick;     /* BUG */
  nsave = stick[0];
  nsave = &stick[0][0];
  nsave = &**stick;
}
```

pointer.bug

```c
/* Example: pointers and two-dimensional arrays */

#include <stdio.h>

main()
{
  int arr[2][3] = {{11, 22, 33},
                   {44, 55, 66}};  /* an array of ints */
  int *ptr;                        /* a pointer to int */
  int i;                           /* row index */
  int j;                           /* column index */

  ptr = &arr[0][0];  /* set pointer ptr to point at the start of the
                        array, i.e. ptr contains the address of arr[0][0],
                        so arr[0][0] is the "pointee" of ptr.

  We could also write ptr = *arr, because this means &(**arr). Now,
  **arr means *(*arr), which means *(arr[0]), which means arr[0][0].

  We could also write ptr = arr[0]; because ptr is a pointer
  to int and so is arr[0]: it points to arr[0][0].

  We could also write ptr = *arr; because ptr is a pointer
  to int (type int *) and arr is a pointer to a pointer to int
  (type int **). */

  /* We now have several ways of accessing the array elements. */

  /* As a two-dimensional array: */
  for (i = 0; i < 2; i++)
  {
    for (j = 0; j < 3; j++)
      printf("%i ", arr[i][j]);  /* the most natural */
    putchar('\n');
  }
  putchar('\n');

  /* As two one-dimensional arrays: */
  for (j = 0; j < 3; j++)
    printf("%i ", *(arr[0] + j));
  putchar('\n');

  for (j = 0; j < 3; j++)
    printf("%i ", *(arr[1] + j));
  putchar('\n');
  putchar('\n');
```

pointer3.c

```c
/* Example: pointers and arrays */

#include <stdio.h>

main()
{
  int arr[5] = {65, 28, 74, 22, 82};  /* declare an array of ints */
  int *ptr1, *ptr2;                   /* and two pointers to an int */
  int i;

  ptr1 = arr;       /* set pointer ptr1 to point at the array,
                       i.e. ptr1 contains the address of arr[0],
                       and arr[0] is the "pointee" of ptr1.
                       (Note that arr is itself a pointer.)
                       We could also write ptr1 = &arr[0]; */

  ptr2 = &arr[4];   /* set pointer ptr2 to point at the last
                       element in the array, i.e. ptr2 contains the
                       address of arr[4], and arr[4] is the "pointee"
                       of ptr2. */

  /* We now have several ways of accessing the same array elements: */

  printf("arr[0] is %i, arr[4] is %i\n", arr[0], arr[4]);
  printf("*arr is %i, *(arr + 4) is %i\n", *arr, *(arr + 4));
  printf("*&arr[0] is %i, *&arr[4] is %i\n", *&arr[0], *&arr[4]);
  printf("*ptr1 is %i, *ptr2 is %i\n", *ptr1, *ptr2);
  printf("*(ptr2 - 4) is %i, *(ptr1 + 4) is %i\n", *(ptr2 - 4), *(ptr1 + 4));
  printf("ptr1[0] is %i, ptr1[4] is %i\n", ptr1[0], ptr1[4]);
  printf("ptr2[-4] is %i, ptr2[0] is %i\n\n", ptr2[-4], ptr2[0]);

  /* We can use them in loops, e.g.: */

  for (i = 0; i < 5; i++)
    printf("%i ", arr[i]);
  putchar('\n');

  for (i = 0; i < 5; i++)
    printf("%i ", *(arr + i));
  putchar('\n');

  for (i = 0; i < 5; i++)
    printf("%i ", ptr1[i]);
  putchar('\n');

  for (i = 0; i < 5; i++)
    printf("%i ", ptr2[i-4]);
  putchar('\n');
}
```

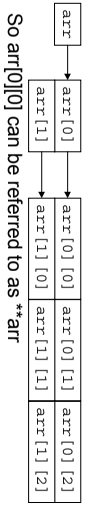
pointer2.c

Two Dimensional Arrays and Pointers

- When we declare

  `int arr[2][3]={{11,22,33},{44,55,66}};`

  - Storage is reserved for 6 ints
  - values are given to them as in the list of lists
  - a pointer to a pointer to an int is created called arr
  - its value is set to the address of the first int



So arr[0][0] can be referred to as **arr

arr[1][2] can be referred to as *(arr[1]+2) or *(arr[0]+5)

```c
/* As a single one-dimensional array: */
  for (j = 0; j < 6; j++)
    printf("%i ", *(*arr + j));
  putchar('\n');
  putchar('\n');

  /* Or, equivalently: */
  for (j = 0; j < 6; j++)
    printf("%i ", *(arr[0] + j));
  putchar('\n');
  putchar('\n');

  /* Suppose we know only the number of elements (6) and have a
  pointer to the first element (ptr). We have to make an assumption
  about the array shape. */

  /* Assuming a one-dimensional array (1 row by 6 columns): */
  for (j = 0; j < 6; j++)
    printf("%i ", ptr[j]);
  putchar('\n');
  putchar('\n');

  /* Assuming a 2 x 3 array (2 rows by 3 columns): */
  for (i = 0; i < 2; i++)
  {
    for (j = 0; j < 3; j++)
      printf("%i ", *(ptr + 3*i + j));
    putchar('\n');
  }
  putchar('\n');

  /* Assuming a 3 x 2 array (3 rows by 2 columns): */
  for (i = 0; i < 3; i++)
  {
    for (j = 0; j < 2; j++)
      printf("%i ", *(ptr + 2*i + j));
    putchar('\n');
  }
  putchar('\n');

  /* Assuming a 6 x 1 array (6 rows by 1 column): */
  for (i = 0; i < 6; i++)
  {
    printf("%i ", *(ptr + i));
    putchar('\n');
  }
  putchar('\n');
}
```

pointer2.c cont