C Tutorial

Pointers, Dynamic Memory allocation, Makefile

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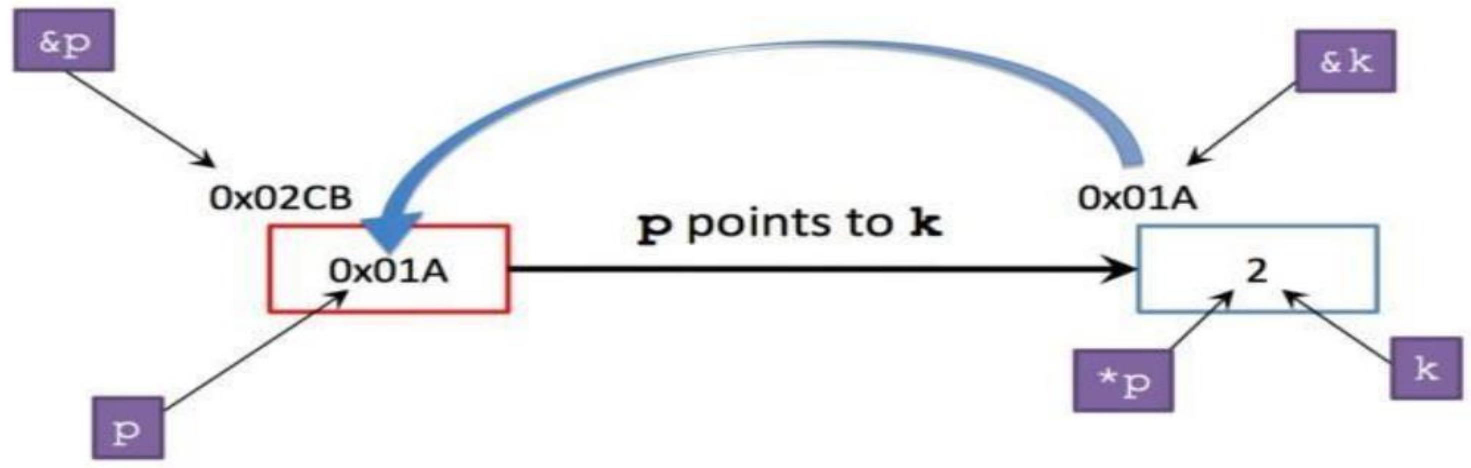
Outline

- What is a pointer?
- & and * operators
- Pointers with Arrays and Strings
- Dynamic memory allocation
  - malloc() and free()
- Makefile

What is a Pointer?

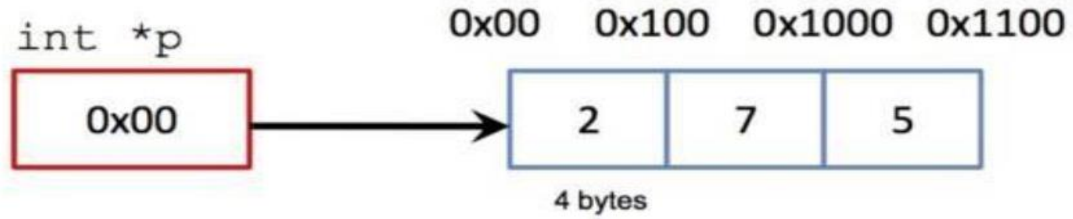
- int k; k =2;
  - ‘k’ is the name given to the memory location which stores the value 2. As the data type used is int, 4 bytes of memory is reserved for k.
  - Internally the memory is identified by an address, which is what ’k’ refers to. This address of ‘k can be accessed by using the & operator, i.e. &k
- int *p = &k;
  - Here ‘p’ is a pointer variable, hence the dereferencing (*) operator before it. The pointer variable ’p’ holds the address where the ’k’ holds the value.

What is a Pointer?



- Hence *p = 2   is equivalent to k = 2

Data Type of a Pointer

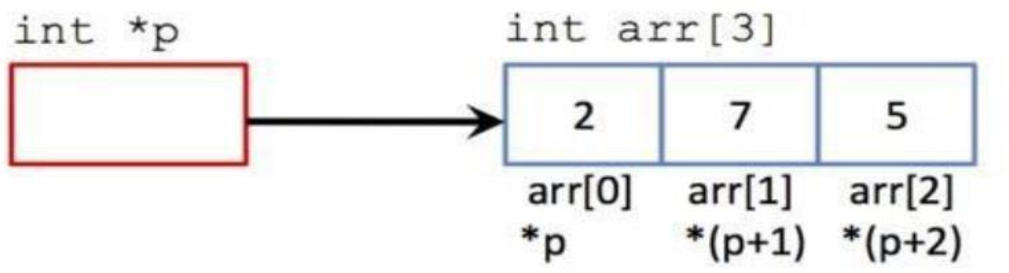


- *(p+1) = ?

  C increments the pointer based on the type of variable it points to. In the above case as it points to int, ‘p’ is incremented by 4, so we have (p+1)=0x100 and *(p+1)=7

Pointers and Arrays

- p = &arr[0];



- The symbol arr itself is a pointer to the first element of the array.
- Hence, arr[i] can also be written as *(arr+i)

Pointers and Arrays

- int arr[3]= {1,2,3}; int *p = arr;
  p is pointing to arr[0](=1);
- Step1: printf(“%d”,*p++)
  - Get value at p: 1 (output)
  - Increment p: p is now pointing to arr[1]
- Step2: printf(“%d”,*++p)
  - Increment p: p is now pointing to arr[2]
  - Get value at p: 3 (output)
- Step3: printf(“%d”,++*p)
  - Increment value at p and then print it
    - arr[2]=3+1=4(output)

Pointers and Strings

- A string in C is simply an array of char values
- So the functioning of pointers with strings is same as that with the arrays.

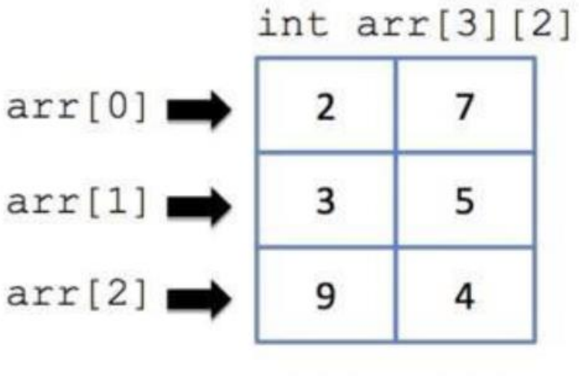
```
char strA[] =  “Ping”;
char strB[] =  “Pong”;
char *pA = strA;
char *pB = strB;
while (*pA) *pB++ = *pA++;
*pB = '\0’;;
```

Pointers and Strings

- Put the reverse of str1 into str2:

```
char str1[] = "Pointers are fun. Yeah right!";
char str2[30], *p1, *p2;
p1 = str1 + strlen(str1) - 1;
p2 = str2;
while(p1 >= str1) *p2++ = *p1--;
*p2 = '\0';
```

Pointers and Multi-Dimensional Arrays



- arr[2] is the pointer to the third row
- So, we can access arr[2][1] as *(arr[2]+1)
- But arr[2] is again same as *(arr + 2)
- So, arr[2][1] is same as *(*(arr+2)+1)
- In general, arr[i][j] is same as *(*(arr+i)+j)

Dynamic Memory Allocation

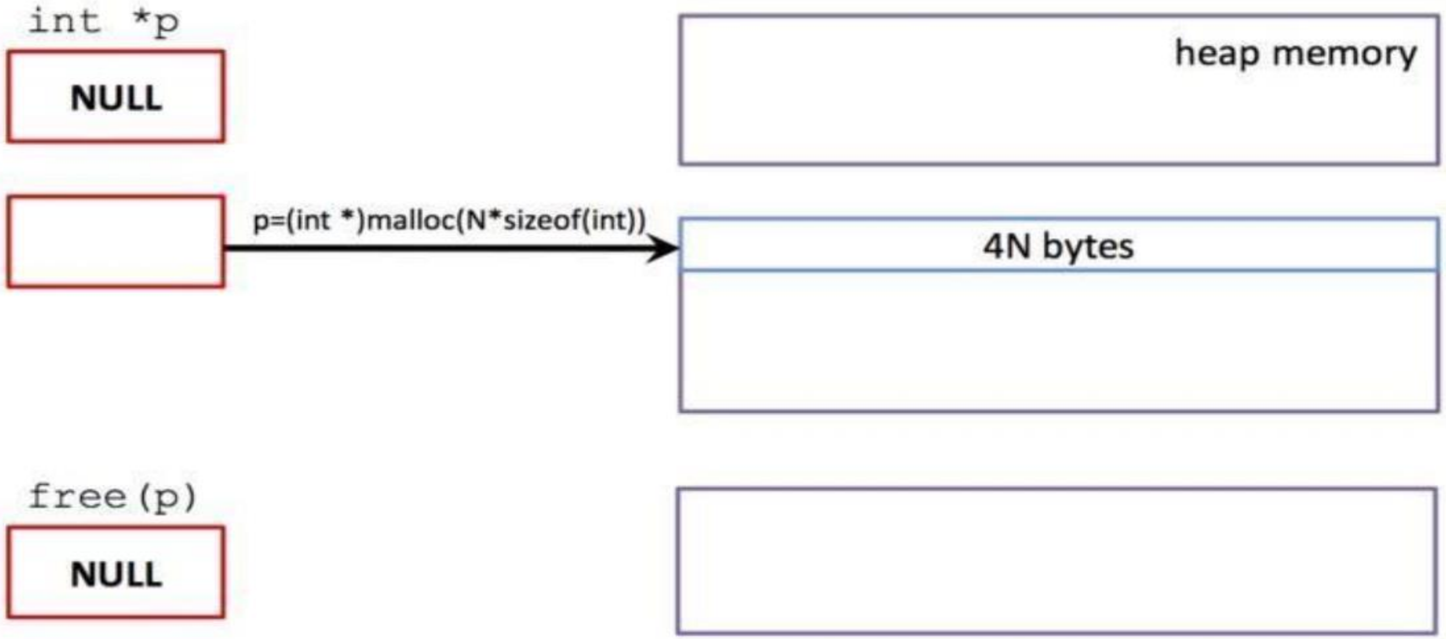
- int arr[1000];
  - sets aside 1000*sizeof(int) bytes of memory irrespective of whether you use it or not
- Instead, use malloc() to allocate memory at runtime depending on requirement
- And then when you are done using it, use free() to deallocate it
- malloc'ed memory will not be automatically freed until process exits

malloc()

- int *p = (int *)malloc(sizeof(int)*N)
  - allocates enough memory to hold N int values
  - returns the starting address of the memory block
  - we store the address in the pointer p
  - malloc() returns NULL if memory could not be allocated
- We can use *p, *(p+1), ..., *(p+N-1) to refer to the integers in the memory block
- But, *(p+i) is same as p[i]
- Effectively, we just dynamically allocated an array to hold N integers

free()

- free(p)
  - deallocates the memory addressed by p
  - It's good practice to set the pointer to NULL: p=NULL



Dynamic Memory for 2D Arrays

- Recall that each row of a 2D array can be referenced by a pointer to a 1D array
- So for 2D arrays, we need a 1D array of pointers

```
        int **p;
        p = (int **) malloc(Nrow * sizeof(int *))
```

- We just allocated memory to hold Nrow pointers, accessed as *(p+i) (or p[i])

```
        for (i=0; i<Nrow; i++)
                p[i] = (int *)malloc(Ncol * sizeof(int))
```

- Each of those pointers now points to a block of memory of size (Ncol*sizeof(int))

Dynamic Memory for 2D Arrays

- To access the integer at row i and column j, use
  - *(*(p+i)+j) or p[i][j]

- Each *(p+i) need **not** point to a memory block of same size
  - Therefore, each column of the array can be of different size

- To free the memory:

```
for (i=0; i<Nrow; i++) free(p[i]);
free(**p); p=NULL;
```

- You may also free only certain columns:

```
free(p[2]); p[2]=NULL;
```

malloc() example

```
#include <stdio.h>
#include <stdlib.h>
int main()
{
    int n, i, *ptr, sum=0;
    printf("Enter number of elements: ");
    scanf("%d",&n);                      // number of elements entered by user
    ptr=(int*)malloc(n*sizeof(int));     //memory allocated using malloc
    if(ptr==NULL) {
        printf("Error! memory not allocated.");
        exit(0); }
    printf("Enter elements of array: ");
    for(i=0;i<n;++i) {
    scanf("%d",ptr+i);                   //  array values entered by user
    sum+=*(ptr+i); }
    printf("Sum=%d",sum);
    free(ptr);                           //  don’t forget free()!
    return 0;
}
```

Makefile basics

- A makefile is simply a way of associating short names, called targets, with a series of commands to execute when the action is requested
  - Default target: make
  - Alternate target: make clean

Makefile

- Basic macro: CC=gcc
- Convert a macro to its value in a target: $(CC)
  - Ex: $(CC) a_source_file.c gets expanded to gcc a_source_file.c
- Basic makefile:

```
CC = gcc
FILES = in_one.c in_two.c
OUT_EXE = out_executable
build: $(FILES)
    $(CC) -o $(OUT_EXE) $(FILES)
```

- To execute: make build

Make clean

```
CC = gcc
FILES = in_one.c in_two.c
OUT_EXE = out_executable
build: $(FILES)
        $(CC)  -o $(OUT_EXE) $(FILES)
clean:
        rm -f *.o $(OUT_EXE)
```

- The target make clean will remove all .o files and the executable

References

- **A Tutorial on Pointers And Arrays in C:** http://home.netcom.com/~tjensen/ptr/pointers.htm
- **Essential C:** http://cslibrary.stanford.edu/101/EssentialC.pdf
- **Reading C Type Declarations:** http://unixwiz.net/techtips/reading-cdecl.html
- **C Programming Dynamic Memory Allocation** http://www.programiz.com/c-programming/c-dynamic-memory-allocation
- **Makefiles** http://www.cprogramming.com/tutorial/makefiles.html