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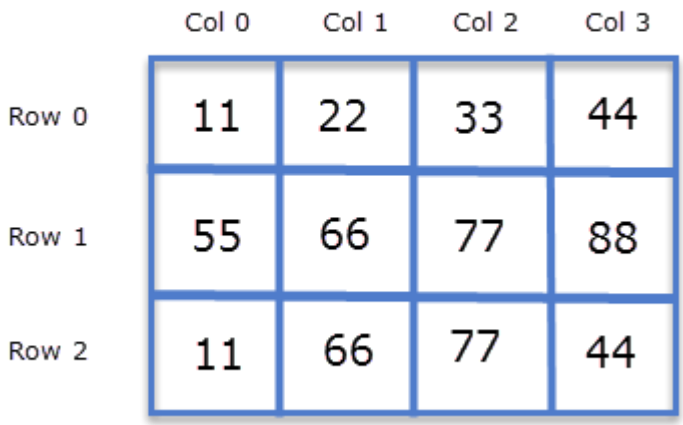
Pointers and 2-D Array

While discussing 2-D array in the earlier chapters, we told you to visualize a 2-D array as a matrix. For example:

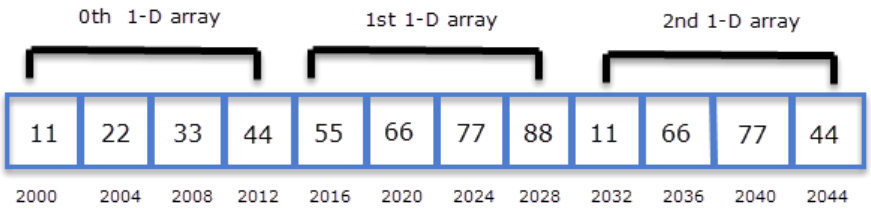
```
int arr[3][4] = {
                    {11,22,33,44},
                    {55,66,77,88},
                    {11,66,77,44}
                };
```

The above 2-D array can be visualized as following:



While discussing array we are using terms like rows and column. Well, this concept is only theoretical, because computer memory is linear and there are no rows and cols. So how actually 2-D arrays are stored in memory ? In C, arrays are stored row-major order. This simply means that first row 0 is stored, then next to it row 1 is stored, next to it row 2 is stored and so on.

The following figure shows how a 2-D array is stored in the memory.



Here is the most important concept you need to remember about a multi-dimensional array.

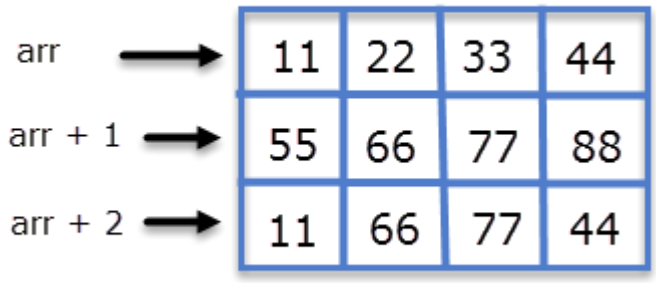
A 2-D array is actually a 1-D array in which each element is itself a 1-D array. So arr is an array of 3 elements where each element is a 1-D array of 4 integers.

Hence in the above example, the type or base type of `arr` is a pointer to an array of `4` integers. Since pointer arithmetic is performed relative to the base size of the pointer. In the case of `arr`, if `arr` points to address `2000` then `arr + 1` points to address `2016` (i.e `2000 + 4*4`).

We know that the name of the array is a constant pointer that points to the 0th element of the array. In the case of a 2-D array, 0th element is a 1-D array. So the name of the array in case of a 2-D array represents a pointer to the 0th 1-D array. Therefore in this case `arr` is a pointer to an array of `4` elements. If the address of the 0th 1-D is `2000`, then according to pointer arithmetic (`arr + 1`) will represent the address `2016`, similarly (`arr + 2`) will represent the address `2032`.

From the above discussion, we can conclude that:

`arr` points to 0th 1-D array.
`(arr + 1)` points to 1st 1-D array.
`(arr + 2)` points to 2nd 1-D array.



In general, we can write:

`(arr + i)` points to ith 1-D array.

As we discussed earlier in this chapter that dereferencing a pointer to an array gives the base address of the array. So dereferencing `arr` we will get `*arr`, base type of `*arr` is `(int*)`. Similarly, on dereferencing `arr+1` we will get `*(arr+1)`. In general, we can say that:

`*(arr+i)` points to the base address of the ith 1-D array.

Again it is important to note that type `(arr + i)` and `*(arr+i)` points to same address but their base types are completely different. The base type of `(arr + i)` is a pointer to an array of 4 integers, while the base type of `*(arr + i)` is a pointer to `int` or (`int*`).

So how you can use arr to access individual elements of a 2-D array?

Since `*(arr + i)` points to the base address of every ith 1-D array and it is of base type pointer to `int`, by using pointer arithmetic we should we able to access elements of ith 1-D array.

Let's see how we can do this:

`*(arr + i)` points to the address of the 0th element of the 1-D array. So,
`*(arr + i) + 1` points to the address of the 1st element of the 1-D array
`*(arr + i) + 2` points to the address of the 2nd element of the 1-D array

Hence we can conclude that:

`*(arr + i) + j` points to the base address of jth element of ith 1-D array.

On dereferencing `*(arr + i) + j` we will get the value of jth element of ith 1-D array.

```
*( *(arr + i) + j)
```

By using this expression we can find the value of jth element of ith 1-D array.

Furthermore, the pointer notation `*(*(arr + i) + j)` is equivalent to the subscript notation arr[i][j]

The following program demonstrates how to access values and address of elements of a 2-D array using pointer notation.

```c
#include<stdio.h>

int main()
{
    int arr[3][4] = {
                        {11,22,33,44},
                        {55,66,77,88},
                        {11,66,77,44}
                    };

    int i, j;

```

```
    for(i = 0; i < 3; i++)
    {
        printf("Address of %d th array %u \n",i , *(arr + i));
        for(j = 0; j < 4; j++)
        {
             printf("arr[%d][%d]=%d\n", i, j, *( *(arr + i) + j) );
        }
        printf("\n\n");
    }

    // signal to operating system program ran fine
    return 0;
}
```

Expected Output:

```
Address of 0 th array 2686736
arr[0][0]=11
arr[0][1]=22
arr[0][2]=33
arr[0][3]=44

Address of 1 th array 2686752
arr[1][0]=55
arr[1][1]=66
arr[1][2]=77
arr[1][3]=88

Address of 2 th array 2686768
arr[2][0]=11
arr[2][1]=66
arr[2][2]=77
arr[2][3]=44
```

Assigning 2-D Array to a Pointer Variable

You can assign the name of the array to a pointer variable, but unlike 1-D array you will need pointer to an array instead of pointer to `int` or (`int *`) . Here is an example:

```
int arr[2][3] = {
                    {33, 44, 55},
                    {11, 99, 66}
                };
```

Always remember a 2-D array is actually a 1-D array where each element is a 1-D array. So `arr` as an array of `2` elements where each element is a 1-D `arr` of 3 integers. Hence to store the base address of `arr`, you will need a pointer to an array of `3` integers.

Similarly, If a 2-D array has `3` rows and `4` cols i.e `int arr[3][4]`, then you will need a pointer to an array of `4` integers.

```
int (*p)[3];
```

Here `p` is a pointer to an array of `3` integers. So according to pointer arithmetic `p+i` points to the ith 1-D array, in other words, `p+0` points to the 0th 1-D array, `p+1` points to the 1st 1-D array and so on. The base type of (`p+i`) is a pointer to an array of `3` integers. If we dereference (`p+i`) then we will get the base address of ith 1-D array but now the base type of `*(p + i)` is a pointer to `int` or (`int *`). Again to access the address of jth element ith 1-D array, we just have to add `j` to `*(p + i)`. So `*(p + i) + j` points to the address of jth element of ith 1-D array. Therefore the expression `*(*(p + i) + j)` gives the value of jth element of ith 1-D array.

The following program demonstrates how to access elements of a 2-D array using a pointer to an array.

```c
#include<stdio.h>

int main()
{
    int arr[3][4] = {
                        {11,22,33,44},
                        {55,66,77,88},
                        {11,66,77,44}
                    };

    int i, j;
    int (*p)[4];

    p = arr;

    for(i = 0; i < 3; i++)
    {
        printf("Address of %d th array %u \n",i , p + i);
        for(j = 0; j < 4; j++)
        {
            printf("arr[%d][%d]=%d\n", i, j, *( *(p + i) + j) );
        }
        printf("\n\n");
    }

    // signal to operating system program ran fine
    return 0;
}
```

Expected Output:

```
Address of 0 th array 2686736
arr[0][0]=11
arr[0][1]=22
arr[0][2]=33
arr[0][3]=44

Address of 1 th array 2686752
arr[1][0]=55
arr[1][1]=66
arr[1][2]=77
```

```
arr[1][3]=88

Address of 2 th array 2686768
arr[2][0]=11
arr[2][1]=66
arr[2][2]=77
arr[2][3]=44
```