Introduction to Programming in C
Department of Computer Science and Engineering

In this video, we will look at the relation between Multi-dimensional Arrays and Pointers.

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And this is by for one of the trickiest topics in the entire course.

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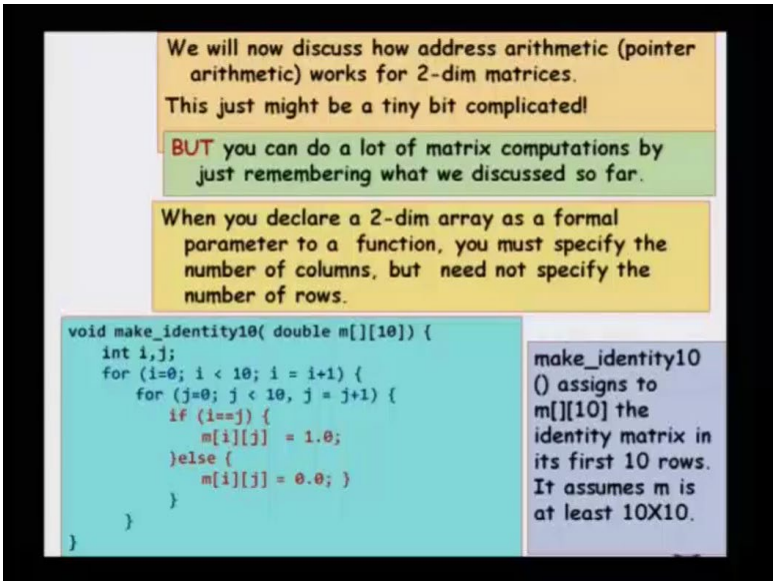

And you can code multidimensional arrays without actually understanding the exact relation between multidimensional arrays and pointers. But, understanding this gives you a better grasp of how C treats multidimensional arrays. So, we will now discuss how pointer arithmetic works with two dimensional matrixes. Because, as soon as we had discussed one dimensional matrix, the next thing we did was we discussed the relation between pointers and 1D arrays.

So, let us try to see what is the relation between pointers and 2D arrays. Now, this is more complicated than it looks at first sight. And you can do a lot of matrix computations by not understanding this. Except that, understanding this gives you a better grasp for what is happening. We have seen that, when you declare a 2D array as a parameter to a function, then you should specify the number of columns, but not the number of rows.

So, let us look at a function which makes an identity matrix, an identity matrix is a matrix that has one along it is diagonal and zero every where else. So, we have void make_identity10(double m[ ][10]). Since, identity matrixes are square matrixes, this essentially says that the code will work for a 10 × 10 matrixes.

Then, I have a for loop going from i = 0 to 10 and a for loop going from, for the columns going from j = 0 to 10. And the code just says that, if I am at a diagonal element that is i = j, then m i j is 1 for all other elements, m i j is 0. So, this creates a matrix of size 10×10.

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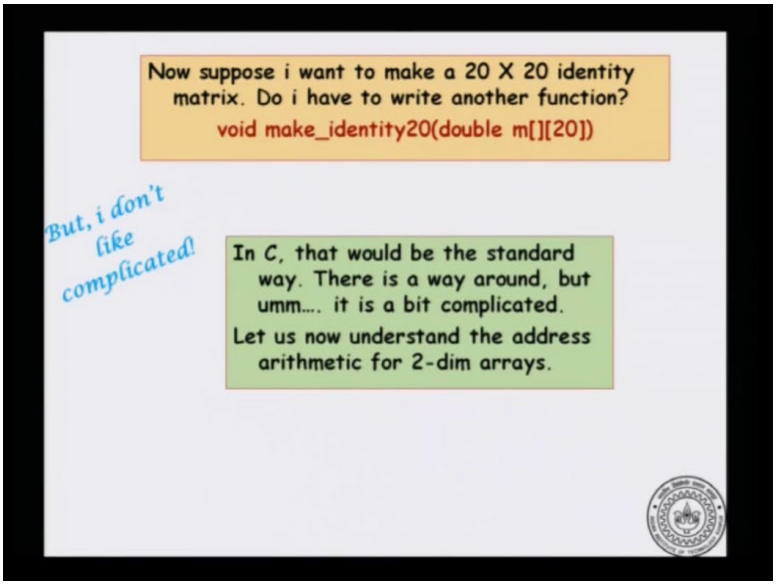

Now, this is a very strange code. Because, it is a function that essentially makes exactly one matrix. It would have been nice, if I would have a function that can create arbitrary size identity matrixes. For example, if I wanted a 20×20 matrix, it looks like, I have to write another function make_identity20(double m[ ][20]), the rows are unspecified, the number of columns is 20.

This is the standard way to do it. But, there is a slightly more complicated way to actually accomplish a function which can take an arbitrary size. So, let us see how these things can be done by understanding, how pointer arithmetic works with 2D arrays.

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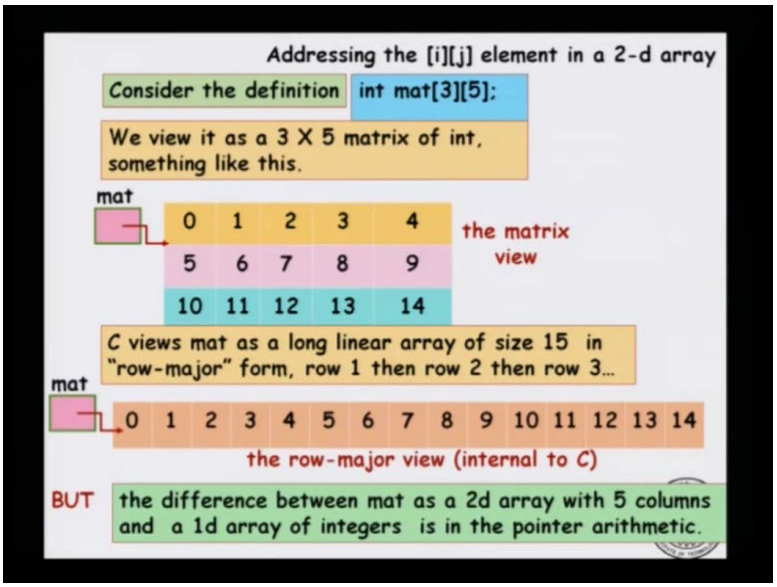

So, let us go back to, how do I address the i j th element in a 2D array? Now, we can view it as a 3 × 5 matrix of integers, something like this. So, it may be an array 0 1 2 3 4, that is row 0 and 5 6 7 8 9, that is row 1, 10 11 12 13 14, that is row 2. So, this is the matrix view which is 3 rows, each with 5 columns, this is the standard view. But, internally C views this as a long linear array of size 15, in what is known as the row major form.

So, let us just look at what it is? Internally, C looks as loops at the array in the following form. It is basically C 0 through 14, lead out in a single row. So, this is the row major view, it is called row major, because first all elements of row 0 will be lead out, then all elements of row 1 will be lead out. And finally, all invents of the lost row will be lead out. But, it is lead out as a linear way.

Now, the natural question to ask is, in that case is a 2D array really at the heart of just a 1D array. So, the difference between a 2D array seen in the row major view point and an actual one dimensional array will come in the pointer arithmetic.

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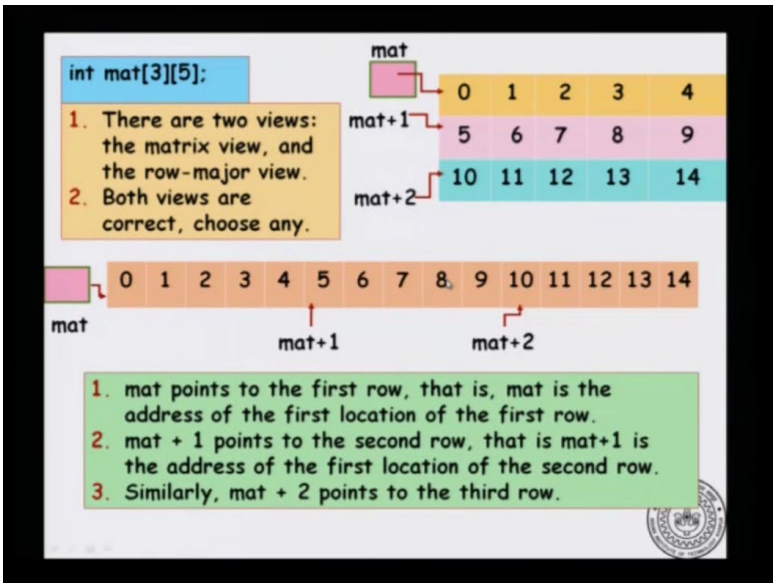

So, as I just mentioned there are two views, the matrix view and the row major view and both views are correct. So, if I have the matrix view, mat is a pointer to the first row. So, mat + 1 will be a pointer to the second row and mat + 2 will be a pointer to the third row. So, row number 3 or row indexed with 2, in the row major view point, here is the difference mat points to the first row and mat + 1 should point to the second row.

So, we cannot say that mat is pointing to the first element here and mat + 1 should point to therefore 1. Now, that is not what happens? It has to be consistent with the matrix view. So, the pointer arithmetic mat + 1 should point to the same element, regardless of whether you are looking at it using the matrix view point or whether you are looking at it using the row major view point. So, mat + 1 will still point to 5 and mat + 2 will still point to 10. So, these two view points are consistent.

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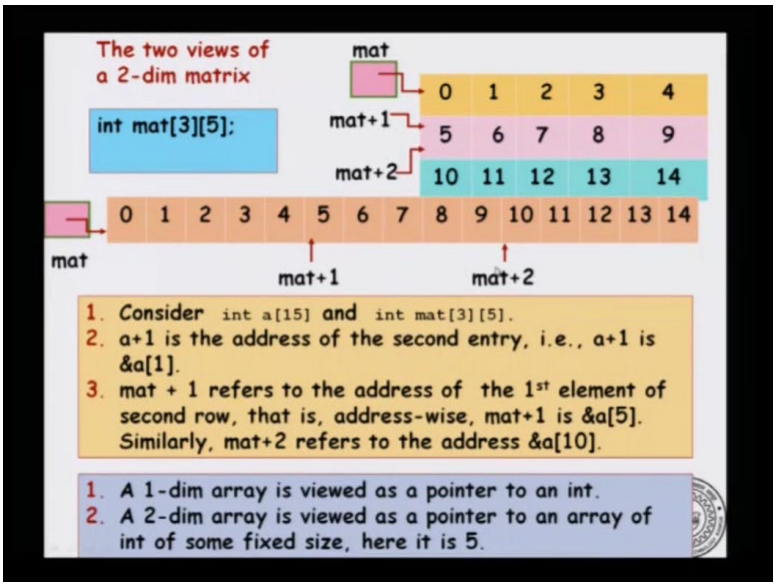

Now, here is the difference with one dimensional arrays. So, we have just repeated the viewpoints here, the matrix view point and the row major view point. Now, had mat actually being a one dimensional array, mat would point to the first element in the array. Therefore, mat + 1 which should point to the second element in the array. So, that is not what happens, it is actually the row major representation of a 2D array and mat + 1 should skip exactly 5 elements, because that is the size of the column.

So, mat + 1 should skip 5 elements and go to the element mat 1 0. So, here is we just of why you need to know the number of columns? Because, in the row major view point I have to implement mat + 1. So, I have to say how many elements should I skip, in order to get to the first element of the second row? And that number is exactly the number of columns in the array. So, the number of columns in the array is 5. So, to get to mat plus from, from mat, I would to skip 5 elements.

Similarly, to get to mat + 2 from mat + 1, I would to skip exactly 5 elements. So, this is the reason why the number of columns is an important information. Because, that tells me in the row major representation, how many elements do I have to skip in order to get to the correct entry in this second row or third row? So, here is the pointer arithmetic for the row major representation. And notice that, this is considerably difference from the pointer arithmetic for a 1D array, in a 1D array, array + 1 will go here, the first element of the array.

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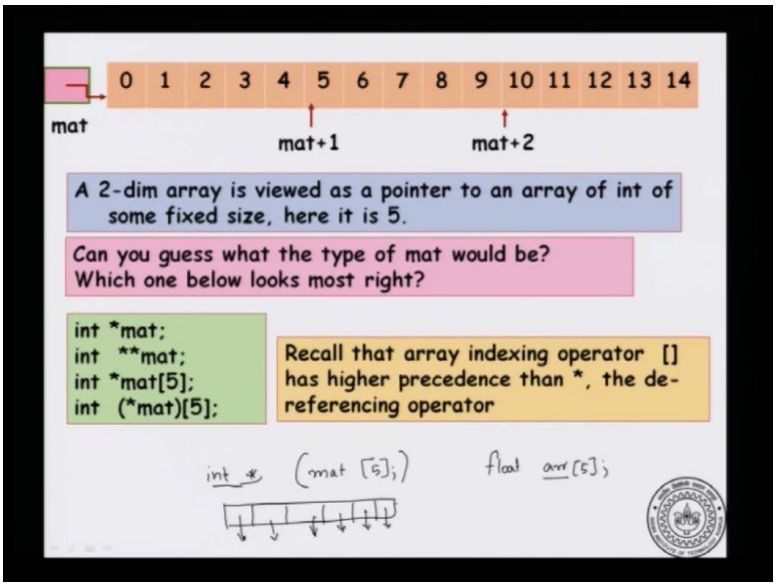

Now, can you try to guess what will be the type of mat? So, here are four candidates and let us go through them to see, what is the most likely candidate? And we will see this in a greater detail, int *mat, mat is a pointer to int. Now, we have seen that, that is approximately an array of integers and that is definitely incorrect. Because, this is supposed to be a 2D array, not an array of integers. Pointer to pointer to mat, we have an seen that so far and that looks like a likely candidate.

So, what about the third and the fourth? The third and the fourth looks confusingly similar. What do they mean? So, here is a hint, the array indexing operator [ ] has higher precedence than *, the dereferencing operator. So, in this case the first says that, so what is this mean? The first declaration is actually int *mat[5] and the second declaration is int (*mat)[5]. So, what does this say?

So, let us compare with the standard declaration like float arr[5]. This means, that array is arr is an array of size 5, each entry of type float. Similarly, this means the matrix mat is an array of size 5, each entry being a pointer to integer. So, it will be some matrix like this, it has five elements and each of them is a pointer. So, here is the view point for declaration 3. Now, what about declaration 4?

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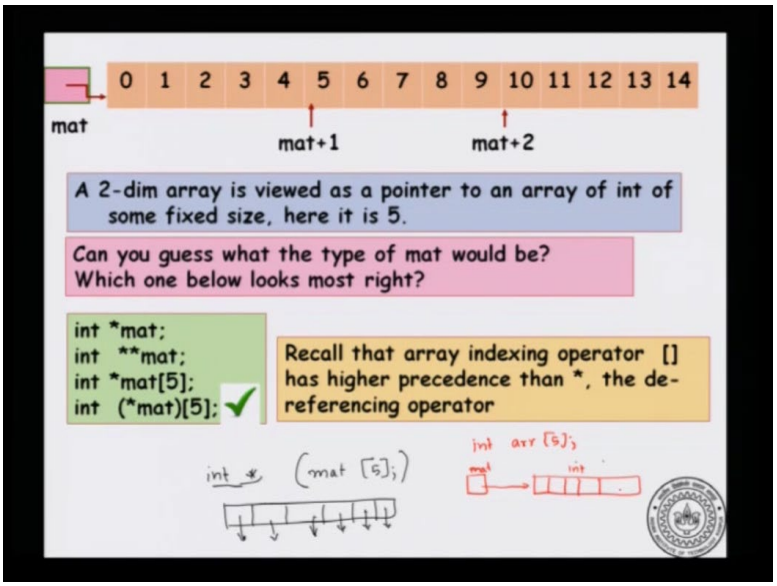

So, there let us see this, so let us compare it with a standard declaration like, let us take a standard declaration like int arr[5]. Again, this says that arr is an integer array of size 5. So, it contains 5 elements, each of type int correspondingly, what this means is that *mat is an integer array. So, here is an integer array containing 5 elements, these are integers. Now, this means that if we deference mat. So, mat is a pointer to an array of size 5 and this is exactly the actual representation of a two dimensional array.

So, notice the difference between these two representations, the first says that mat 5, mat is an array of 5 entries and each entries is a pointer to an int, so it look like this. So, it is an array of 5 pointers to int. The lost declaration says that, *mat is an array of int of size 5. So, mat is a pointer to an array of integers of size 5. So, here is the difference and we will argue that the fourth definition is essentially what we want and we will see this in a greater detail.

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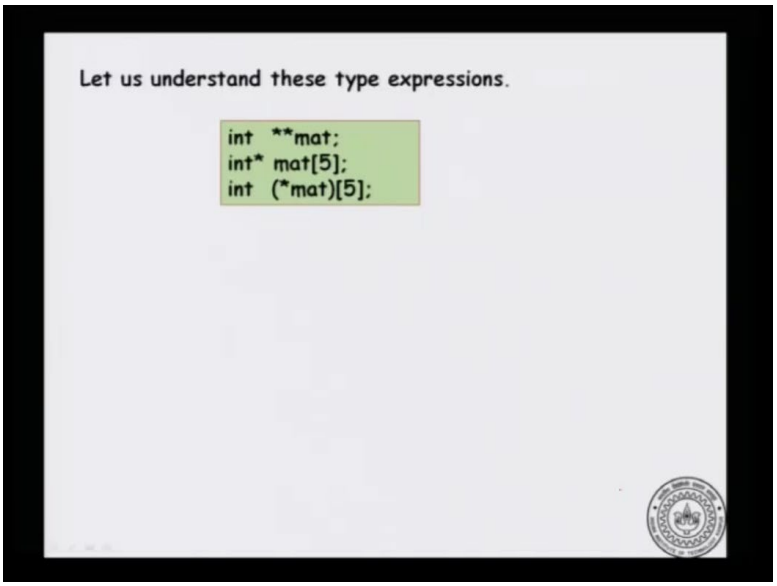

So, let us understand these type expressions in greater detail and we will see this in the further video also. We particularly pick on one representation here. So, we have argued that the 2D array is similar to the last declaration here, I eliminated the most obviously wrong declaration, which is in *mat, that is basically a one dimensional array. So, I have just eliminated that, we will examine all the others.

What I have just said is that a 2D array is similar to the last declaration. But, even the previous two declarations do make sense. And there may be situations, where you need to use such variables. Let us examine them in greater detail.

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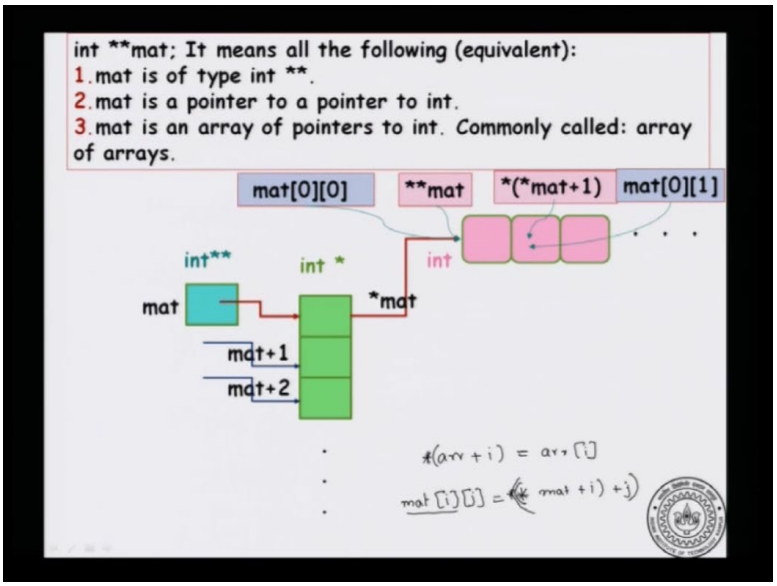

So, let us look at the first one which is int **mat and it means all of the following equivalent ways. So, all of these are an equivalent ways of looking at the same thing. You could say that a matrix of type int ** or you could say that matrix is a pointer to a pointer to an int. Since, arrays are pointers approximately, you could also say that mat is an array of pointers to int and this is also commonly called array of arrays.

So, you have mat int **. Now, this is a pointer to an array of integers. Now, every pointer to an int is essentially a pointer to an array, you can look at it like that. So, you can say that mat will point to an array of pointers and this array of pointers, each of them may point to a different array. So, you dereference mat once, you will get a pointer to an integer and again you deference once more, you will get the actual array.

So, what happens when I do mat + 1? It will go to the second entry in the array of integers. Now, that may be a different array all together. So, mat[0][0] is similar to **mat, this is just a way, address arithmetic works. And both of them are addresses, both of them are pointing to this location, both of them mean the content of this location. Similarly, *(*mat + 1) = mat[0][1]. So, in the case of one dimensional arrays we have just mentioned the equation that arr[i] is the same as *(arr + i).

And what we are saying here essentially is that, mat[i][j] is the same rule applied twice. So, I could say mat[i] = *(mat + i). So, that will give me an array and then, I need the jth

element of that. So, you can again do *(*(mat + i) + j). So, these are two ways of looking at this array.

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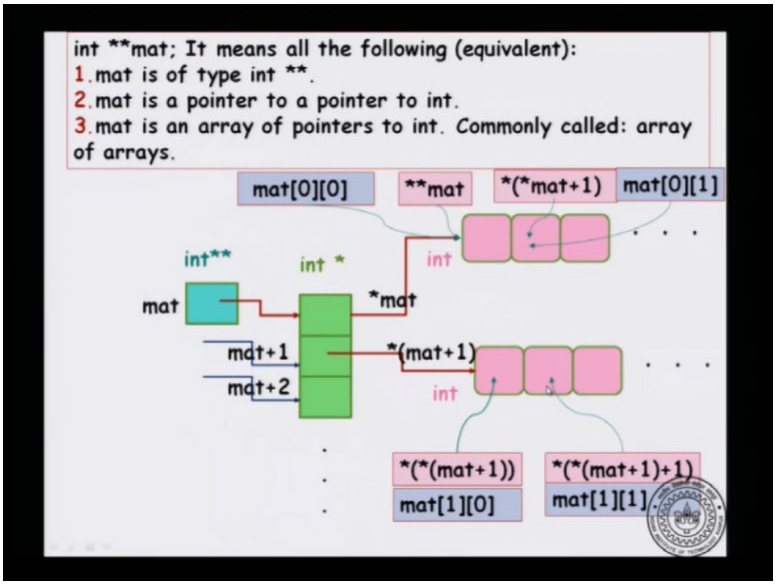

So, mat + 1 will be the next element in the pointer to integers and it is the same as and when you deference it, you will get another array. So, in order to get the first element of this array, I could say mat[1][0] or using the pointer notation, I have *(* mat + 1), these are the same and similarly for other elements of the array. So, one of the advantages of this kind of int **mat is that, I have freedom in both dimensions.

You can see these as the rows of a matrix and these as the columns of a matrix. If you see that, then you can see that I have a lot of freedom here, first of all the number of rows is not limited. Because, it is just int **mat, I could have any number of rows here. Now, another main advantage and the reason why this is somewhat popular is that, the length of row 0 need not be the same as the length of row 1, these are just pointers to integers.

So, the first pointer to integer may be pointing to a row of size 2, the second pointer may be pointing to a row size 3 and so on. So, the row lengths need not be the same. So, think of an array where row 0 is two elements long and row 1 has three elements in the row and so on. So, if you have extremely ragged arrays, then int **mat is a nice representation to take.