Introduction to Programming in C
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In this video, we will *t with a topic that is considered one of the trickiest concepts in C. These are what are known as pointers. We will just recap what we know about arrays, because arrays and pointers are very closely related in C.

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The memory allocated to array has two components:

A consecutively allocated segment of memory boxes of the same type, and

A box with the same name as the array. This box holds the address of the base (i.e., first) element of the array.

OK, Consider the definition.

int num[10];

num num[0]num[1]num[2] num[9]

too much theory. Give examples please

This definition for num[10] gives 11 boxes, 10 of type int, and 1 of type address of an int box.

Hmm...

1. We represent the address of a box x by an arrow to the box x. So addresses are referred to as pointers.
2. The contents of an address box is a pointer to the box whose address it contains. e.g., num points to num[0] above.

The memory allocated to any array has two components. First is there are a bunch of consecutively allocated boxes of the same type. And the second component is there is a box with the same name as the array. And this box contains the address of the first element of the array. So, that let us be clear with the help of concrete example. So, let us consider a particular array of size 10 declared as int num[10]. Conceptually, there are 10 boxes from num[0] through num[9]. These are all containing integers. Plus there is an additional eleventh box – num. So, it has the same name as the name of the array. And it contains the address of the first location of the array. So, it contains the address of num[0]. These are num[0] through num[9] are located somewhere in memory. So, maybe this is memory location 1000. So, num contains the number 1000, which is supposed to indicate that, the address of the first location in the array is 1000 or num points to the memory location 1000. So, conceptually, this gives 11 boxes, which are 10 integer boxes plus 1 box, which holds the address of the first box.

Now, we represent the address of a box x by an arrow to the box x. So, addresses are referred to as pointers. And this is all there is to C pointers. Pointers in some sense are variables, which hold the addresses of other variables. That is an exact description of the concept of pointers. Now, we will see now what that means and what can we do with pointers.

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What can we do with a box? e.g., an integer box?

int num[10];

That's simple. We can do operations that are supported for the data type of the box.

For integers, we can do + - * / % etc. for each of num[0] through num[9].

True!. But we can also take the address of a box.We do this when we use scanf for reading using the & operator.

OK. Say i want to take the address of num[1] and store it in an address variable ptr.

ptr = &num[1];

But what is the type of ptr? And how do i define ptr?

ptr would be of type address of int. In C this type is int *.

```
int * ptr;
ptr= &num[1];
```

Let us just step back a minute and say what can we do with a particular box or particular variable in memory, which is an integer. So, that is very simple. For example, you can scanf into that box; you can print the value in that box; you can do arithmetic operations on that box like plus, division, %, and so on. And you can do this for each of the boxes from num[0] through num[9], because each of them by itself is in integer. But, we will also see a new operation, which is that, you can take the address of a box. So, we have already done this when we did scanf. So, we mentioned & of a variable. So, we will see these & operator in somewhat more detail.

So, suppose I want to take the address of num[1] and store it in an address variable ptr. So, what I am essentially saying is that, you can say ptr = &num[1]. So, num[1] is an integer box; it is an integer variable; & of num[1] is the address of that integer in memory. So, you assign it to the variable ptr. But, every variable in C needs to have a type. What is the type of ptr? And how do you declare or define such a type – such a variable? Now, ptr holds the address of an integer. In C, you denote that by saying that, the type of ptr is int *. So, here is a new type that we are seeing for the first time. We are saying ptr is of type int *. Just like you can say that, if I have int a, you can say that, a is of type int. In this case, we can say ptr = &num[1].

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To see the meaning of ptr =&num[1], let's look at the memory state.

```
int num[10];
int * ptr;
ptr = &num[1];
```

Here is the state after int num[10] gets defined.

OK, ptr is of type pointer to integer. But what does ptr = &num[1]; mean?

num

num[0] num[1] num[2] num[9]

ptr

The statement int *ptr; creates a new box of type "address of an int box", more commonly referred to as, of type "pointer to integer".

The statement ptr = &num[1]; assigns to ptr the address of the box num[1]. Commonly referred to as: ptr now points to num[1].

We have discussed right now we have int num[10], int *ptr, and ptr = &num[1]. So, ptr is the pointer to an integer. But, what does ptr = &num[1] really mean? So, let us look at the memory status once we declare this array. So, we have num, which is the address of the first location. And then we have somewhere in memory, we have 10 consecutive locations corresponding to the array – num[0] through num[9]. Now, I declare int *ptr. So, I create a box. Now, this box is supposed to hold the address of some integer variable. So, ptr is of type address of an integer box or more commonly referred to as pointer to integer. The statement ptr = &num[1] says that, now, points to num[1] or ptr contains the address of num[1]. And pictorially, we denote an arrow from ptr to num[1] just like I denoted an arrow going from num to num[0], because the name of the array is a pointer to the first location of the array. The name of the array is a box, which holds the address of the first location of the array. Similarly, ptr is a box, which holds the address of num[1]. So, we say that, ptr points to num[1]. And we denote it pictorially by an arrow.

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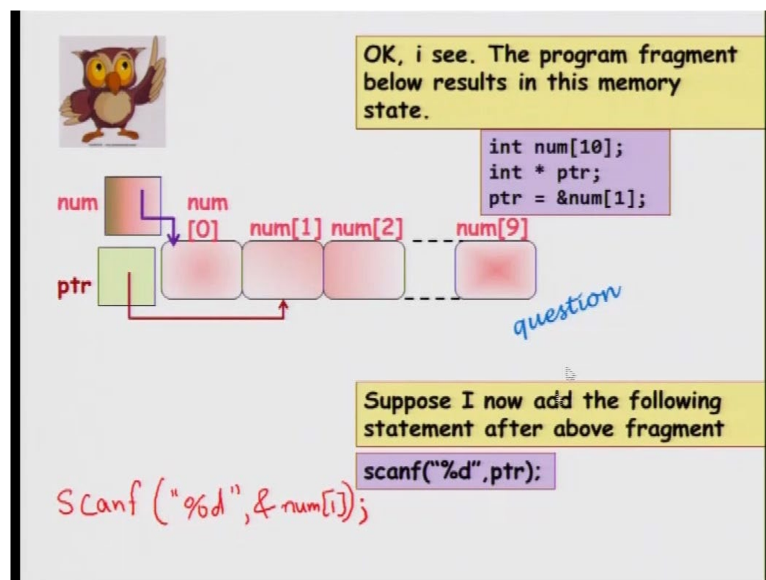

The program status is like this – state is like this. Now, suppose I add one more statement after all these three statements; I say scanf("%d",ptr). Now, earlier when we declared an array and we read into an array directly, I said that, you can do the following. I can write scanf("%d",&num[1]). So, this will value whatever the user input into the first array

using the & operator. Now, ptr = &num[1]. So, it is a reasonable thing to ask – can I say scanf("%d",ptr)? There is no & operator here because ptr is &num[1]. This was our original statement and this is our new statement.

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OK, i see. The program fragment below results in this memory state.

```
int num[10];
int * ptr;
ptr = &num[1];
```

num
num [0]
num[1]
num[2]
num[9]
5
ptr
question

1. Yes! scanf("%d",ptr) reads input integer into the box pointed to by the corresponding argument.
2. The box pointed to by ptr is num[1].
3. So num[1] becomes 5.

Suppose I now add the following statement after above fragment

scanf("%d",ptr);
Input
and input is :
5
Does num[1] become 5?

And the answer is yes, you can do it. Suppose the input is 5, does num[1] become 5? So, scanf("%d",ptr) really does work like scanf("%d",&num[1]). So, it reads the value input by the user and it looks up ptr. So, it is an address. So, it goes to that address and stores it there. So, now, we can clarify a long standing mystery, which is the & operator in the case of scanf. So, we can say that, scanf second argument is a pointer; which says where should I put the input by the user? For example, if I have float variable and I scanf as %f and then sum address of a float variable, it is done similar to reading an integer into an integer variable. What scanf takes is an address of int variable or float variable as it may be. If you have a %d, then it takes a pointer to an integer variable and takes the input value by the user and puts it into that address. So, as far as scan f is concerned, it does not matter whether you gave it as &num[1] or whether you initialized ptr to &num[1] and then gave ptr. It is an address and it will put the integer input by the user into that location. So, num[1] indeed does become 5.

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num
num [0] num[1] num[2] ... num[9]
ptr
5

num is of type int [] (i.e., array of int). In C the box num stores the pointer to num[0]. Internally, C represents num and ptr in the same way. So the type int * can be used wherever int[] can be used.

Well, what else can you do with ptr?

Here are the interesting parts! You can
1. de-reference the pointer.
2. do simple arithmetic + - with pointers.
3. compare pointers and test for ==, <. > etc., similar to ordinary integers.

What's so interesting? Please give examples.

So, the location of the num[1] is now containing the value 5. Now, what else can you do with a pointer? Num is an array; it is of type int [ ] – pair of square brackets. And in C, the box num contains the address of the first location of the array, which is num[0]. So, internally, as far as C is concerned, the address of num[0] is just like address of any other integer location. So, the type int * can be interchanged with int [ ]. So, you can think of num itself as just a pointer to an integer; or, you can say that, it is a pointer to an array; which gives you the additional information that, the next 10 values are also integers. If you just say pointer to an integer, the next location may be something else. But, internally as far as C is concerned, an array name num can also be treated as pointer to an integer.

Now, here are some other interesting things that you can do with pointers. Whenever you declare a data type, you also define what all operations can you do with a date type. So, 2 and 3 are fairly simple; we have already seen it with integers, floating points and so on. You can do simple arithmetic + and - with pointers. You cannot do * and /. You cannot do that. But, you can do + and -. Similarly, if you have two pointers, you can test for = =, you can test for <, you can test for > and so on as though you are comparing ordinary integers. So, 2 and 3 are what we have seen before; except that, in 2, you cannot do multiply and / and %. All these things are not done with pointers. But, addition and

subtraction can be done. But, there is a new operation, which is dereferencing a pointer. We have not seen this operation before with earlier data types.

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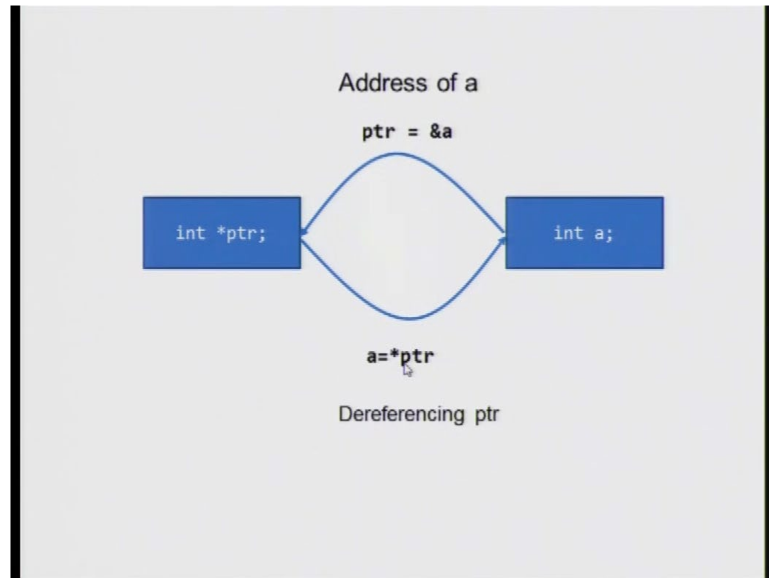

What is dereferencing? Let me pictorially represent what it does. Suppose you have int *ptr and int a. So, a is an integer variable and ptr is a pointer to int. If I want to store the address of a int ptr, I do it as follows: ptr = &a. So, this means that, take the address of a and store it in ptr. So, now, you can say that, ptr points to a. Now, I can also think of a reverse operation; which is ptr contains some address. Go look up that address; so that will be an int. And store that value in int.

So, that is what is known as the * operator – a = *ptr. This means that, ptr is an integer pointer. So, ptr will point to a location, which contains an integer. *ptr will take the contents of that location and store it in a. So, this is known as the dereferencing operator. So, the address operator takes an integer variable and stores the address in a pointer. The dereferencing operation takes a pointer; looks up that address; and stores the value in a. So, you can visualize the & operator and the * operator as sort of reverse operations of each other. & takes an integer and takes the address of that; * takes a pointer and takes the value of the address pointed to that.

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num num[0] num[1] num[2] num[3] num[4] num[9]

10

ptr 5

De-referencing a pointer ptr gives the box pointed to by ptr. The de-referencing operator in C is *.

Hmm...

printf("%d", *ptr); Output 5

Since ptr points to num[1], *ptr is the box num[1]. Printing it gives the output 5.

Consider statement *ptr = *ptr + 5;

This will add 5 to the value in box pointed by ptr. So num[1] will become 5+5 = 10

Dereferencing a pointer therefore gives you the value contained in the box pointed to by the pointer. The dereferencing operator is *. So, if I say printf %d * pointer, what it will do is – look up the location pointed to by ptr. In this case, it is this integer box. The contents of that box is 5 and it will be printed. So, the output will be 5. Not for example, the content of ptr. So, the content of ptr may be like 1004; it will not print 1004; but what it is supposed to do is look up the location 1004; it contains the value 5; print that value. So, *ptr is the box num[1]. And printing it gives you the output 5.

Now, can I consider a statement like *ptr = *ptr + 5? This is perfectly legal. What this will do is *ptr is an integer value. It is equal to 5, because look up this location ptr; that is an integer; take that value; which will be 5. So, this will be 5 + 5 – 10. And where do you store it? You store it in the integer variable corresponding to *ptr. The integer variable corresponding to *ptr is num[1]. So, I would have normally said num[1] equal to *ptr + 5; but num[1] is the same as *ptr. So, I can say *ptr = *ptr + 5. So, this will look up that location; add 5 to its contents; and store it in that location. So, num[1] will now become 10.

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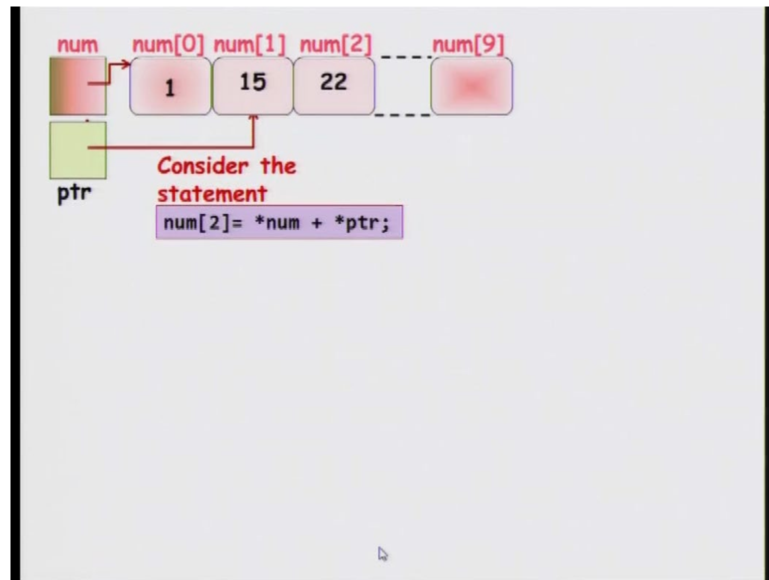

Similarly, you can consider other examples. For example, I can consider a statement like num of 2 equal to *num + *ptr. The novelty here is that...