Programming in Modern C++
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Lecture 41
Input-Output: File Handling in C

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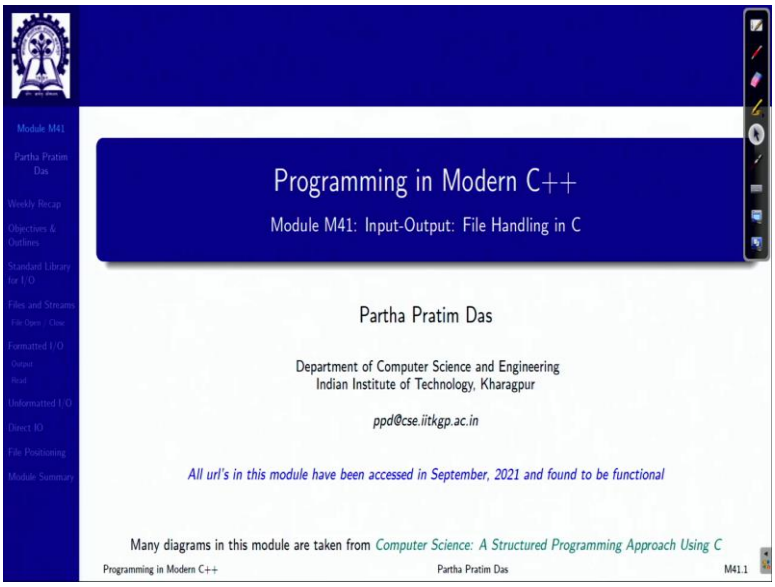

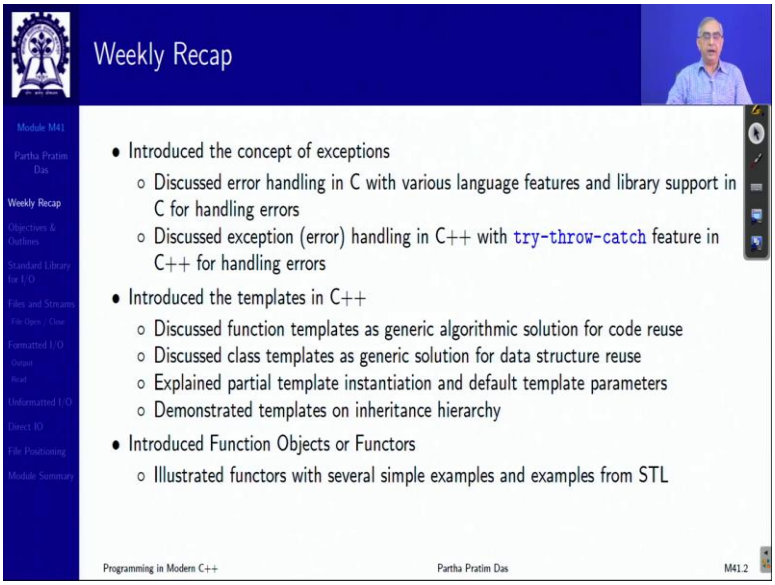

Welcome to Programming in Modern C++. We are in week 9 we are starting it with Module M41. In the last week, we have discussed some key concepts of C++ particularly in terms of exceptions and error handling, introducing the try throw catch mechanism. We introduced generic programming or meta programming through templates in C++. And we specifically took a look at a special type of objects or classes called function objects or functors. And there we will see extensive use of those in the modules coming hereafter.

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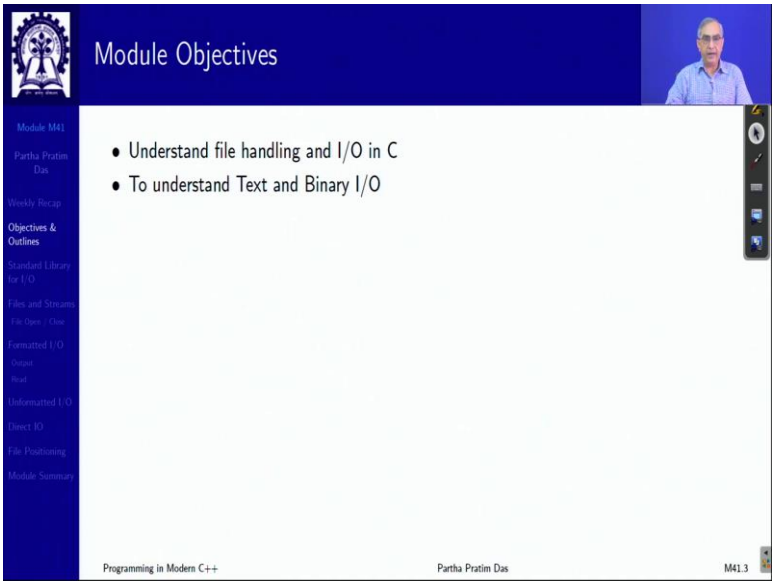

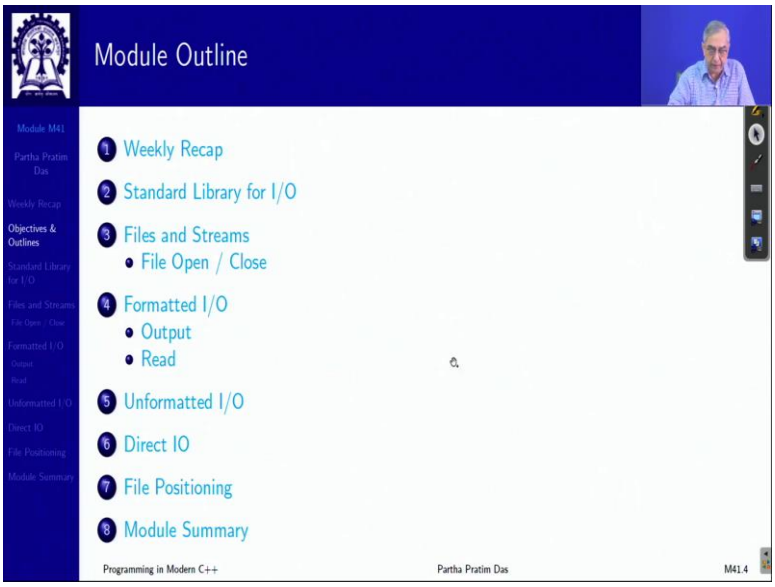

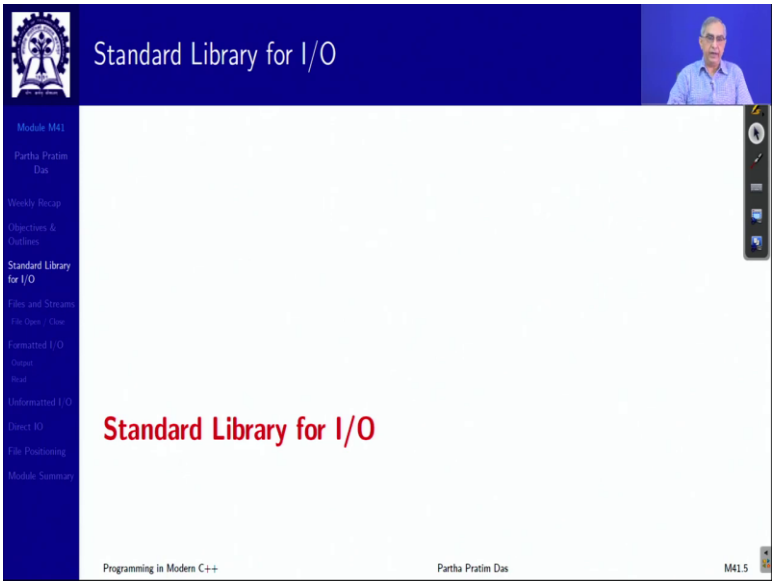

In the module today, we are going to discuss about file handling and input output in C and particularly understand the text and binary input output, how it is to be done in C? This is an outline and will be available on the left pane as always. So, in C, the language by itself does not have any support for input output, input output is provided totally in terms of C standard library.

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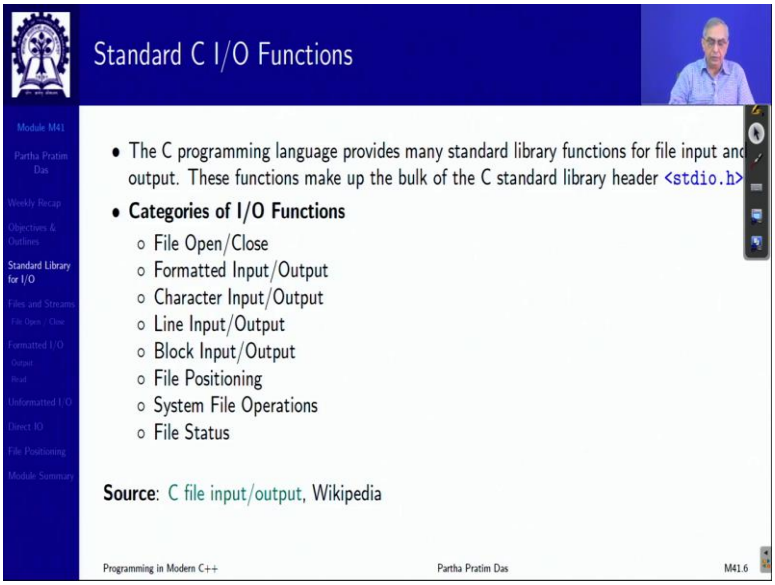

And you know that it has a header stdio standard io.h which needs to be included in a source file for doing any kind of file or terminal or printer input output operations. It provides many functions and the functions can be broadly categorized in terms of opening and closing files, formatted as well as unformatted input output, block input output, file positioning, certain checking of file status, system file operations and so on. There is a long list and we will discuss some of the representative functions here which are more commonly used in regular programming.

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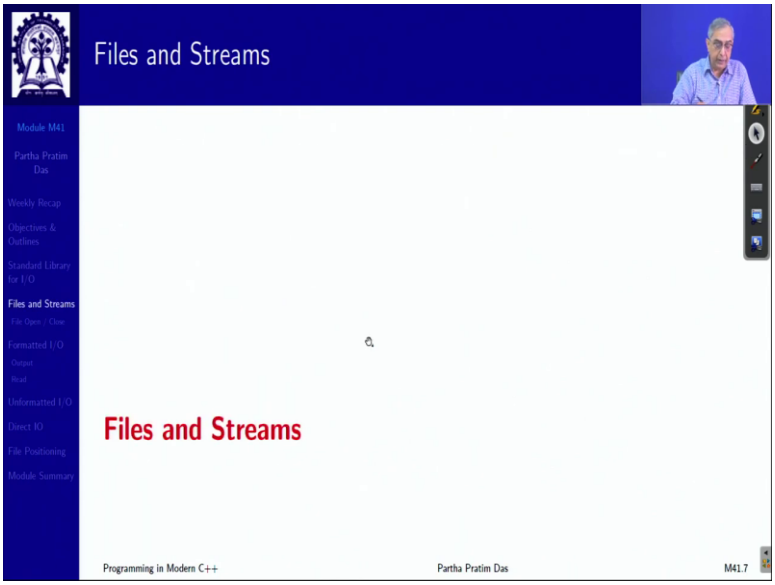

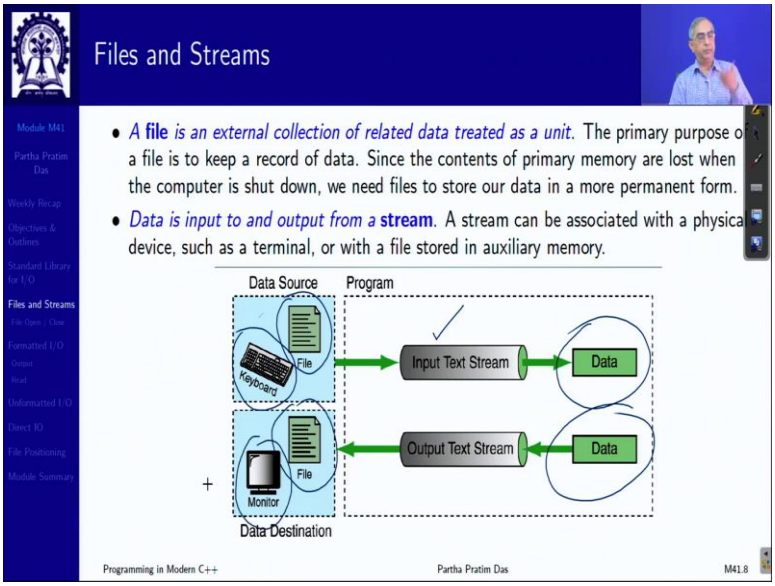

So, the first thing we introduce here is what is file and what is stream? The basic notion of stream is very critical. And actually C was a pioneer in introducing the concept of stream which eventually got imbibed into Unix and it is all there everywhere. We understand what is a file, it is an external collection of related data, which is treated as a unit and more often a file is treated as a sequential data structure, which means that starting from the beginning of the file, you can keep on moving forward reading or writing and you get the subsequent data elements that exist, though it is possible to treat it, also as a kind of random access by positioning the particular reader.

Now, stream in contrast is kind of an abstract concept, which the name naturally derives from the natural English word of stream which keeps on flowing. So, it is something which can be associated with a physical device like a terminal or a printer or a file stored in the auxiliary

memory. So, when we have for example, these input devices like key board or a file, then from that we create an input text stream, because these are input devices, and that brings in the data into the memory.

Similarly, the other way, if the data residing in the memory can be put through the output text stream, which is kind of a continuous one in this, in a stream you do not go back, you just keep on doing things forward. And that can be subsequently stored in a file or displayed in a monitor or maybe printed on a printer and so on.

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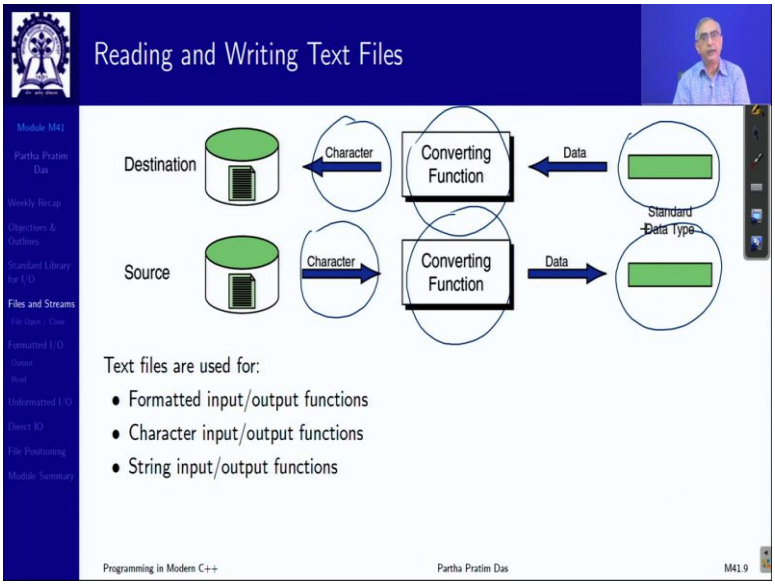

Now, how do we read or write text files? We are already familiar to a good extent doing it particularly on the console. So, for doing a text file, we have the data represented in some standard in the form of some standard type, it could be an integer data, character data, string data and so on. So, you take that and you apply a conversion function, a conversion function, So, that the data can be suitably represented as a sequence of characters.

This is important, because a text file is simply a sequence of characters and then you put that in your destination or the or in the reverse direction if you have a text file which is a sequence of characters, you take each character one by one and then apply the appropriate conversion function you are you will be more familiar with this in the name of Format Specification and convert that into a form which is representable in the memory according to the corresponding type and you stored that in the type.

So, this is the basic idea they have of doing io with a text file, it can be used for formatted input output or unformatted ones like character input output or even free input output can be done with the text files.

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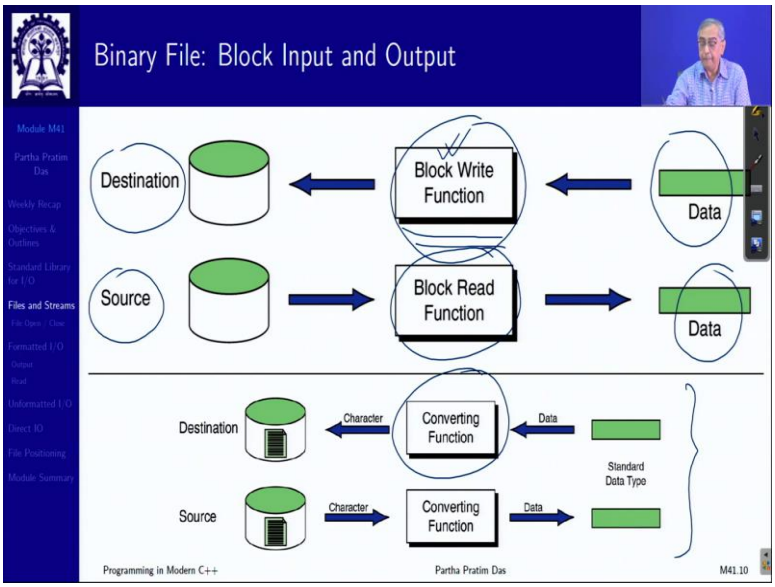

The other form of input output which is available through the C standard library function are kind of direct or block input output. So, you have the data represented in the memory as before, then you have a block write function, that is it checks takes the data as the chunk as it exists and puts it to the destination, and the difference here is it is not unlike here below is what you do for the text file. So, unlike doing a conversion, it is not doing a conversion it takes the data in the binary form and puts it to the destination directly without trying to do any kind of conversion.

So, this could be formatted, this could be unformatted, this could be written simply in the binary form and so on. Similarly, the reverse happens from a source, you do a block transfer of whatever bit patterns you get, and put that in the memory. So, these are the two broad types of input output that is available in terms of C functions.

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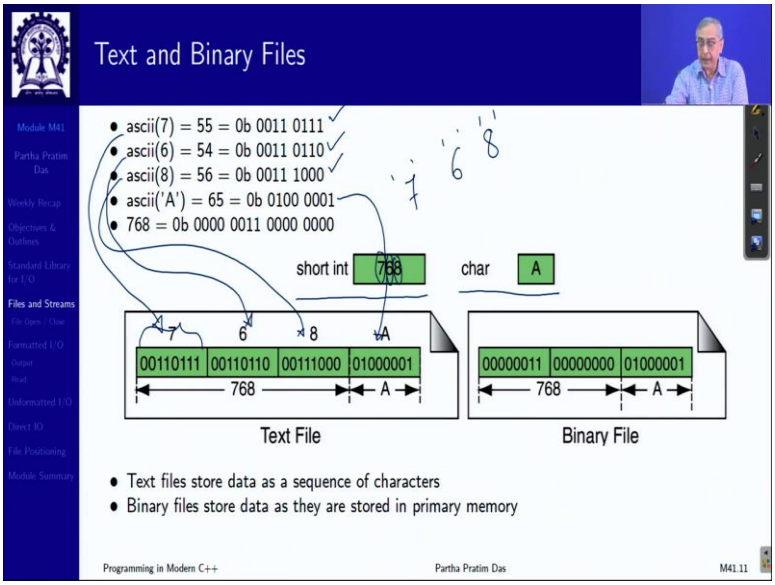

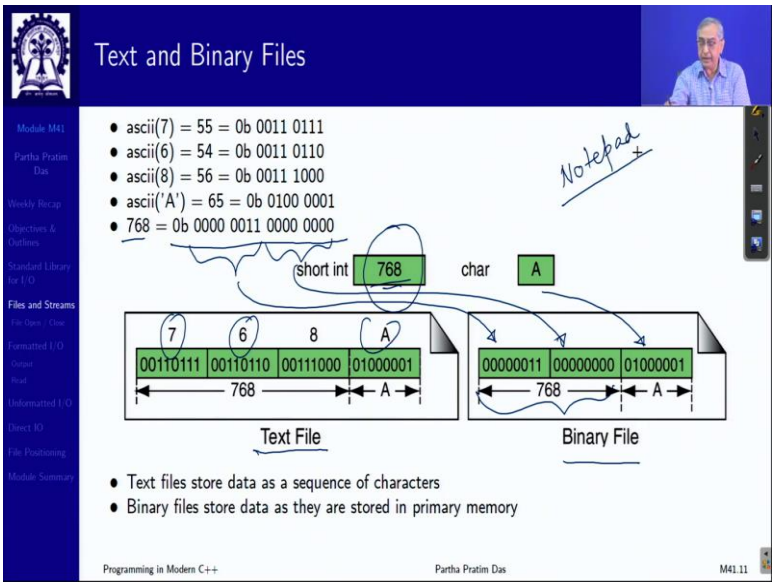

So, just to understand the text and binary files in little bit more depth, suppose I have a short integer 768. And I have a character in character A capital A uppercase A. Now, if you represent it in terms of a text file, what you will do is, you will take each one of these 7, 6 and 8, each one you take as a character and you put the ASCII code of the character in the file. So, here is the ASCII code of 7.

For your convenience I have written the ASCII codes here you can see, these ASCII code of 7 being written in 8 bits, next is the ASCII code of 6 being written in 8 bits, next is ASCII code of 8 being written in 8 bits and then the code of ASCII code of uppercase A which is 65 is written here.

So, it is being written character by character. So, a text file every component of the text file is a character typically it is 8 bit character, that is 1 byte character, it could be Unicode 2 byte characters as well that those kinds of text files are also possible. In contrast, if I say a file is a binary one, then it will represent this number in its binary form, that is as it is stored in the memory. How will it be stored in the memory? This is the entire binary representation.

So, 768 as we can see, it needs 2 bytes because one byte can keep up to 255. So, 768 is more than that, it will keep, it will need two bytes which can keep up to 16k numbers. And therefore, if you see this is the higher order byte which is here, this is a lower order byte which is here.

So, in a binary file, you are not representing these characters, but you are representing the value as a whole here the value 768, whereas when it comes to the character A, since character A is an individual data, it has this ASCII code. So, the character A is represented as before there is no difference in that. So, that is the basic difference between text file and binary file.

Examples are like any program source we are writing is a text file naturally, but an image that we click, image that we display is a binary file because it does not have characters, it just has the bit patterns of different intensity values. Similarly, even say something I mean just to be clear, suppose you have a doc file, doc or docx file the word file. Now, you when you visualize it through the Word, you will find that it displays you text, but that is what actually a text file.

The viewer is showing you as a text, but along with that, it is also showing you different annotations, like some words may be bold, some words may be italicized, there are alignment pads, there is paragraph separators and all that which are actually not text character information. So, if you actually ask a doc file or a docx file is actually a binary file too. Just to check what you can do is, you can in say windows, you can use a notepad application to open a docx file. You will find that you are not seeing the text as you are familiar to see you will see a whole lot of you know garbage nonsense characters, because notepad necessarily is a text editor.

So, it tries to, any file it opens it tries to separate it, punctuate it in 8 bits together and represent it as a character, but the representation inside the word file is not in terms of the ASCII codes, they are in terms of other symbols and binary values. So, you will see that

garbage, but if you open a program source file through notepad, you will see a very nice, you know, nice text that comes in. So, that is the basic difference. And that is a reason that we do need both of these to be available.

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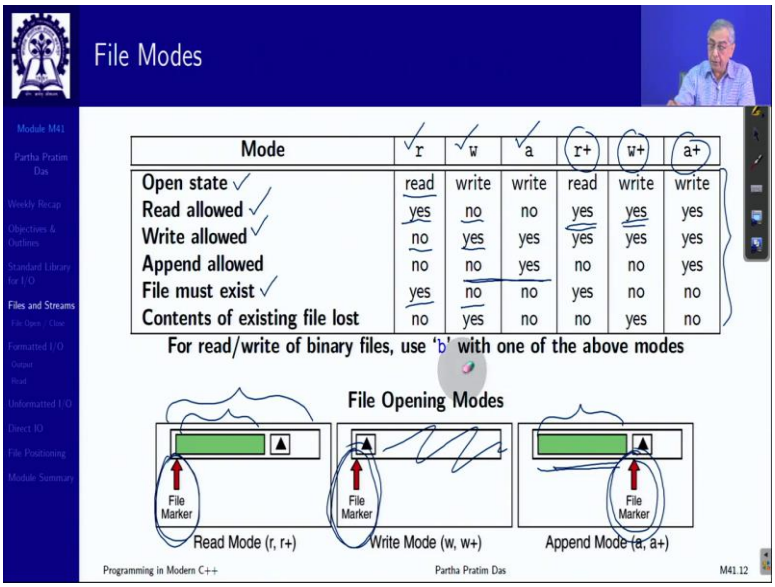

Now, every file is associated with a mode, that is you can either do input to a file, do input from a file or you can do output to a file. So, there are this is specified by certain flags, read, write flags. So, when you associate a stream with a file, you have to specify which mode are you using. So, you can read, write at the two dominant modes.

So, if the file has been open, which means that it has been associated with a stream, then in that you can do a read if you have opened it in the read mode, that is you are taking inputs from it. You can do write if you have opened it in the write mode, when the read be allowed, if you have opened it in the read mode, but if you have opened a file in the write mode, you will not be allowed to read from that. It will be an error.

Similarly, write will be allowed if you have opened the file in the write mode, but read will not be allowed. If the file is being opened in the read mode, it must exist otherwise you will have an error, but in the write mode it will not need to exist, if it exists, it will be cleared, all contents will be cleared and overwritten new and if it does not exist a file will be created.

So, this is the basic difference between the read and write mode. There are other modes like append which is pretty much like write, but it does some different behavior as you can see in terms of here. For example, if you open in append mode, you will not be able to write, you will be able to append only that is it will happen. So, you can see how that goes on.

This is the view of the stream that you have here. And you have opened means you have put a marker on it, the marker, which remembers in the sequential order where you are. So, when you do it in the read mode, it will always put the marker at the beginning because you have to start reading from the beginning. When you do it in the write mode.

It will also have it in the beginning, but you can see in the read mode, we expect content to be there in the right mode, there will be no content. If there were contents when you open it in the write mode, that content is purged out. Whereas if you open it in the append mode, it already has content and you are putting mode to it. So, it is like append mode is important, because if you do not write the entire file in one go you write some data.

And then maybe some other program write some more data then maybe again your program write some more data, you cannot do it by the write mode, because the moment you open it by the write mode, everything that you had written earlier it purged in append mode that purging is not done. But as much as has been written, the file marker will go right after that and start writing from there.

So, these are the basic three modes, then there are + modes on those, which says that read and something more. So, you can see what are the different behaviors I have written down here in some cases, like if something is opened in r+, then read of course is allowed, but write we if it is open in w+, then also you can you are able to read. So, you can use the + modes to do both read and write, append and read these kinds of things together.

So, these are the basic modes and particularly, if you have a binary, so, if you open a file in these modes, it will be opened as a text file, if you want to open a binary file, you will have to write b along with the mode. So, you write this it opens as a text file, you write this it opens as a binary file, that is a simple rule that you will have.

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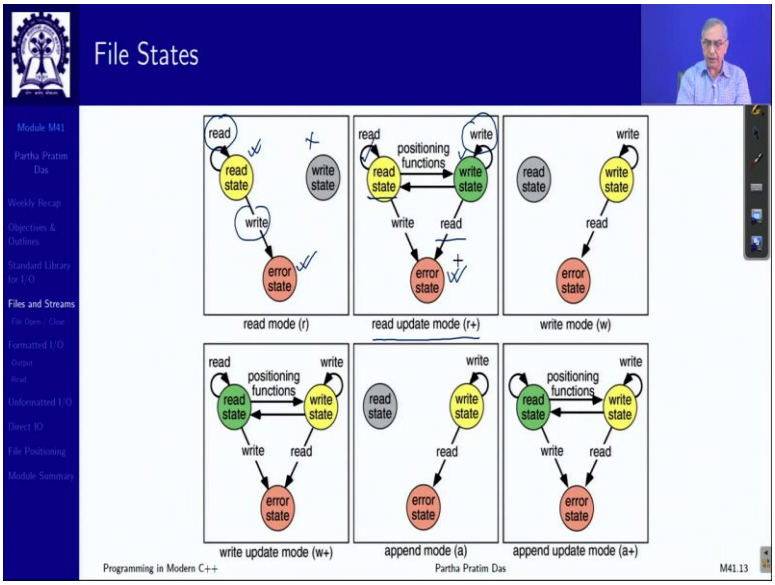

Now, naturally, depending on in which mode you have opened it the file will maintain a state based on whether you are reading or you are writing and here in this diagram, I have just tried to summarize the states, like if you have opened something in the read mode, you do every read it continues to remain in the read state, but if you try to do a write it goes to an error and the write state is not reachable because you cannot write there.

Whereas if you do it in the read+ mode, read update mode, then in the read state it can keep on reading, you can reposition your marker, I will show how to reposition the marker, and come to the write mode where you can keep on writing you remain in this state it can again reposition go back to the read mode. So, you can write some data go back read it again, go forward write again and so on.

But if you try to do read on a write state or write on a read state, then you will come to an error, repositioning properly is absolutely necessary for doing the other state of operation. So, that is the basic principle you can go through each of these diagrams and based on the mode chart I gave you in the last slide you can understand these state transitions.

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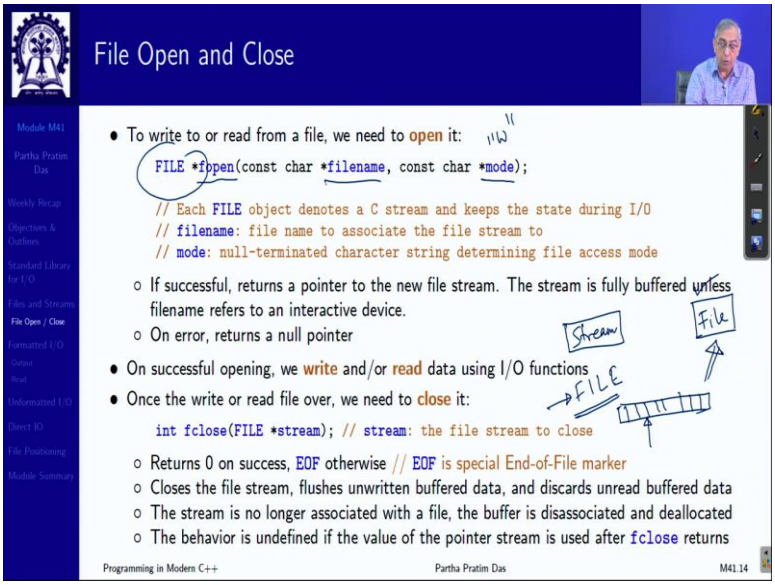

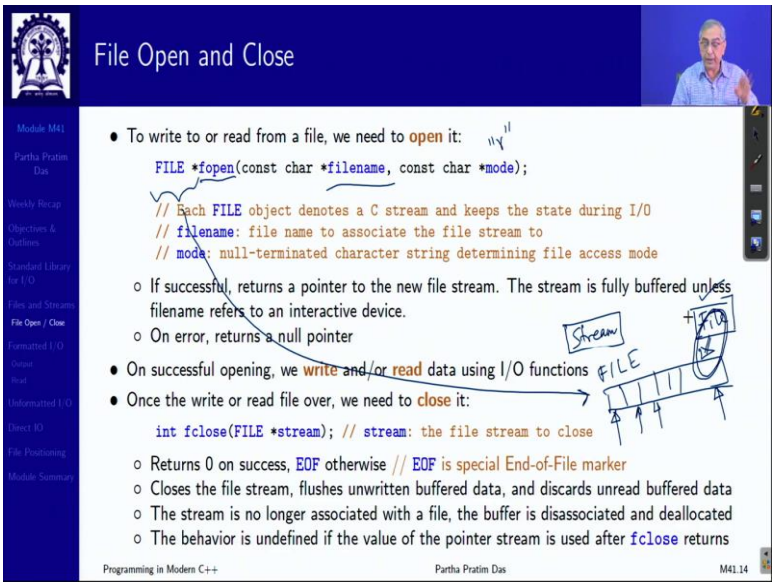

Now the basic form of io is like this. Let us say you have a file. So, that file, let us say physically exist in the disk system or needs to be created in the disk system. What do you do? You visualize this in the program as a stream and that stream type in C is a data structure called capital FILE, which is defined in the stdio.h library, this has a buffer to do your io and it has a marker on that buffer.

So, what happens when you say, you have open it, this is how you open it, fopen, give the file name which is this entity and give the mode you want to open for writing. So, he will give it w here. Then what you get? You get a pointer to this file structure. And everything that you do, you actually refer to this pointer, pointer to the file which means that whenever you are

trying to write something you are doing a printf rather fprintf because you are writing to a file, then you actually the data keeps on going to the buffer.

When the buffer gets full, it will write it to the file and then flush itself and again keep on. The reason it is done in this way, in this buffered way is simple that the file being on the disk actual writing to the disk could be very, very slow. So, you want to avoid during that, at every instant you keep on accumulating things in a buffer, which is in the memory, which is very fast and only periodically when the buffer has become full or when you are done with the file and you want to close everything you write that actually to the file.

The same thing happens in the case of read, again, you again you will open, let me just clear this out this part. So, what you have is, you are opening it in the read mode. So, you will do read to provide the file name this must exist now, because you want to read and what you get is a file pointer, pointer to this data structure file, which contains this buffer.

So, as you start reading from it, which you will do by fscanf a chunk of data is actually taken from the physical disk file and the buffer is filled up and the marker remains here at the beginning. Now, as you keep on reading data, the marker keeps on progressing and when it is exhausted the buffer the next chunk will again be brought from the file.

So, you can understand that this particular transfer part is expensive, whether you are reading or writing because it is making accesses to the disk. So, you avoid that by doing this buffered stuff, which is happening automatically inside the library functions. So, the steps are simple you have to open a file, which means associate a stream with a file then you do write or read depending on the mode or mixture of that read update, write update depending on the mode in which you have opened and then you do a close, by close you dissociate.

Now, you say that no more this file structure a pointer to the file structure will mean the file that you had associated it with. So, with that, if you are writing then whatever data was there in the buffer is flushed onto the disk file and you are your disk file is saved it will remain there forever and the file structure is released, if you are doing a read then if anything left in the buffer that will simply be discarded and the linkage will be broken and this file structure will be released. So, this is the basic process of io, rest of it are nothing but simple function call.

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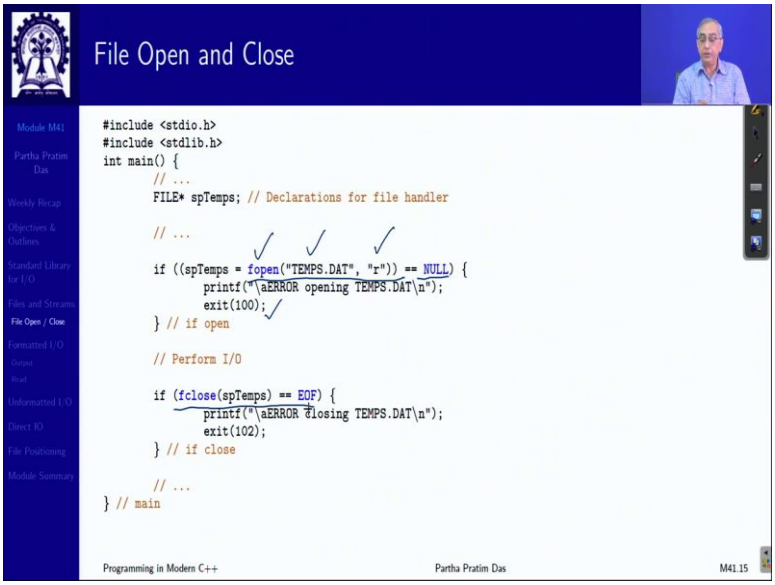

So, for example, here we are showing how to open. We are opening this file name in this mode with fopen. It will give you the stream pointed and if the opening has an error suppose we are opening with the read mode, so the file must exist. Suppose the file does not exist, then it will not be able to open then it will not be able to associate. So, if it does that, if that happens, then it returns a value 0 in null pointer. And by that you know that you could not open it successfully, So, you exit.

Similarly, when you are closing it returns you a value typically a value 0 to mean success, otherwise, you read it returns with end of file marker, which is a special character, which is the marker put at the end of every file meaning that this is a point where there is nothing more in that file structure. So, suppose you could not close because your disk is full. So, it is not possible to flush out the buffer and write the remaining data on to the file because this does not have space. So, in that case, your fclose will fail and you will get EOF as a return value.

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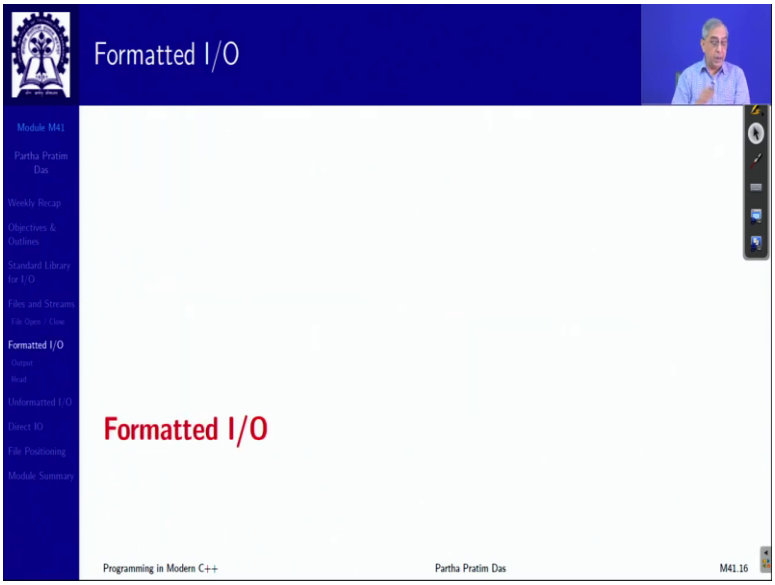

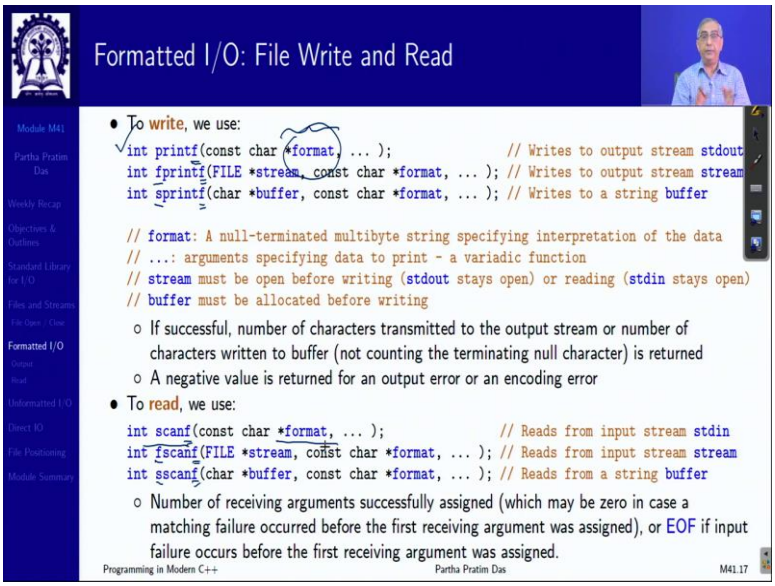

So, this is the basic you know process. Now, I will quickly go through the functions. So, you know the printf, so, I will not detail it any more, you know the use of formats. And so just you know remember that in this library, the function names are done in a very systematic manner. So, f at the end of this name, whether you are doing print, or we are doing scan is meant to represent format.

So, it shows that formatted. You are doing it with formatting which means that it will have a format string to say how the conversion has to happen, whether it is for output or is for input. And if you have a f or an s at the beginning, f means that you are doing it with the file, s means you are doing it with a string buffer. A string buffer could also act as a source or a destination of your read write operation exactly in the same way. Rest of it is exactly like

printf as you have used where by default, your file is stdout, which is always open you do not need to defer, you never need it to open the file because stdout is always open.

Similarly, when you do scanf when you are doing reading, you have the similar format stuff specified and you do not need to open it because it will always use stdin and that is always open when your program starts. So, that is the basic process.

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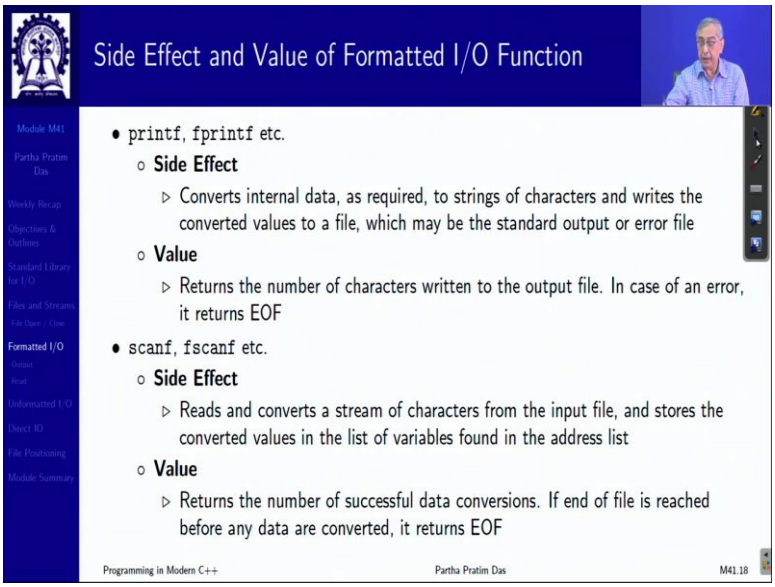

Naturally both printf and I mean all kinds of printf and scanf they do the operation of writing or reading and they return a value, for printf the return value gives you how many characters you have written and for scanf it gives you how many data elements that you have converted and read.

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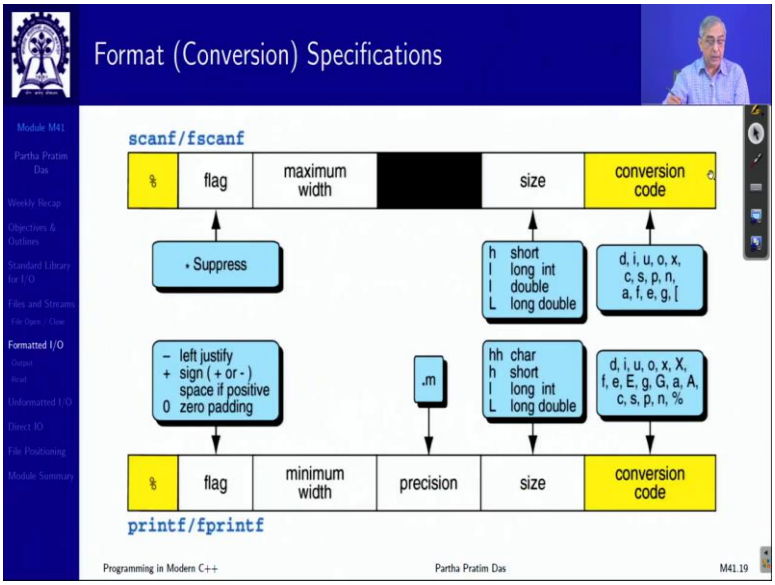

So, these are the, so, this is the different kinds of format conversion you have this app shown in terms of a diagram. So, it always starts with a percentage then you have a flag for alignment and so on. You can specify maximum width for scanf, minimum width for printf you can provide precision for a printf and then you provide the size which is mean how much size you want basically. And then you have the conversion code which you have to align with the type of the data that you are printing that you already have seen in the printf.

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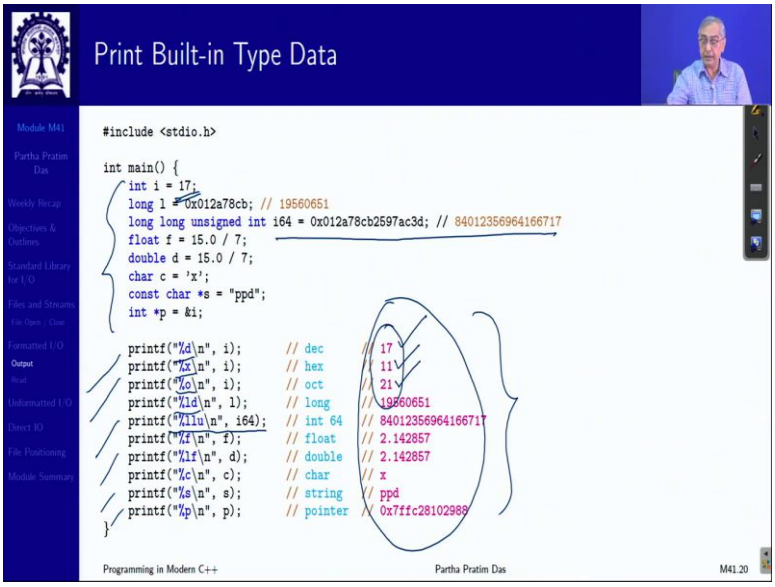

So, here is an example which you can try to run these are different types of data and these are printf on those and you can see what are the values that are being printed. Just be careful with this particular line because unless you have a 64 bit machine this particular data type

declaration and the corresponding percentage %llu writing will not work. It works only in the 64 bit type. So, if your system does not have that, then just comment out these two lines and rest of the code will work you can see what kind of data you get.

And you have all different types of formats that are possible both in terms of the data type as well as the way you want to visualize. For example, %d, %x, %o, all work with each type, but they write the data in different forms. So, same 17 with %d is written as 17, but with %x is written as 11 because it is hexadecimal. So, 11 is 1*16+1, 17. Similarly, if you do percentage o it will be written as 21, in the octal system two times 8 is 16+1 like this. So, you can you can easily use that.

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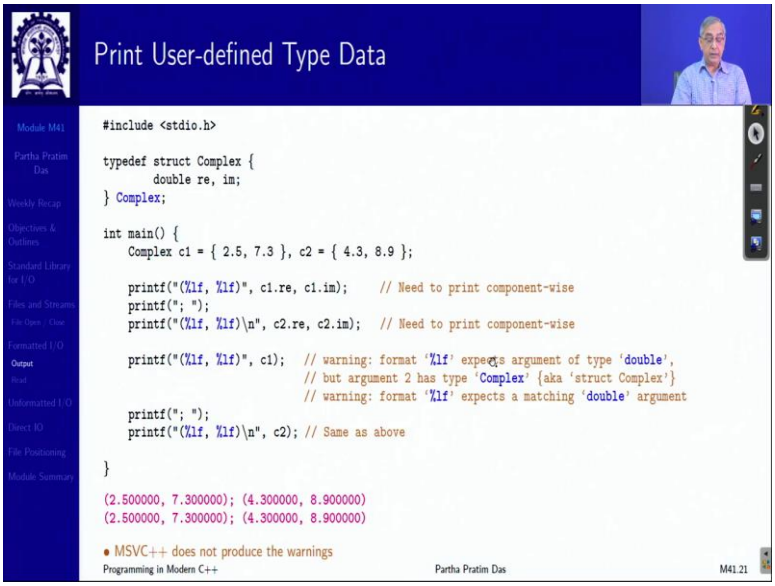

You can use these, but if you have user defined data type like a complex as we have seen, then you will not be able to extend printf for doing that you have to take them component by component and use them you have seen this before.

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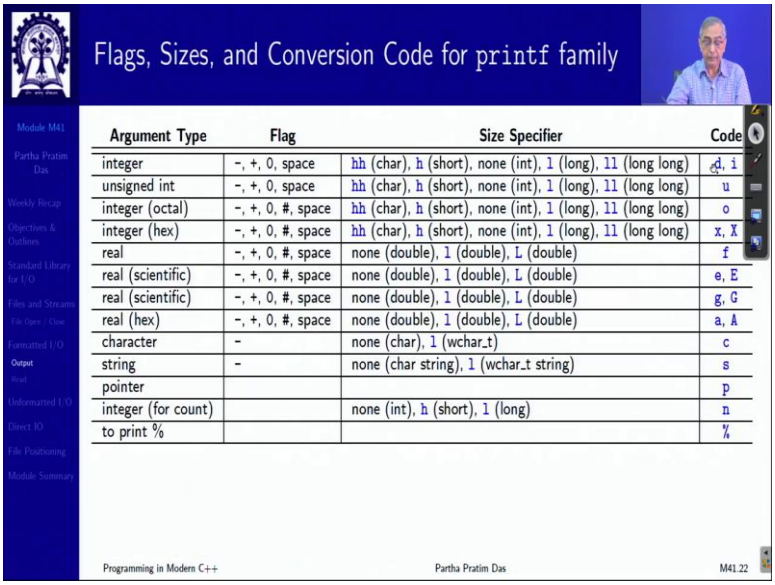
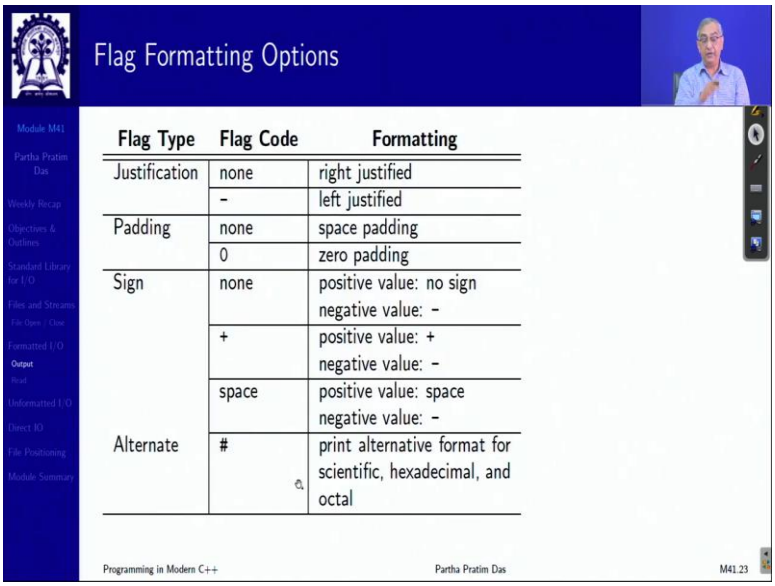


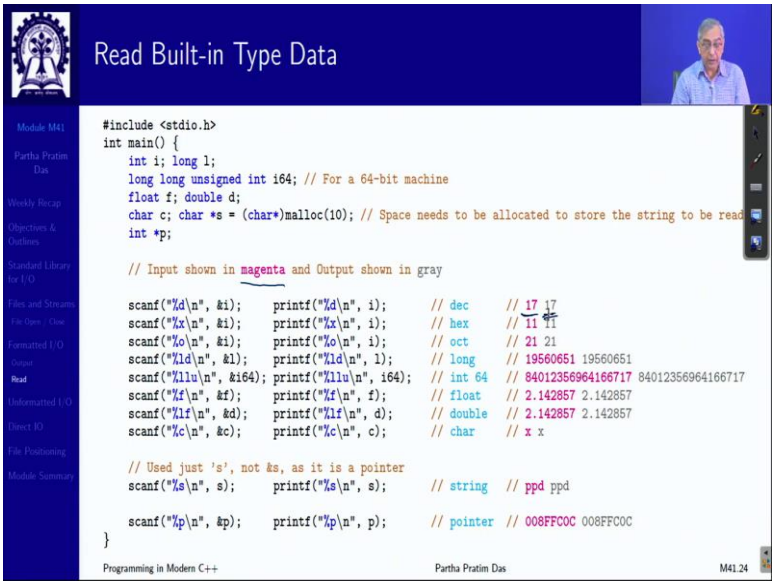
Argument Type	Flag	Size Specifier	Code
integer	-, +, 0, space	hh (char), h (short), none (int), l (long), ll (long long)	d, i
unsigned int	-, +, 0, space	hh (char), h (short), none (int), l (long), ll (long long)	u
integer (octal)	-, +, 0, #, space	hh (char), h (short), none (int), l (long), ll (long long)	o
integer (hex)	-, +, 0, #, space	hh (char), h (short), none (int), l (long), ll (long long)	x, X
real	-, +, 0, #, space	none (double), l (double), L (double)	f
real (scientific)	-, +, 0, #, space	none (double), l (double), L (double)	e, E
real (scientific)	-, +, 0, #, space	none (double), l (double), L (double)	g, G
real (hex)	-, +, 0, #, space	none (double), l (double), L (double)	a, A
character	-	none (char), l (wchar_t)	c
string	-	none (char string), l (wchar_t string)	s
pointer			p
integer (for count)		none (int), h (short), l (long)	n
to print %			%



Flag Type	Flag Code	Formatting
Justification	none	right justified
	-	left justified
Padding	none	space padding
	0	zero padding
Sign	none	positive value: no sign negative value: -
	+	positive value: + negative value: -
	space	positive value: space negative value: -
Alternate	#	print alternative format for scientific, hexadecimal, and octal

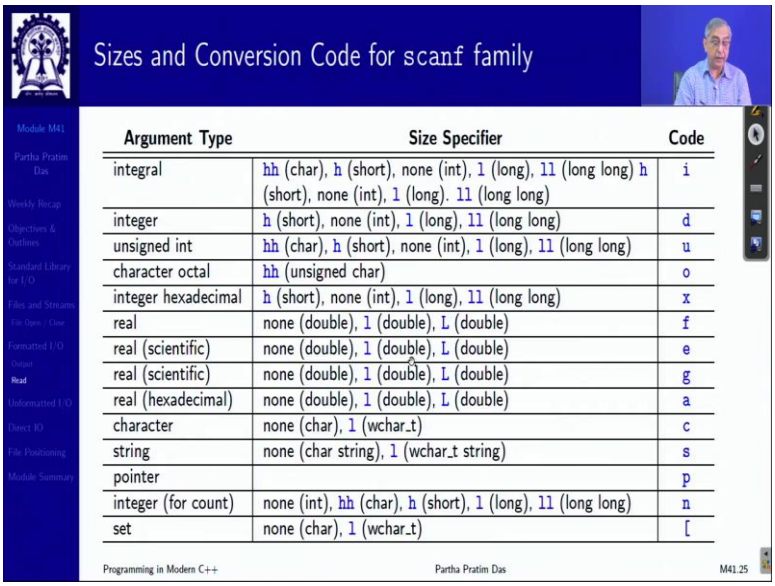
Here I have given some charts, which certainly I am not going to go through right away. This chart is for your reference, So, that if you want to use a particular type of format, you can get all the information in this charts of different flags, formatting options of padding justification and so on.

(Refer Slide Time: 28:40)

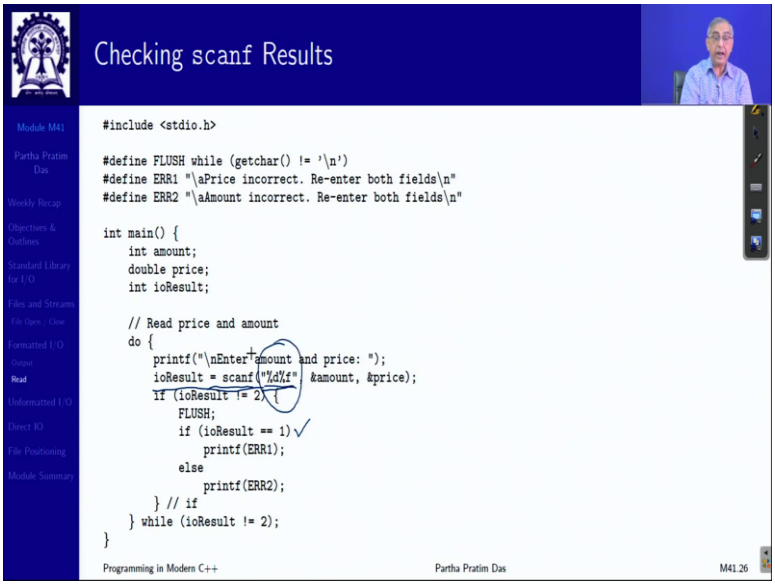


Similar exercise will also apply to read in terms of scanf exactly as you have done, the formats are more or less similar, the format codes are more or less similar. And here I have shown just to be confirmed that what you have read, what you have read is what you are getting, I have shown the corresponding printf as well, you can just run it and get comfortable with the common formats of data that you have.

(Refer Slide Time: 29:10)



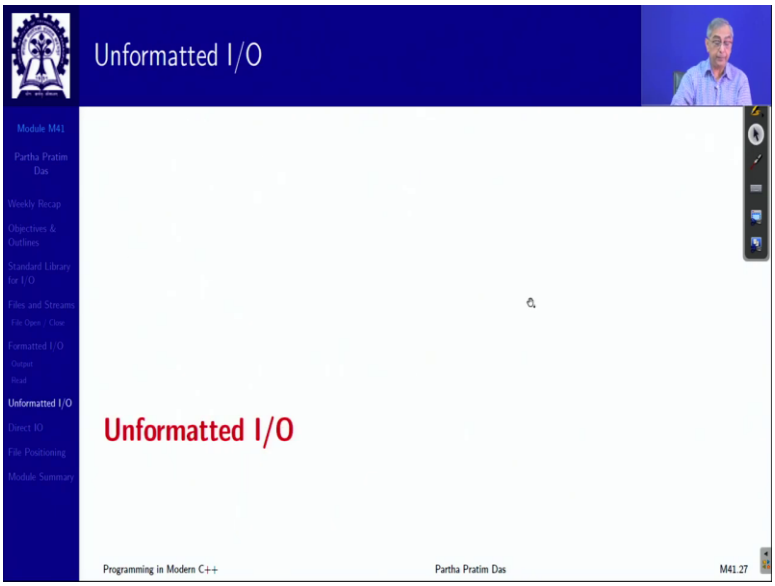
Argument Type	Size Specifier	Code
integral	hh (char), h (short), none (int), l (long), ll (long long) h (short), none (int), l (long). ll (long long)	i
integer	h (short), none (int), l (long), ll (long long)	d
unsigned int	hh (char), h (short), none (int), l (long), ll (long long)	u
character octal	hh (unsigned char)	o
integer hexadecimal	h (short), none (int), l (long), ll (long long)	x
real	none (double), l (double), L (double)	f
real (scientific)	none (double), l (double), L (double)	e
real (scientific)	none (double), l (double), L (double)	g
real (hexadecimal)	none (double), l (double), L (double)	a
character	none (char), l (wchar_t)	c
string	none (char string), l (wchar_t string)	s
pointer		p
integer (for count)	none (int), hh (char), h (short), l (long), ll (long long)	n
set	none (char), l (wchar_t)	[

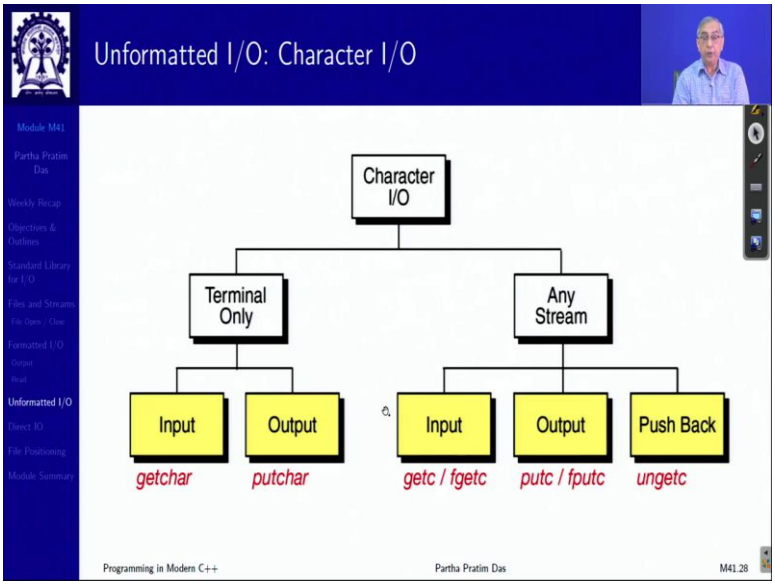


Again the similar conversion chart for the scanf which you can refer to and when you do scanf you could for example, you have given scanf for two values as we are here. So, as I said the scanf will return how many data elements you have converted. So, if you have given for two and you have provided only one data, then certainly you will have an error or so, if it is one or you have not provided any data, you have just tried to kind of say that there is no data.

So, then also he will have error. So, with scanf you can use this kind of checks to see that you have gotten as much data as you had actually needed to have from the input.

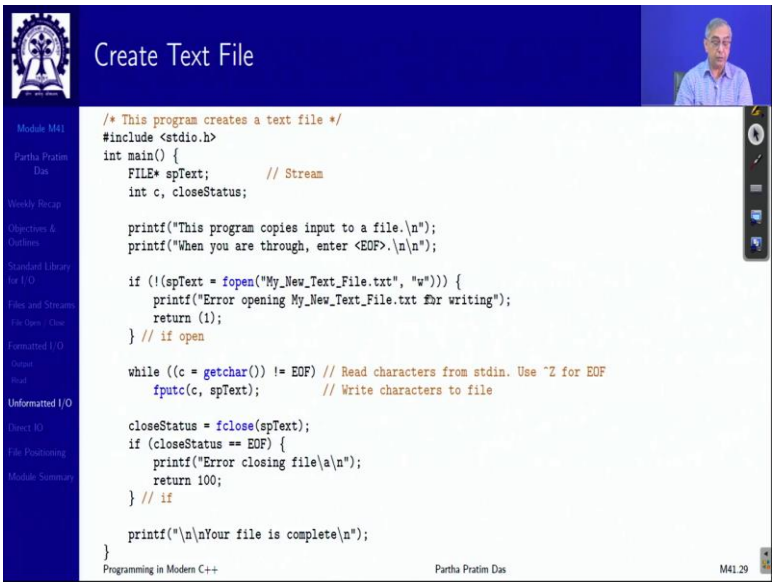
(Refer Slide Time: 30:04)





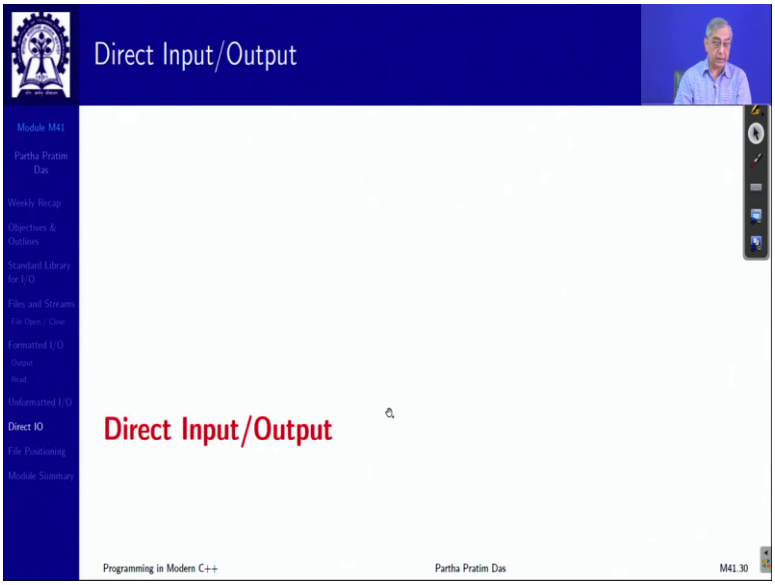
IO could be unformatted also like you can read character wise and these are the different types of functions that are available. If you are doing it with terminal, it is getchar and putchar which does input-output of individual character otherwise with any stream you will have getc or fgetc, (now, the naming convention). So, getc will get it from a steady in fgetc will get it from a file similarly, putc, fputc, ungetc and so on.

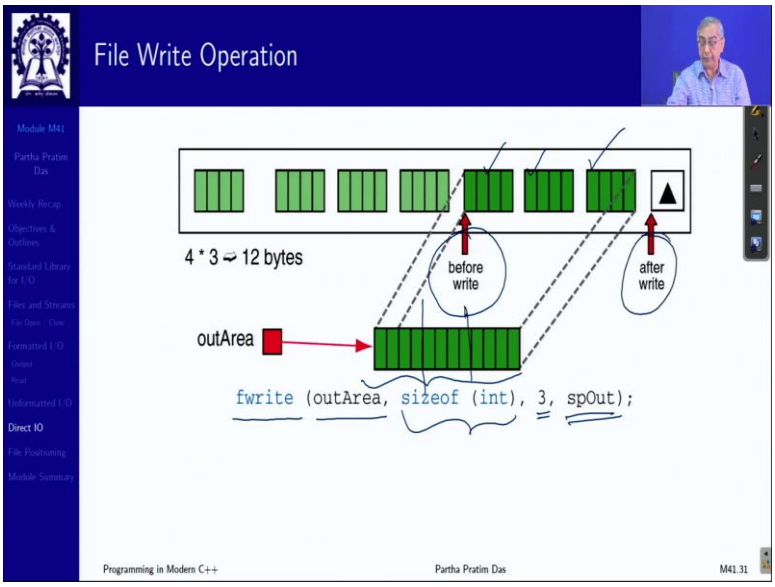
(Refer Slide Time: 30:35)



Here is a text file example given which I will not go through, please try it on your system and see how you get.

(Refer Slide Time: 30:46)



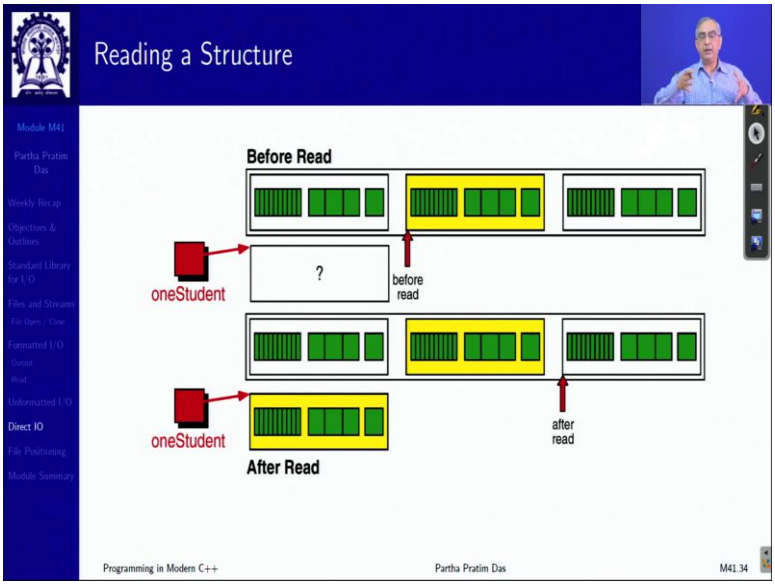


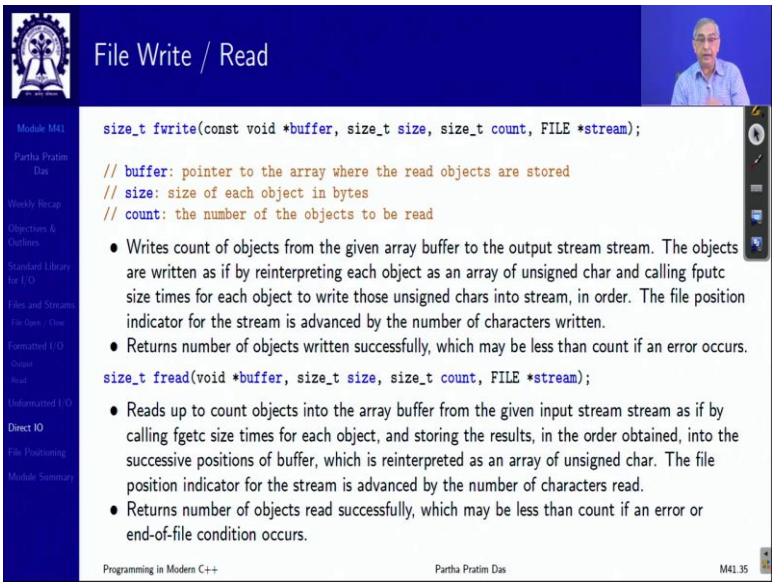
Besides this, you can also have direct input-output that is particularly what you want to do with a binary file is take a chunk of data and directly write it. So, here for that you use different functions possibly fwrite, which takes a buffer like this. So, you need to specify that what is the units in that buffer. So, I said there are three units: total sizes, its size of int,

So, every chunk has to be size say 4 bytes, and there will be three such and it has to go to this stream. So, it takes in this way, it takes three chunks of ints and put it to the output. So, that is our basic operation, you can see that this is where your marker was before you started doing it and this is where it goes after you are done with it. So, directly using fwrite you can directly do that. Similarly, there is a version called write which works which does not need the spout which will work with stdout.

You can do similar stuff with directly taking a structure and writing it in using the fwrite. You can do the inverse by reading using fread again you need to have the buffer into which he will read, the size of every unit and how many units you want to read. And then finally the stream these diagrams will obviously corresponding to fread there is a read which can happen with the stdin.

(Refer Slide Time: 32:28)





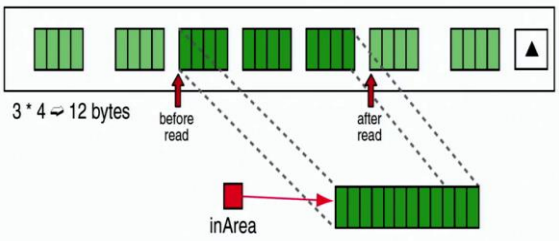
You can read by structures also. So, these are all, here you are not parsing it in terms of specific characters you are just you know taking things in block and reading or writing them. So, here are the two major functions fwrite and fread which I have already explained here are the details you can go through.

(Refer Slide Time: 32:51)

File Positioning

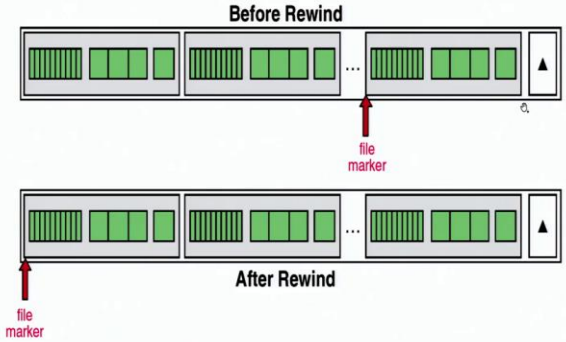
File Positioning

File Read Operation



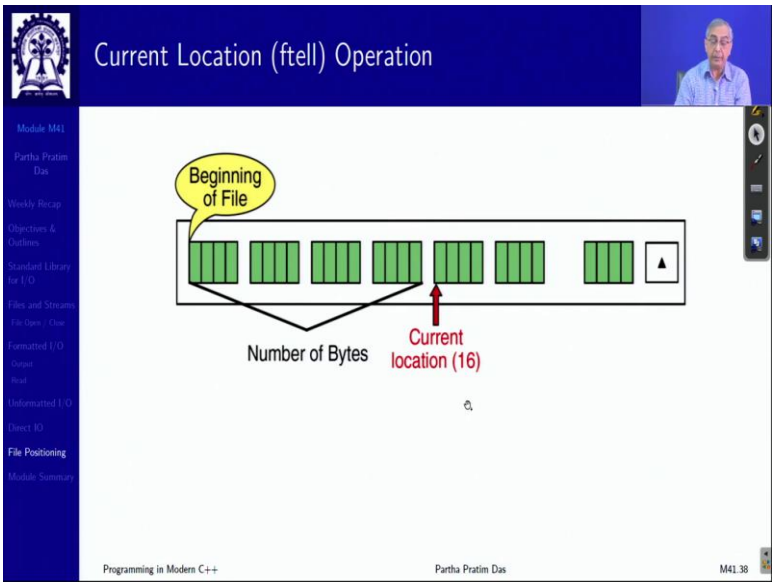

```
fread (inArea, sizeof (int), 3, spData);
```

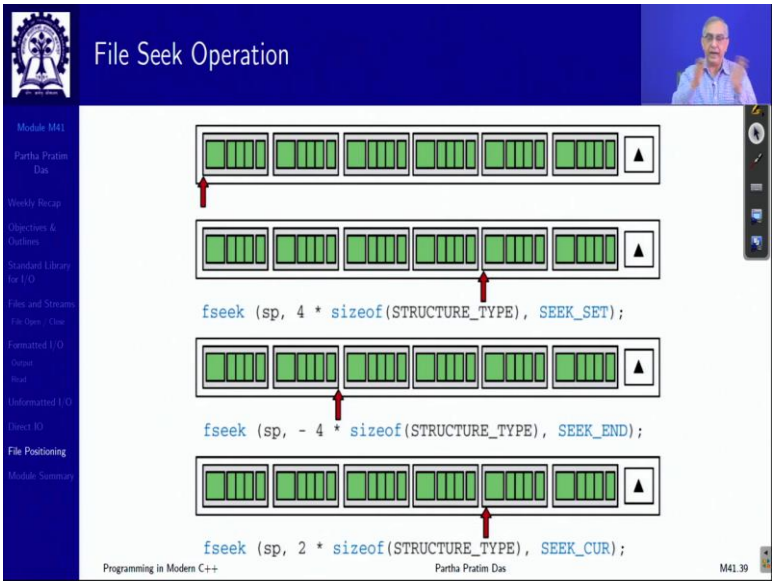

Rewind File



Naturally for you know, for using the + mode, the update mode, you need to reposition the marker. So, it is possible that you have done some tasks and you can reposition. So, there are at certain functions to do that you can rewind, which will bring the file marker from wherever it was to the beginning of the file, but it can be done specifically at different points also.

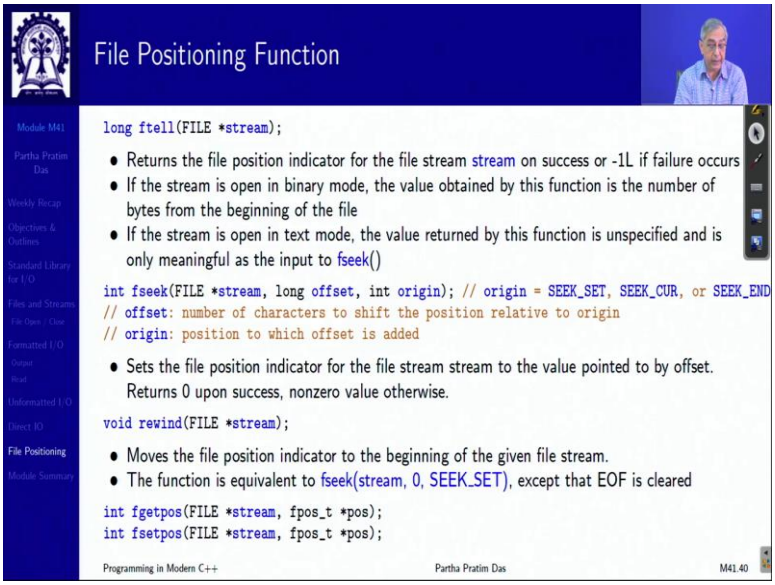
(Refer Slide Time: 33:20)

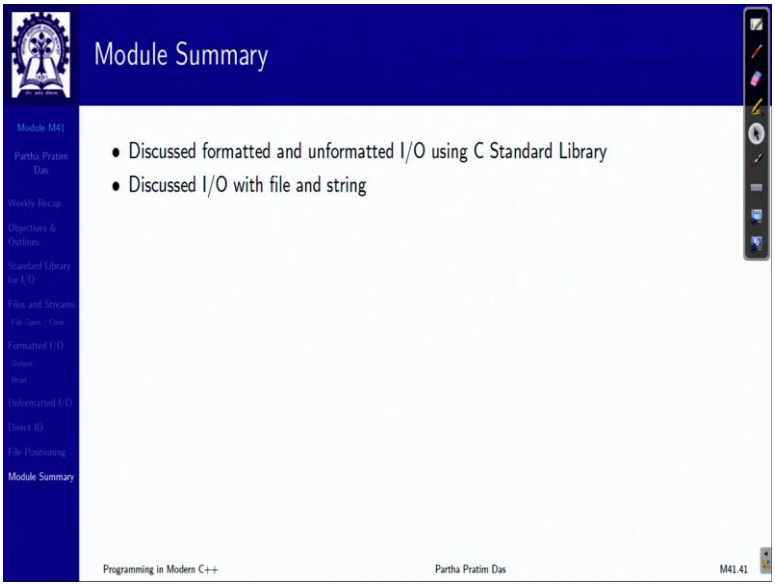




You can actually note the current position of the file marker also by a function called ftell, you can reposition the file marker anywhere by doing it fseek operation you can set it to a point you can set it to the end you can set it to the beginning and so on. So, rewind is basically a special case of seek operation. So, these by this you can reposition your marker and then again restart read or write as we had explained in the update operation.

(Refer Slide Time: 33:54)





So, these are the common functions which we will need for doing this ftell, fseek and rewind. So, this brings us to the end of this naturally input output standard io is a very very big topic. So, I just tried to give you the basic idea of association between file and stream and the buffered input or output that typically goes on through the system for performance. And going forward. We will see the same view in terms of C++. Thank you very much for your attention.