Programming in Modern C++
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Lecture 47
C++ 11 and beyond: General Features: Part 2

Welcome to Programming in Modern C++. We are in week 10 and we are going to discuss module 47.

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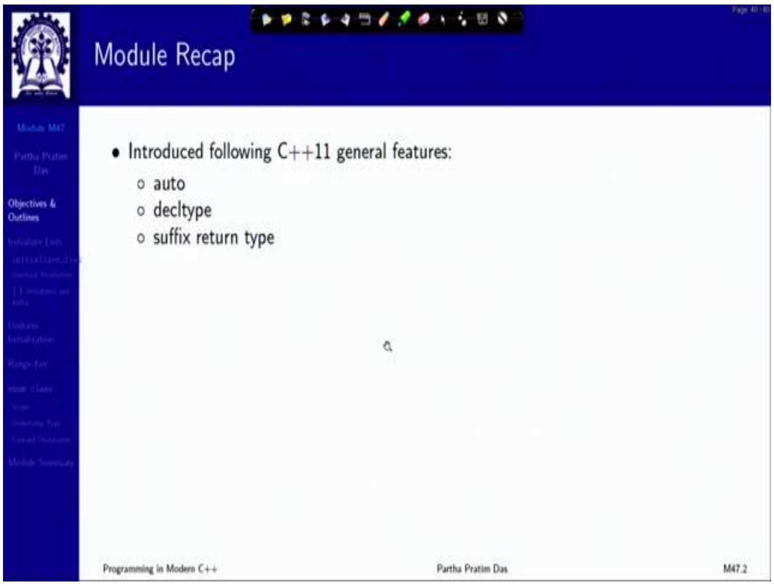

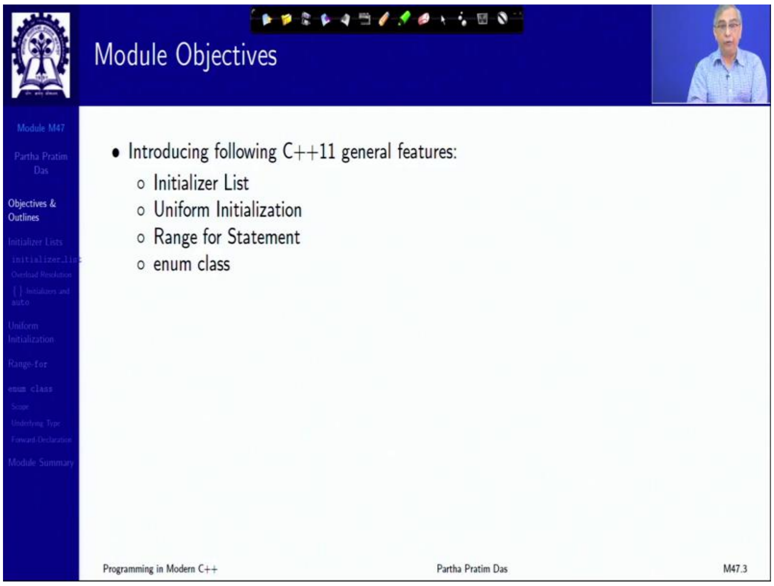

In the last module we have introduced the overall features of C++11 and talked specifically about auto, decltype and suffix return type. We will continue on that and introduce these four general features in this module.

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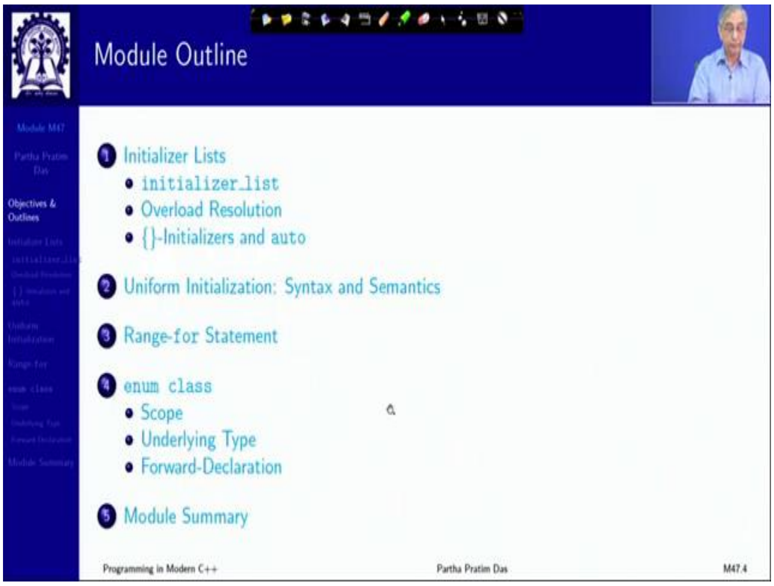

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So, we start with initializer_list. The whole idea is how do you initialize a particular variable in C++11.

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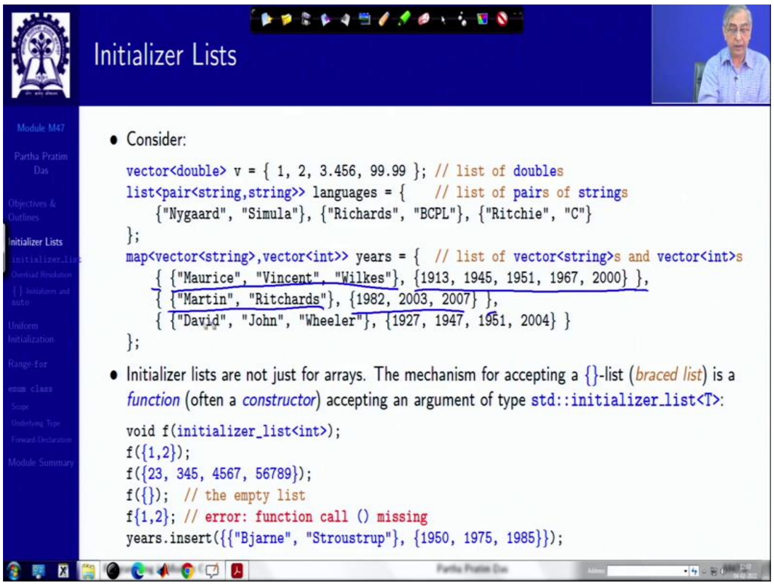

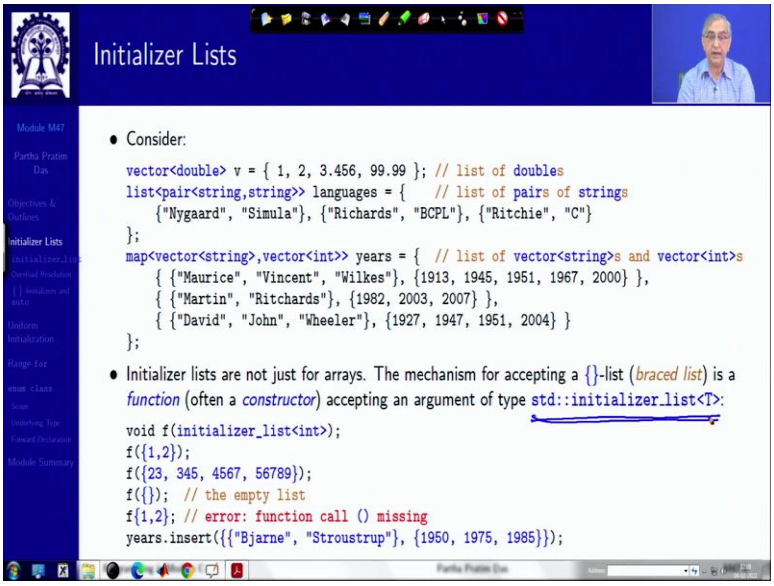

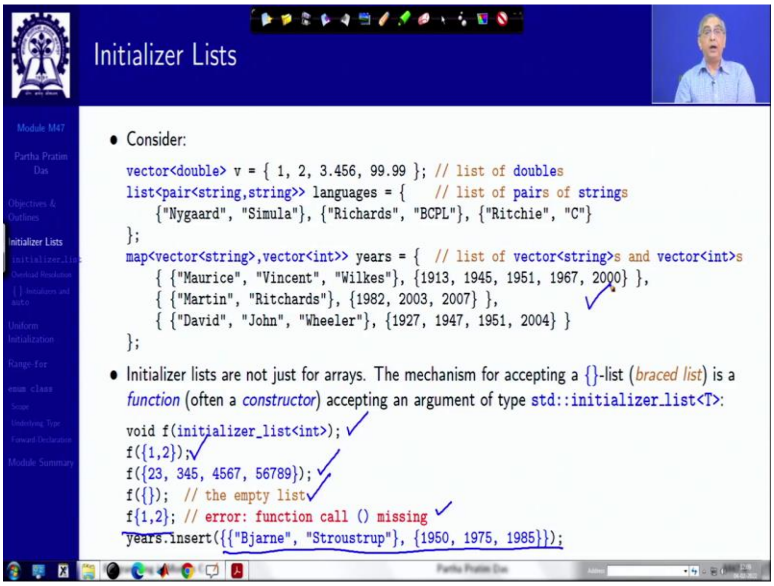

So, let us look at some of the initialization styles that we already know. We can initialize a vector by putting the values like this, we can initialize a list of pairs of strings, so this each one gives you a kind of a literal which is a pair of strings and then you have a list of them, so this is a list. You can do it for a map, which is just to declutter, do it for a map which has a key which is a vector of string and value which is a vector of int.

So, what you have, in each case is the vector of string, vector of int paired together, vector of string, vector of int paired together. So, these are some of the ways that you initialize and you can see that in every case that, I mean, for these kind of vectors and arrays you have a nice curly brace or braced initializer syntax. But initializers list is not just for is, it kind of tries to generalize and it is often actually a function, it is often actually, a constructor hidden behind it which accepts arguments of this type.

So, this is provided by a new component in C++11 standard library that gives you an initializer_list. So, we will see what that initializer_list is, so with that you can just define a function with initializer_list of type int, which means that you will have braced initialization of integer values or you can directly then call this function like this or like this or like this that is an empty list, but you cannot call it without the parentheses. This is missing. You can use it say in insert, we did insert earlier and, for example, for this vector, map I can do an insert of this form, so that is what the initializer_list is about.

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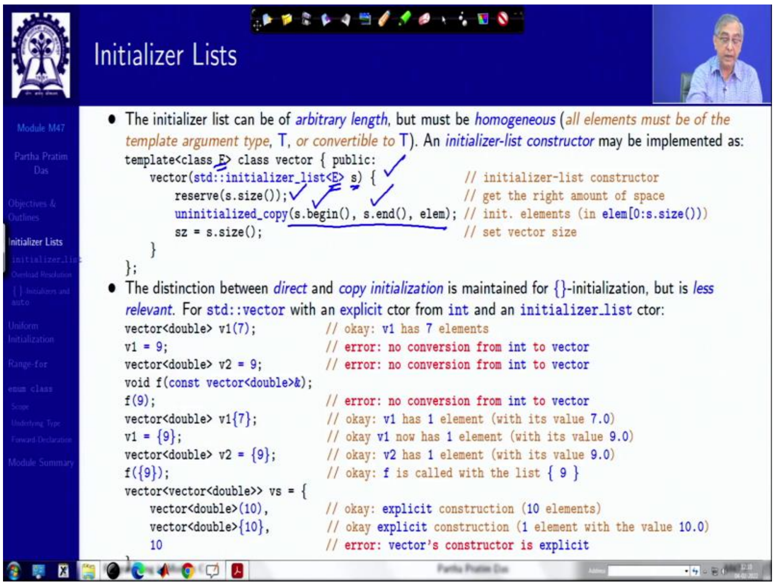

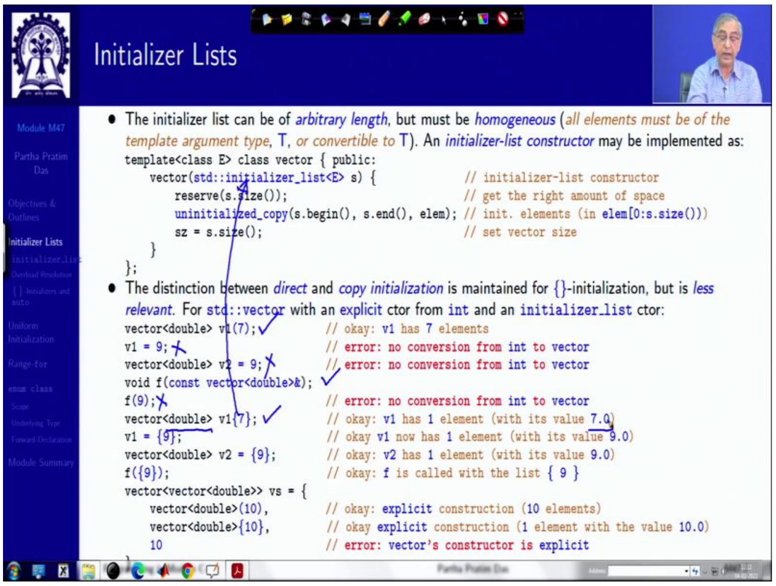

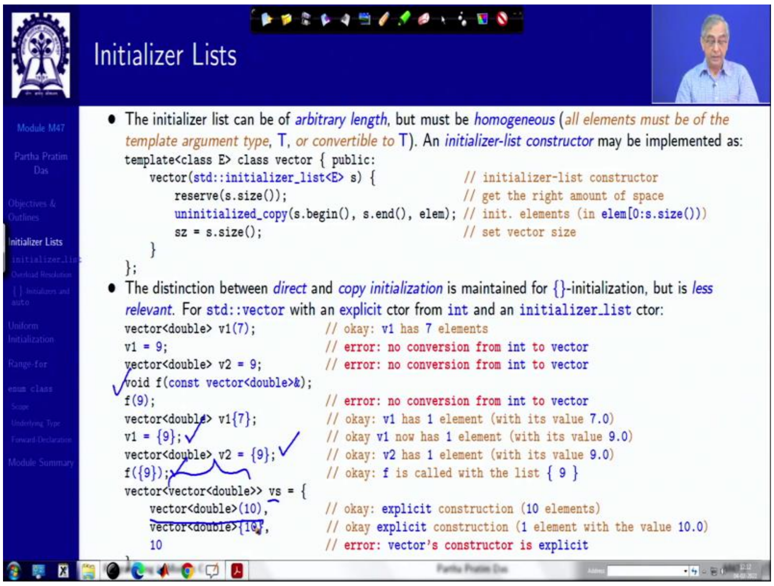

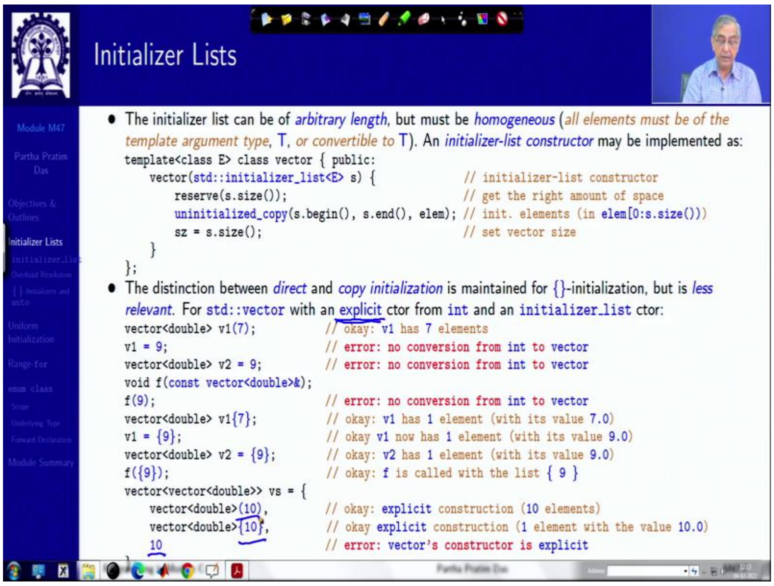

So, an initializer_list can be of arbitrary length 0, 1, anything, but the key point is it has to be homogeneous, which means that each element you use in the initializer_list must be of the same type, initializer_list has a type t, so it must be of the same type, t or something which is convertible to t. So, with that I can write a constructor of vector which takes an initializer_list of underlying type E. So, it is a vector of E.

So, that list is s, so I, internally I reserve that much of space for, that is required for s and then I do a uninitialized_copy is an algorithm available, so I do a copy of from iterating from s.begin to s.end into elem which is the element array set the size. So, this is a typical way an initializer_list can be used. Now, the distinction between direct and copy initialization is there for braced initialization, but it is less relevant I should say.

So, if I say v1 within parentheses 7, then v1 has 7 elements, I cannot use this because there is no conversion from int to vector. I cannot use this again for the same reason there is no conversion, if I have this function I cannot use this because again there is no conversion from int to vector, but I can use this. What it does? I am doing an initializer_list of length one having the value 7, so this will invoke the initializer_list constructor and create a vector having the value 7, I have given the type, underlying type as double, so this will implicitly convert that to 7.0, so that is the use of the initializer_list in construction.

So, similarly, this will give a vector with value, with one element value 9.0, similarly here, this will call f(), this f() with the list containing 9 and now if I want to see the subtle difference, suppose I am trying to define a vector of vector of double. So, I have a vector of double and I have a vector of that. So, every element, the initializing element for vs has to be a vector of double because that is element type.

So, I define vector<double> within parentheses 10. What does that mean? That means an explicit construction of 10 elements, whereas if I use curly brace, it means an initializer_list, so it means a list containing one element 10, so it is a explicit construction of a vector having one element with the value 10.0, 10.0 because its double.

If I try to use 10, I will get an error, because there is no implicit construction available, you can see that. We have said that the constructor is explicit, which means that unless you specify the constructor will not be invoked, here it was specified so it was got invoked. So, that is the property of the initializer_list.

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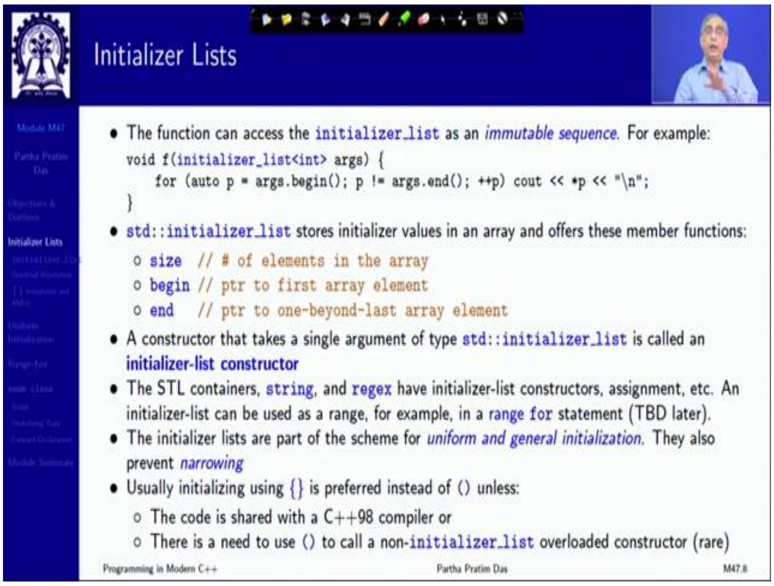

So, it is an immutable sequence that means that you cannot change it, everything is a constant there and it gives you three functions to know the size, the number of elements in the initializer_list array and a begin() and end() to do iteration for that. Now, the constructor of the kind we just saw where there is only one parameter which is a initializer_list type is called an initializer_list constructor.

Like we had default constructor, we had copy constructor, now we have a new kind of constructor called initializer_list constructor. So, several STL components now have initializer_list constructor as well. So they are a way to have uniform initialization across various different kinds of objects.

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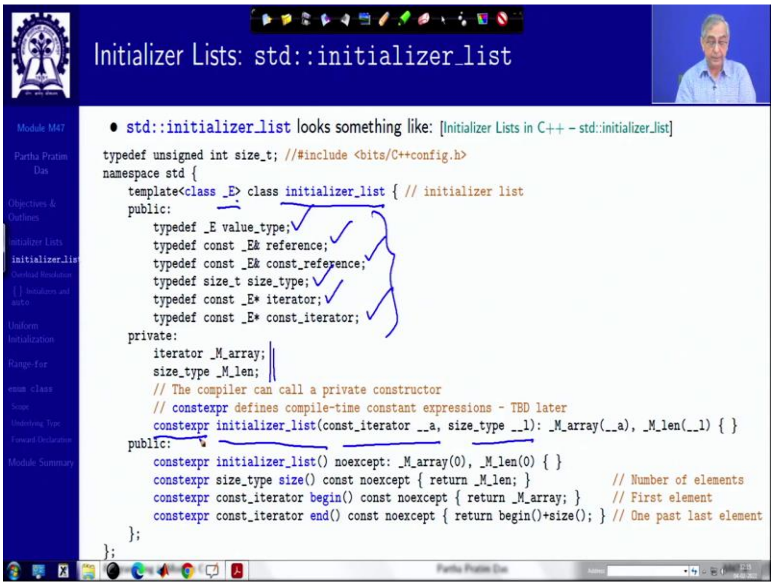

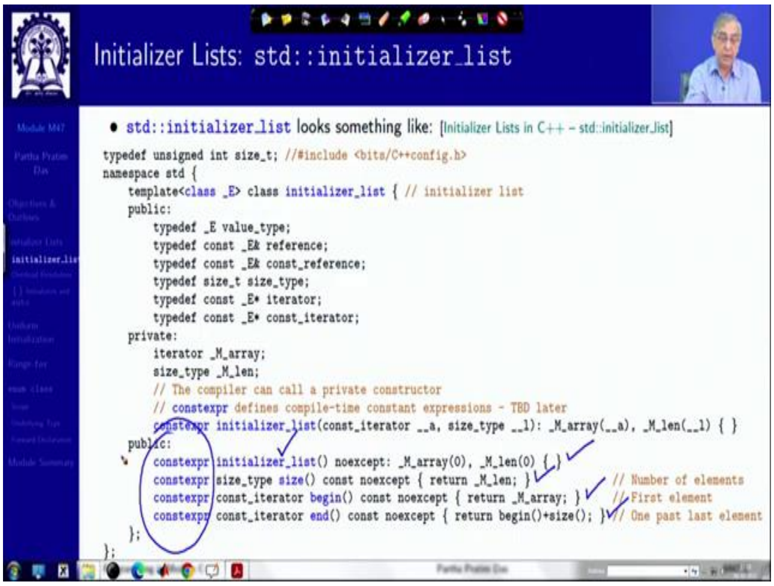

Now, if you just wonder as to how does the initializer_list look like in the std, the standard library namespace, so here is how it goes, this is underlying type and this is the class, these are the different types, so you can say, see that I said that initializer_list will actually keep it as an array, it will have to remember the initialization values, so it will keep it as an array. So, it is kind of a container.

So, you can see all different types that we had seen in the container are also defined for the initializer_list, beautiful uniformity as you see. And it has certainly private members to store the values and the size and it has a constructor which takes the iteration over __a and the size __l to actually do the construction, the constructor is made private because we do not expect to call it explicitly from the user code.

The compiler will call it and compiler can always call the private member and this actually is a constant expression. We will talk about constant expression later on, what it in general means is, a constant expression is one that can be evaluated at the compilation type and will not change after that, it becomes immutable after that. So, with that what you have in the public is a constructor, a default constructor which just constructs a null list.

You have (a size operator) a size() member function, a begin iterator and an end iterator, all of them are constant expression because it is, initialization is with constant so everything is computable at the compile time as a constant expression. So, this is what your basic initializer_list internally looks like. So, knowing that really helps.

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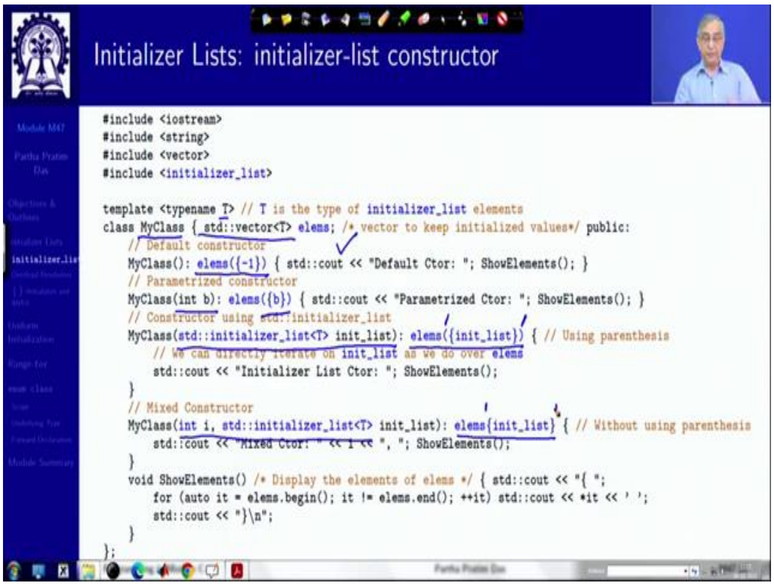

So, with that let us take an example with different variants. So, I am trying to define MyClass with a vector of T elements, my class is templatized by T, I have a default constructor, so if I have a default constructor then I just initialize it with some arbitrary default value list of -1. I have a parameterized construction, which takes b, the list containing, I have a initializer_list construction which takes an initializer_list and copies it to elem.

I can have a mixed constructor also, which takes an integer and an initialization list and copies it, you can see that using this brace is, using this parenthesis is optional here. So, the four types of different constructors I have defined and I have given a ShowElements() function to really iterate over what I have initialized.

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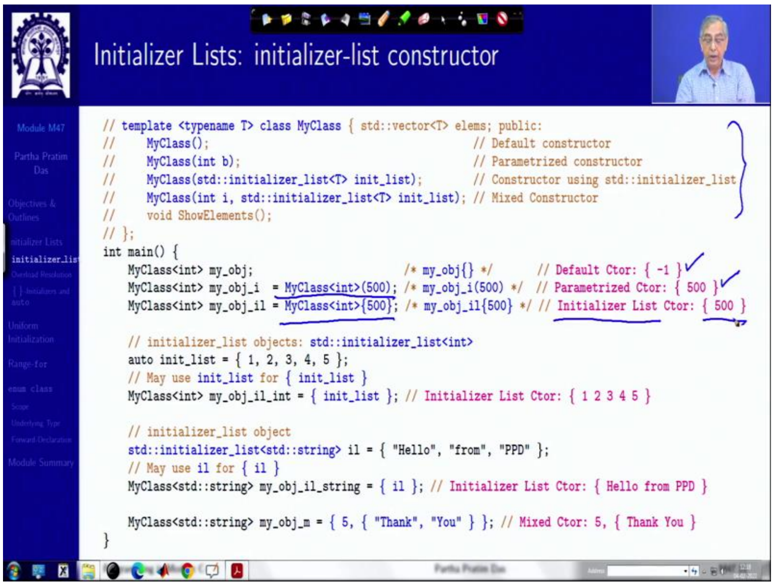

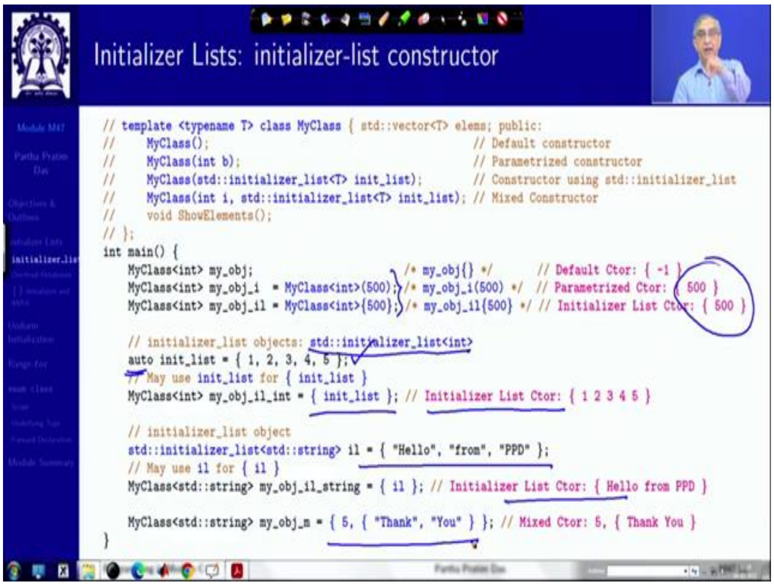

So, now if I try to use these constructors, this different construction I have repeated again here for your quick reference, so if I just do my_obj, it must construct things by default, so it default constructs and it has a list containing -1 that we did. If I do it with my int within parentheses 500, it picks the parameterized constructor and puts 500 as a list.

If I do class my int with braced initialization, so I have an initializer_list containing 500 that is b, that will call certainly my initializer_list constructor, it calls the initializer_list construction. So, you can see that you know both of these give me finally the same object or same, the object containing the same value, but use different constructors. You can also do it by separately creating the initializer_list.

So, what auto deduces (is it deduces) this type from the actual initializer_list and then you can use that to initialize the my object, the initializer_list constructor will be used. Similarly, you can do it for a string, again the initializer_list constructor is used, you can do it for a pair of integers and an initializer_list of string, so you will get mixed constructor called. So, this is how the constructors will map to the respective type and will be called.

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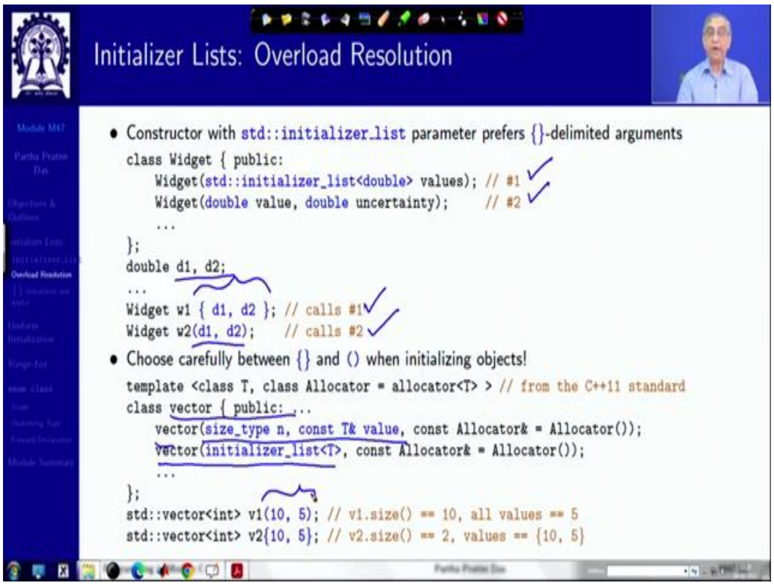

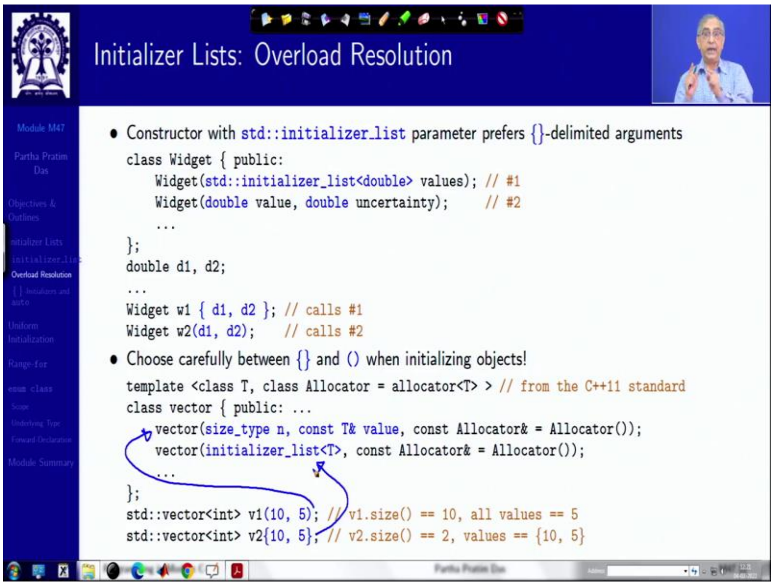

Now, naturally, since you have multiple constructors there will be overload issues. What do you, overload, so you must have understood this now, that if I have curly braces, then the initializer_list constructor if it is there will be preferred, so here I have one which is initializer_list constructor and one which is simple parameterize constructor. So, for the same d1, d2 if I define w1 as with curly braces, it will call 1, but with parentheses it will call 2.

Similarly, if I look at ah the vector class in the standard it has one parameterized constructor which takes the size and the default value, it says that construct a vector of size n each should be filled up with value and other takes just the initializer constructor, so if you call v1, if you construct v1 with 10 and 5 given in parentheses, this will take likeness of the first constructor. And therefore, what you will get?

10 will be considered as n, 5 will be considered as value, so you will get a vector of 10 elements each initialized with 5, whereas if you use curly braces, then your initializer_list constructor will be preferred. So, you will get a, consider this as a list containing 10 and 5, so your vector of int will now have two elements, size is 2, one is first, one is 10, second one is 05. So, there are, in terms of overload there are subtle differences, in terms of using parentheses and using curly brace, so be careful about that.

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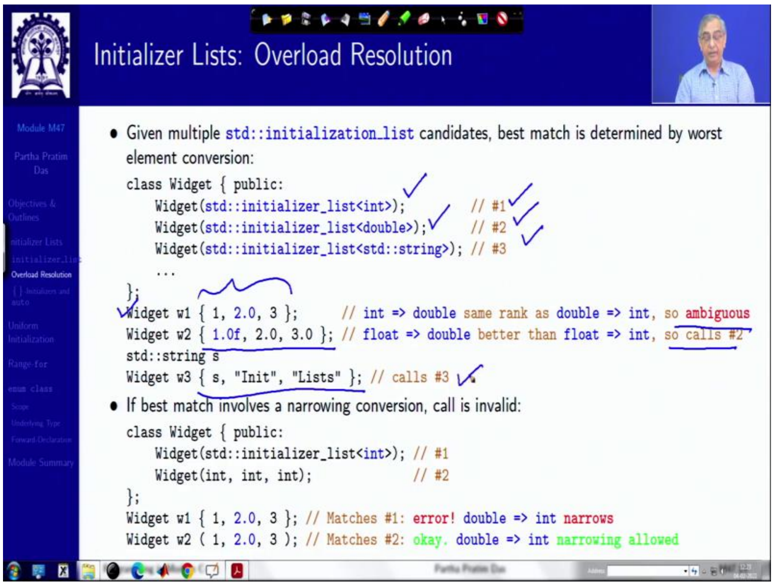

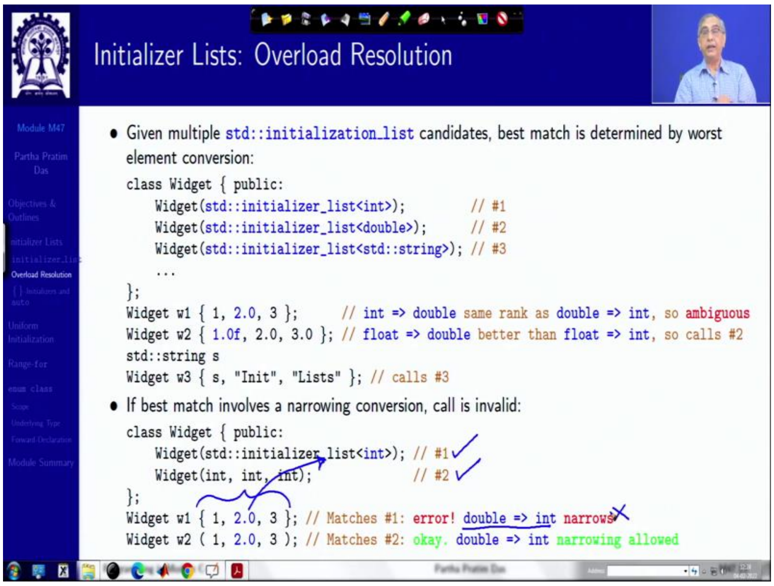

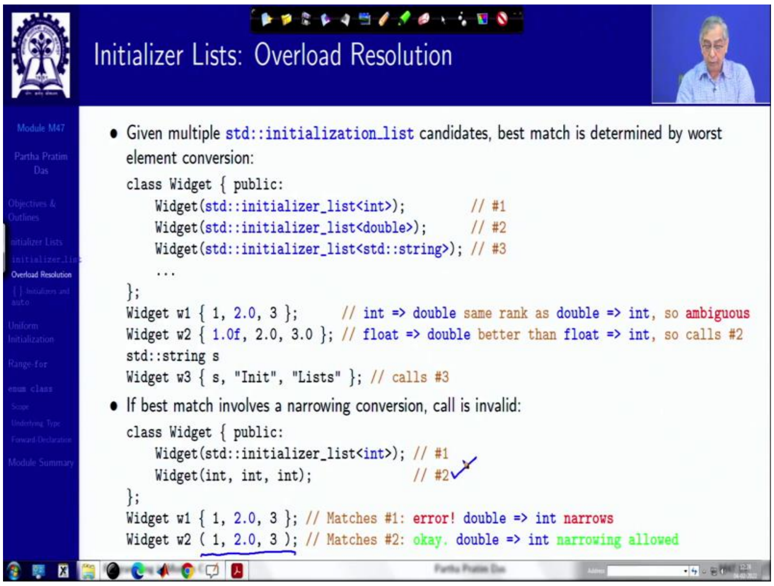

This, some more on this, like these are three initializer_list constructors are overloaded with different element types. Now, what will happen if I try to call construct w1 with this, it is all are initializer_list, so the choice is to be between them, so if I want to do w1, where the second element is 2.0, it has two choices, one is to convert 2.0 to 2 and call the first one. Or it can convert 1 and 3, to 1.0 and 3.0 and call 2.

So, it is either int to double conversion or double to int conversion, both of these conversions of the same rank, remember the overload resolution strategy we had. So, this kind of a construction will be ambiguous. It will not compile. If you do this, so then also you have conversion issues because the first element is a float where the other two are of, type 2.0 and 3.0 are double that is C++ default type mechanism.

So, if we have to, so the only candidate is this one here where you need to do a float to double or if you have to do this then you have to do a float to int, double to int. Now, float to double has a better rank than float to int, so what will happen, it will call the constructor number 2, and if you just use strings, then it will call constructor number 3, obviously.

Now, let us say I do a overloading with some twist, I have an initializer_list and I have another constructor with 3 int parameterized, I am calling it with 1, 2.0 and 3. Now, what will this mean? This will mean that the only constructor to call is this, which means the double value will have to be converted to int, which is narrowing.

So, here we learnt a golden rule that initializer_list does not allow narrowing, does not allow narrowing implicitly, so this double to int will not be allowed and there will be an error, whereas if you use three values within curly brace, within parentheses, then you are actually by overload you are binding to the second constructor where the narrowing is allowed and that will compile and w2 will get constructed. So, this is the difference, you have to remember that narrowing is not allowed for braced initializer.

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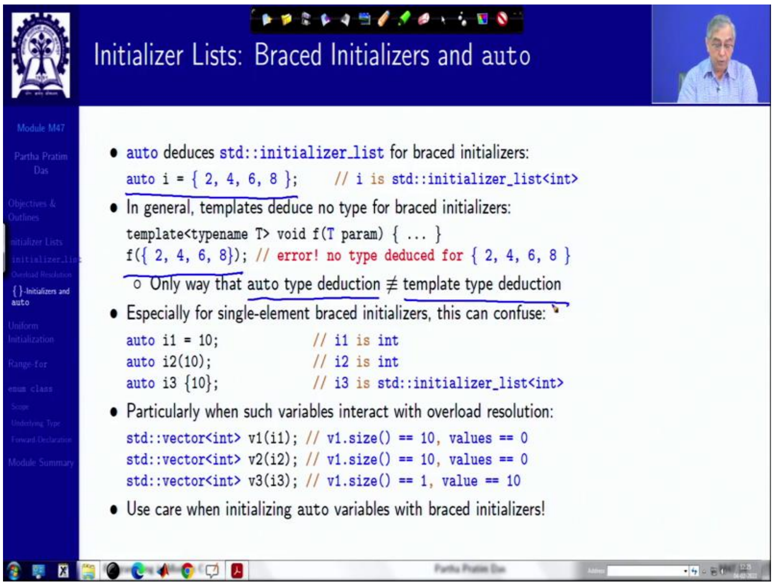

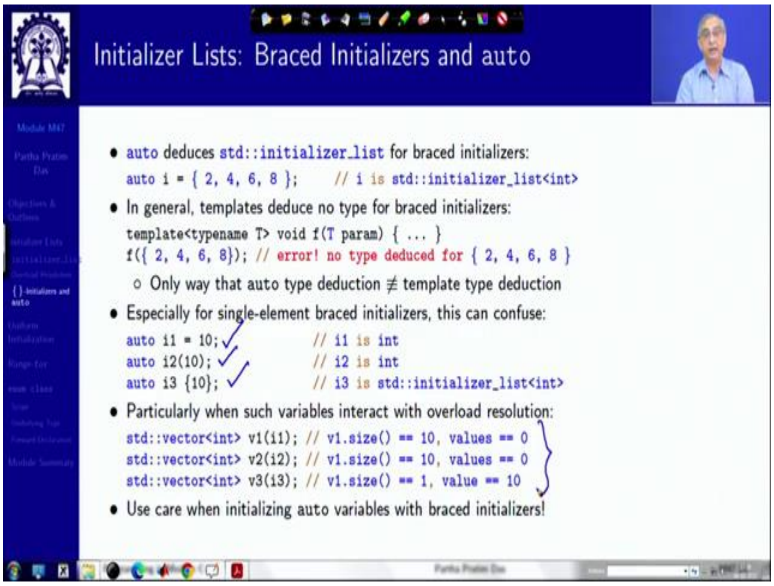

So, if you look at it with auto, this auto we have seen earlier also will deduce a initializer_list of int, you cannot directly use it in place of a template parameter. You would have expected to do that, but this is only one place where auto can go ahead with the type deduction, but template type deduction does not work.

So, auto can do more, template type detection will not be able to deduce, the T has a type, std::initializer_list, but of int but auto would be able to do that. So, with that there are more examples that you can use, you can use a single element with initialization, a parenthesized initialization, initializer_list and you can see what the effects would be. The first two will necessarily mean vectors of size 10 initialized with default value 0, and the last one will mean a vector of size one with value 10.

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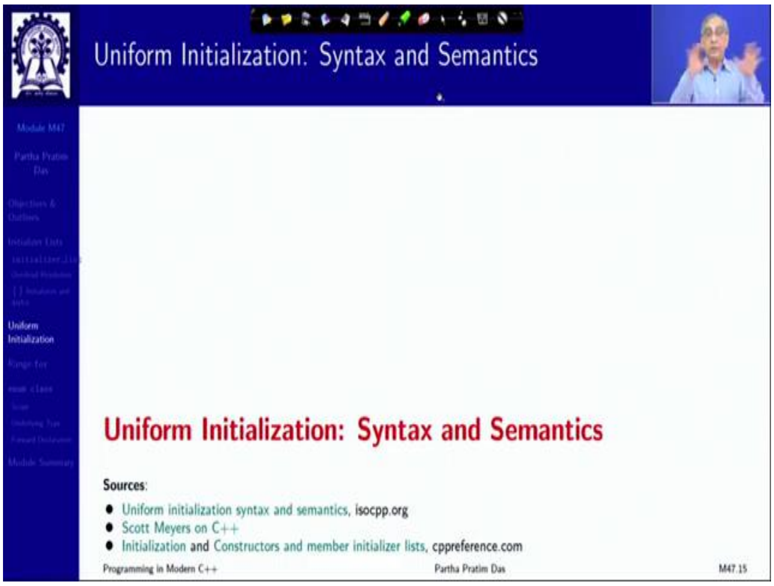

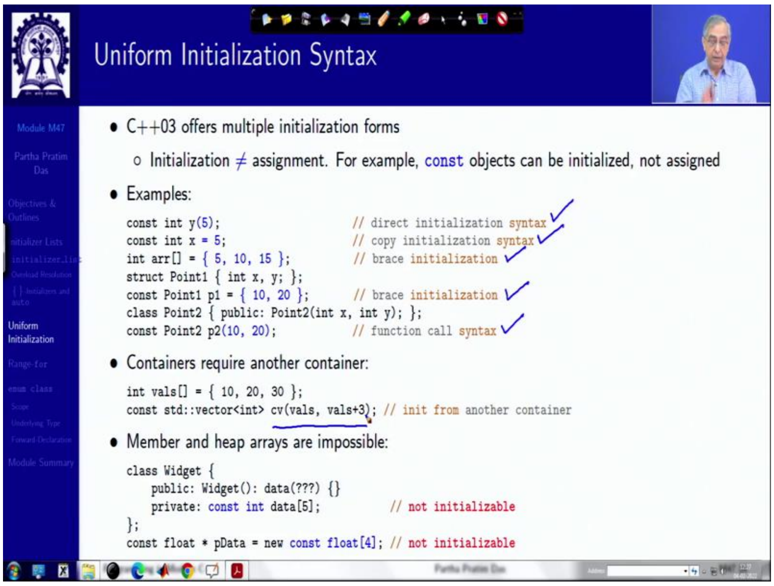

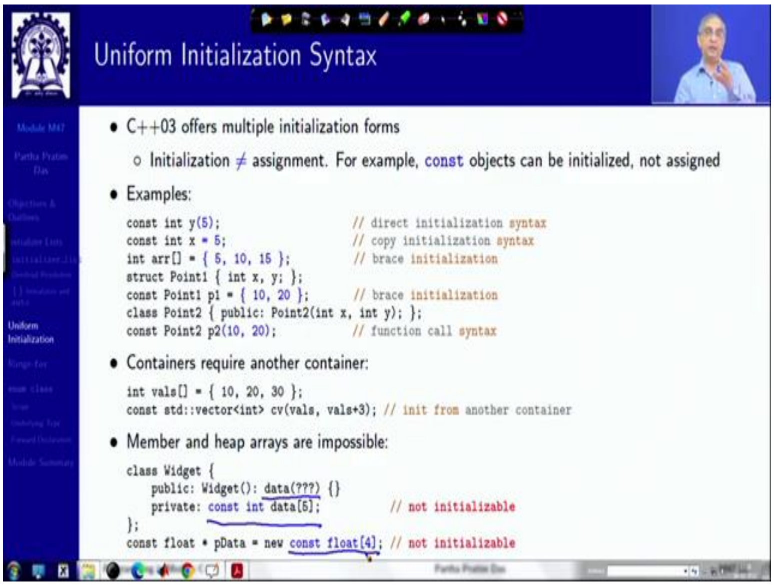

So, this was the initializer_list. The question is why are we trying to do that because what we want is we want to make initialization uniform, initialization syntax and semantics uniform. So, is it non-uniform? The answer is yes. If you look at C++03 there are multiple ways to do initialization. And remind you initialization is not same as assignment, like constant objects can be initialized, they cannot be assigned.

Initialization is something which happens when you are defining the variable, so these are the choices you have in C++03, 98. This is you can have a direct initialization syntax by parentheses, by using initialization symbol you can have copy initialization, you can have braced initialization for array, you can have braced initialization for a structure, you can have a function called syntax for calling the constructor.

You can also initialize one container from another. So, these are all different types and depending on the context we have got used to different types of syntax, somewhere it is braced, somewhere it is not braced, but that still lives out certain things which we cannot initialize. For example, if your object has a …, you want to have a array of …, array data of size 5 containing constant integers.

Now, there is no way to initialize this. There is no way to initialize arrays in this context where it is const. You cannot do this. Similarly, if you are trying to dynamically allocate an array you cannot initialize that, so we say that if I have to dynamically allocate a objects, array of the objects of a user defined type, then that type must provide default construction so that I do not need to do an initialization.

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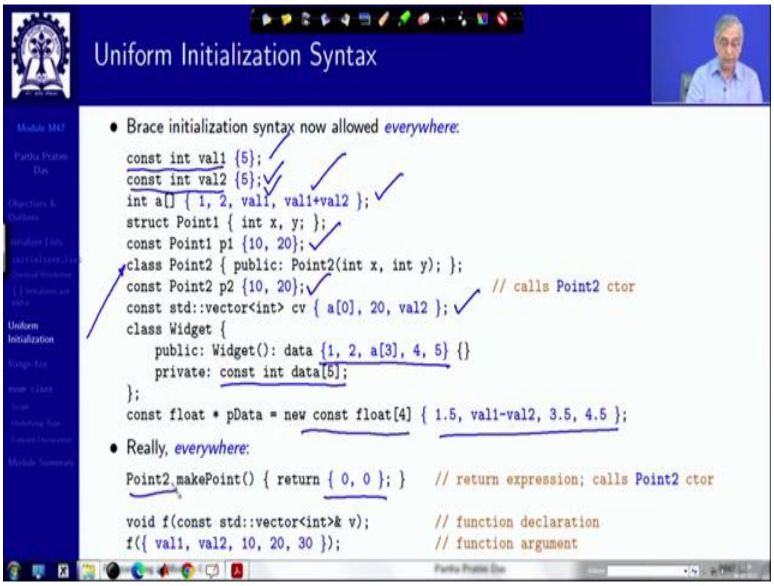

Now, this is in terms of syntax, the braced initialization is now allowed everywhere, so you can use it simply like this or you can use it in the way you are doing in terms of the array. You can obviously, you have to make sure that every element of the initializer_list is homogeneous and is a constant expression, so this is a constant variable val1, constant variable, so I am using those in the initialization of the array.

I can use this as it is for a structure, I can use it for calling a constructor, I can use it to initialize vector, everywhere, braced initialization can be used, and the interesting thing is it can be used now even if I have a constant integer array or something like that, I can just do a braced initialization here. I can also do braced initialization with dynamic allocation.

So, it can be used really everywhere, for example, I can return a braced initialized value from a function, so this is in the context of say class Point2, this will call the constructor of the class, I can pass it to a function, so everywhere braced initialization can be used, so that makes things really uniform.

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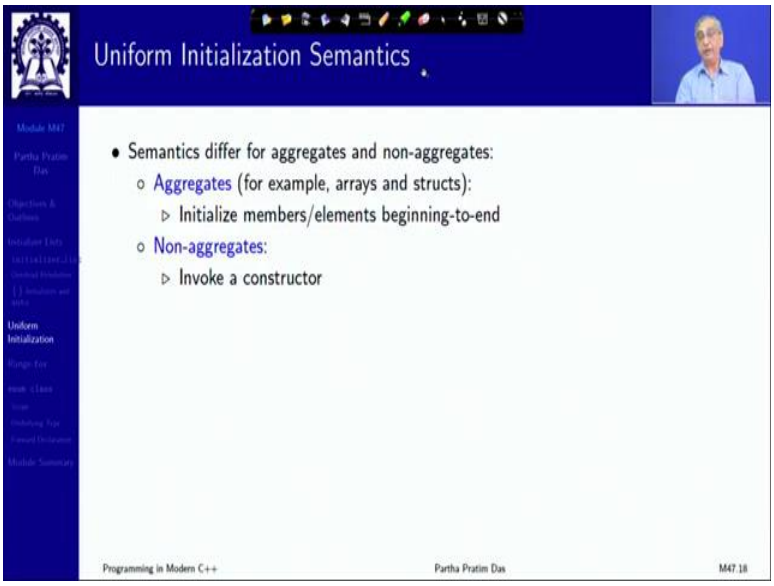

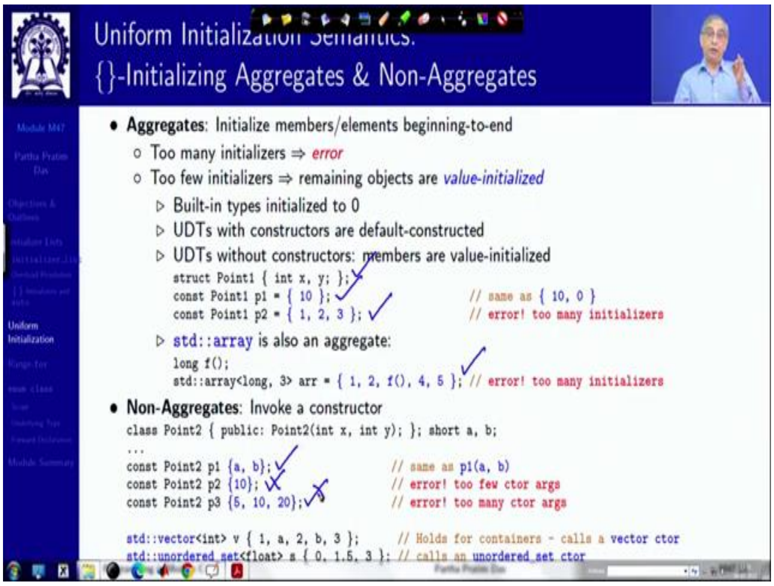

Now, that was about the syntax, in terms of semantics what we have, we have some difference between aggregate types and non-aggregate type. If it is an aggregate type, like it is an array or that kind of a container something then you have to provide the initialization and those will be initialized member by member. If you have too many initializers, then you will have an error, if you have too few, then you will have default values.

And for built-in types that is 0. So, you can see that I have a structure x, y here, so if I initialize it with 10 the second value will be taken as 0, if I try to initialize with 1, 2, 3 it will give me an error, similar thing for an array, std::array also we have not done it yet. It is pretty much similar to array but it is a new container here.

But if it, if I have a non-aggregate type that is which is not an array, then I can have not an array or a structure so to say, then it will invoke the constructor, so in all these cases it will try to invoke the constructor. In this case it will go through fine and in this cases this will not work because the number of parameters do not match. So, this is a construction process, this is not just the initialization, therefore, for non-aggregates the number of parameters have to match which was not a requirement right here.

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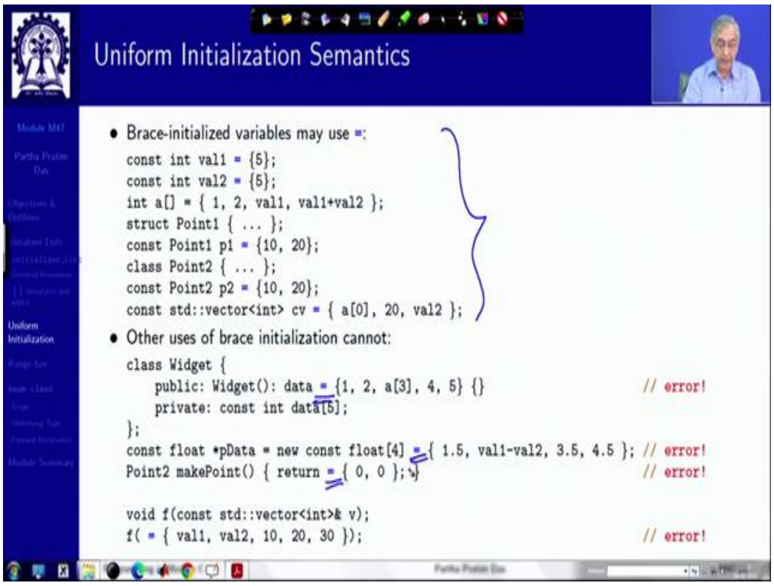

So, there are several places where you can also use the equality symbol, the initialization symbol as in these cases. I will not go through each one of them with a minus syntax issues, but these are places where you cannot use the initialization symbol equal to, so these are error.

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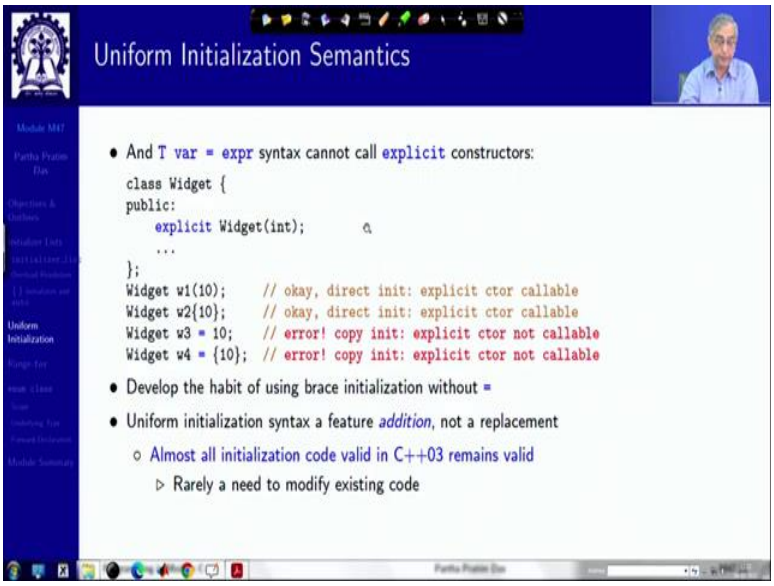

So, basically the core idea is as you get used to this, do not, I mean, learn not to use the initialization symbol anymore, just use the braced initializer or the parentheses if you have to do that, so this is small examples of that.

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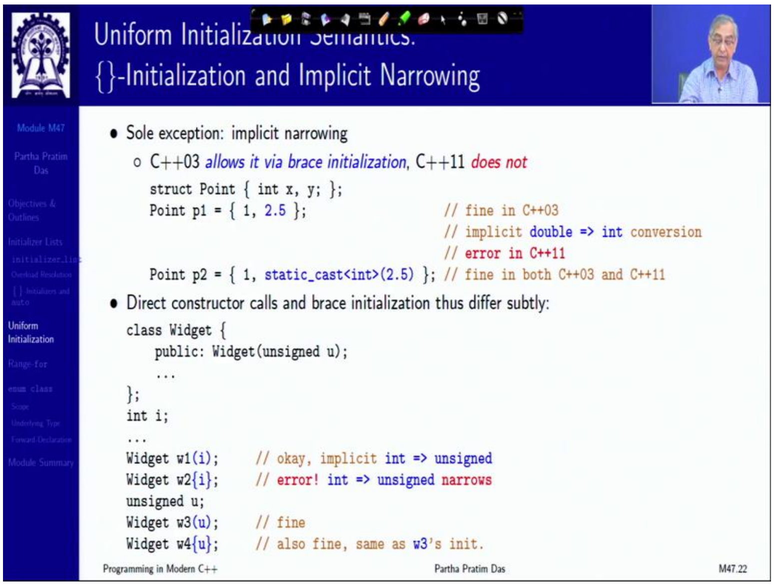

So, the implicit narrowing, there is another example on implicit narrowing. I will leave it for your self-study.

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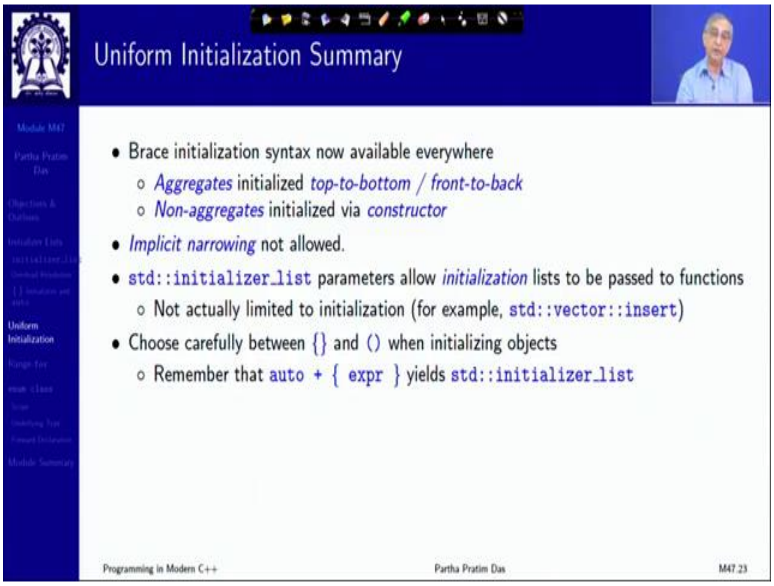

In summary braced initialization is available everywhere, aggregates will initialize top to bottom, front to back, non-aggregates will initialize via constructor and implicit narrowing is not allowed and initializer_list parameters will allow the initialization list to be passed to functions.

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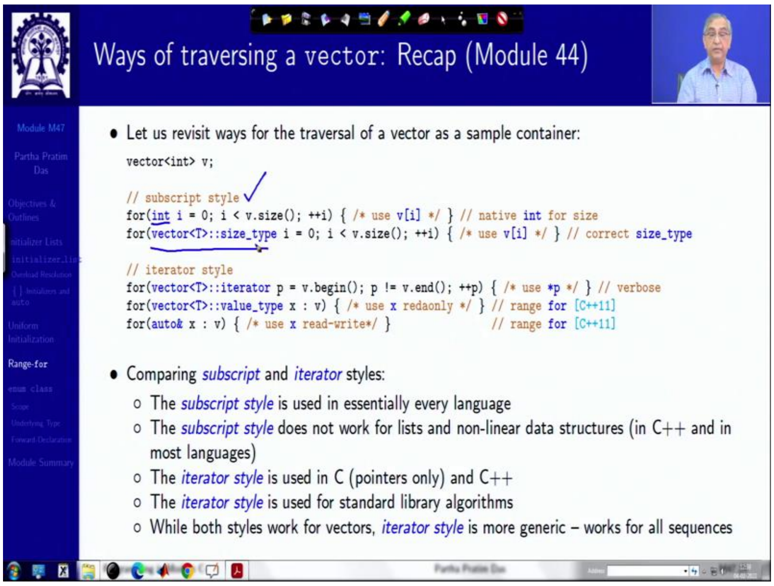
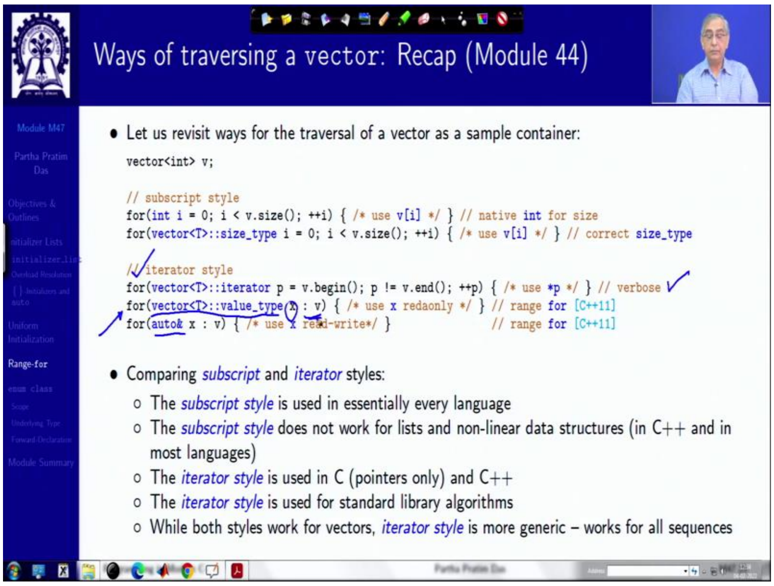

Ways of traversing a vector: Recap (Module 44)
Module M47
Partha Pratim Das
Objectives & Outlines
Initializer Lists
initializer_list
Overload Resolution
{ } Initializers and auto
Uniform Initialization
Range-for
enum class
Scope
Underlying Type
Forward Declaration
Module Summary
Let us revisit ways for the traversal of a vector as a sample container:
vector<int> v;
// subscript style
for(int i = 0; i < v.size(); ++i) { /* use v[i] */ } // native int for size
for(vector<T>::size_type i = 0; i < v.size(); ++i) { /* use v[i] */ } // correct size_type
// iterator style
for(vector<T>::iterator p = v.begin(); p != v.end(); ++p) { /* use *p */ } // verbose
for(vector<T>::value_type x : v) { /* use x redaonly */ } // range for [C++11]
for(auto& x : v) { /* use x read-write*/ } // range for [C++11]
Comparing subscript and iterator styles:
The subscript style is used in essentially every language
The subscript style does not work for lists and non-linear data structures (in C++ and in most languages)
The iterator style is used in C (pointers only) and C++
The iterator style is used for standard library algorithms
While both styles work for vectors, iterator style is more generic – works for all sequences


Ways of traversing a vector: Recap (Module 44)
Module M47
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initializer_list
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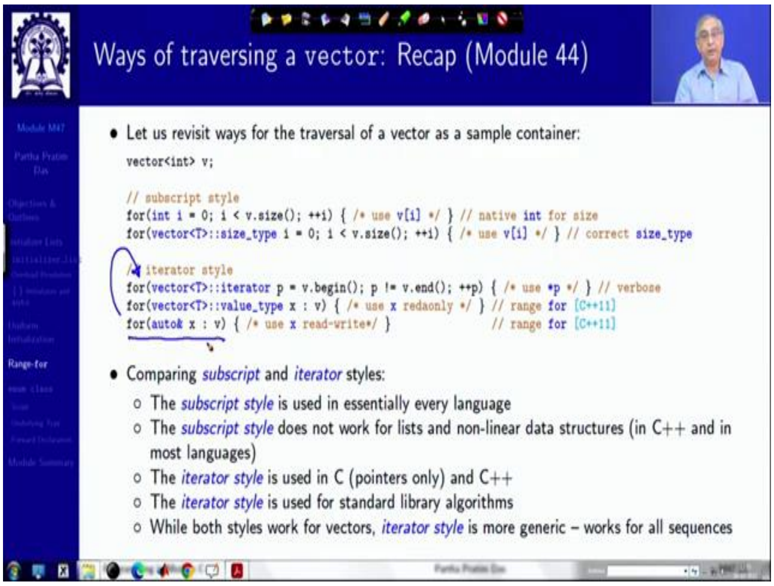
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Now, with this let us look at some of the other related features, one is range-for. We have seen this in module 44, when we are discussing about vector. Range-for talks about how to iterate over an entire data structure. So, we saw different styles that we could use a subscript style for a vector, either using the native int for size or the actual size type of the vector or we can use the iterator style, which is the verbose actual iterated style.

But C++11 allows us to do short forms of this. What were you saying in this one? We are saying that the value type, take the value type as x and : v, it means, this means this, so it will allow you to go over this, only thing is this will be read only. You can even use a shorter form, you can just say auto& x or auto x.

If you do auto& x this will be a reference, so it will, that reference will allow you to also make changes to the elements of the vector. The subscript style is common but the iterator style has power because it can be used not only in vectors, but in any other container which has support for iterators.

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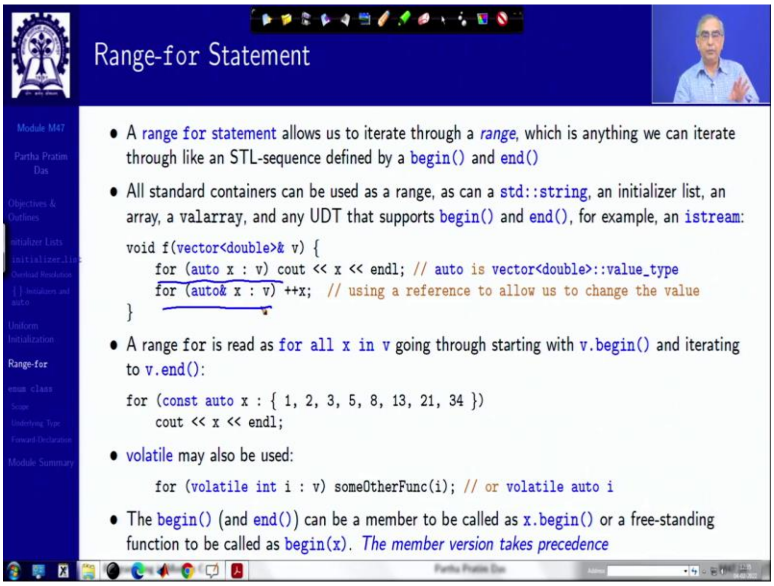

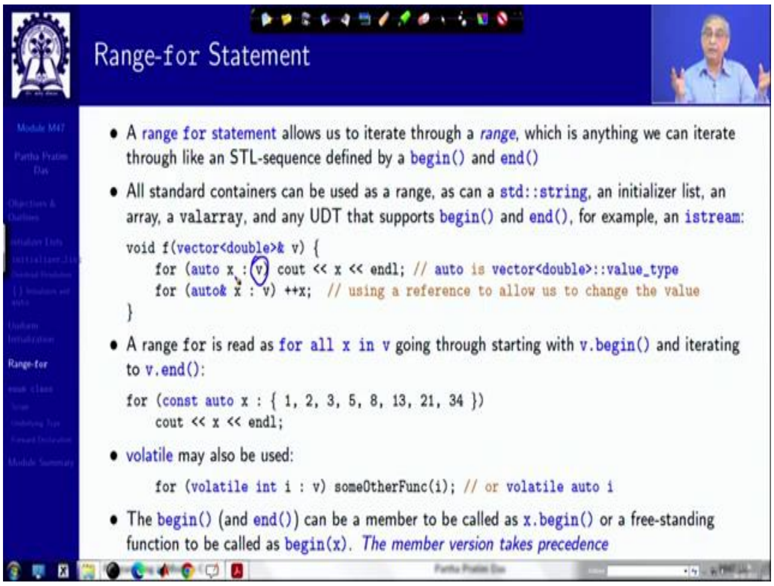

So, some, so this range statement basically allows you to do this. These are the, this is just that what you need to learn is you can use auto x : the container you want to traverse or auto& that and auto& that will allow you to write, auto will only be read. And this is possible, this range-for, this is possible provided the element on which you are trying to go over supports begin and end either as member function or as free-standing function.

Without that this will not be possible to perform this. It is a very convenient way to write very, very compact and uniform code and makes more code generic in that way, because now you are not even having to write what is the type of that iterator at all. You can, not begin, end, anything, of course, it works only when you have to iterate the entire data structure.

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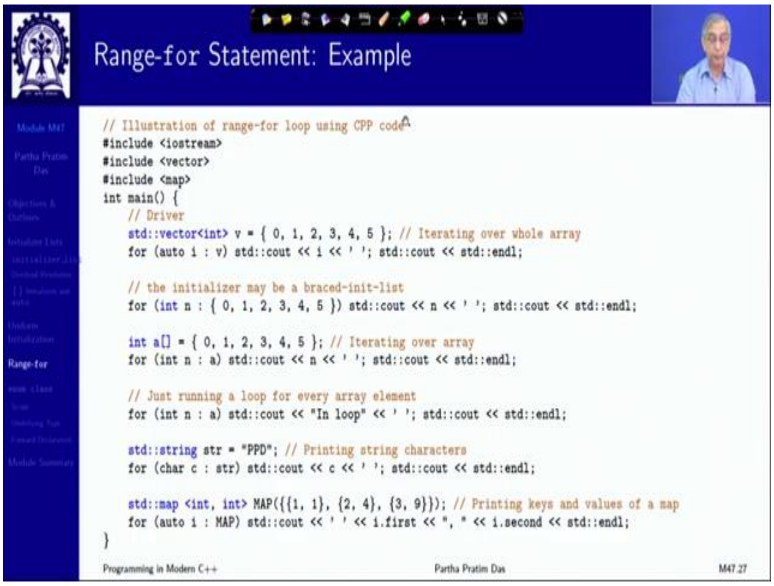

And, so this is, there are, these are some examples for you to study at home and get conversant with the use of range and with that we will we will close on the discussion of this module.

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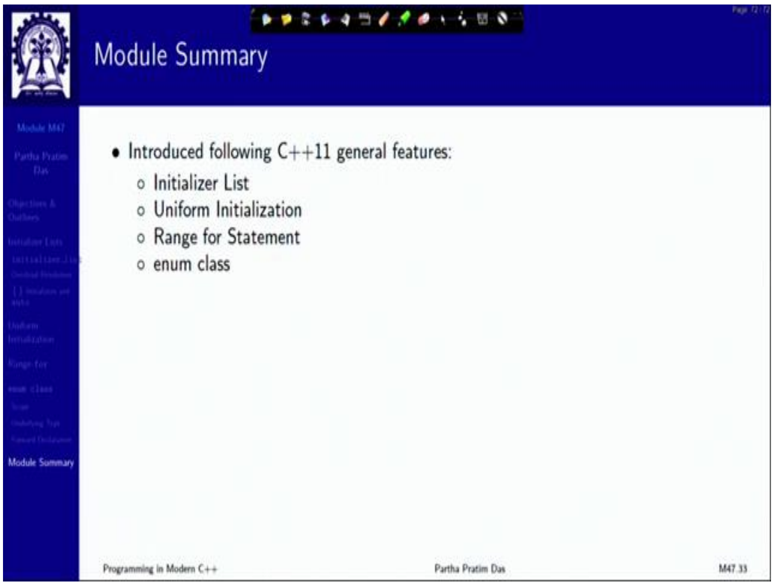

In this we have introduced three C++ general features, initializer_list, uniform initialization and range-for statement. Thank you very much for your attention and will meet in the next module.