Functional and Conceptual Design
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Lecture No. 22
Identification of Modules

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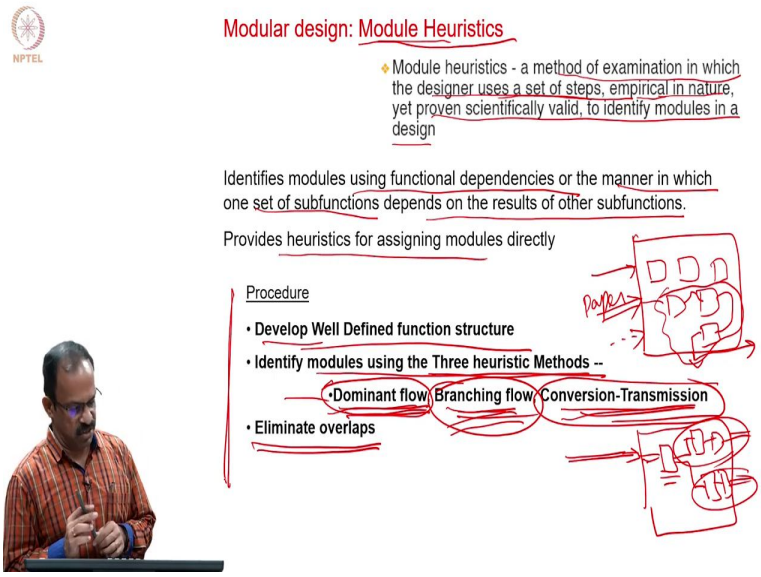

Hello, Good morning. Welcome back. So we are discussing the product architecture. In the last class we discussed the product architecture and the two types of architecture one is the integral architecture and the other one is the modular architecture and then we saw how the modules can be identified using some standard procedures. One of the methods we discussed in the last class where we try to group the functions which have something common, some flows common and then use some common sense approach to get the modules identified.

And then we found that it has got some limitations because there are no specific rules to identify the modules and many times we may end up with the wrong answers using these methods and therefore, we go for another method which we call it as heuristics based approach or module heuristics. We use some heuristics to identify the possible modules and then combine some of these modules depending on what actually we are finally looking for.

The module heuristics is a method of examination in which the designer uses a set of steps empirically nature, yet proven scientifically valid to identify modules in a design. So, we use this method to identify modules in a product but the method is more empirical in nature so it is not analytical in this case. So, it is an empirical method and it has got some steps already identified which we call the heuristics and then identify modules.

This is known as the heuristics based approach for identification of modules in a product and we have multiple modules, in this multiple modules can be identified using multiple heuristics so we have different heuristics to adopt.

Identify modules using functional dependencies or the manner in which one set of sub functions depends on the results of other sub functions. So we look at the functional decomposition again and then I try to identify what kind of functional dependencies exist between different elements and how the set of sub functions depends on the results for other sub functions. How the results from a particular group of sub functions goes to the other set of functions and how they depend on each other.

So, these are the things that we will look at in the heuristics method and based on this we identify the main heuristics to be used for identifying the modules. So, the procedure is like this. So, you develop a well-defined function structure that in the case of the previous case also we did the same thing we developed a well defined function structure based on the flows that is the material energy and information and then identify modules using the Three heuristics methods.

So, these are the Three heuristics that we want to use. The first one is known as a Dominant flow heuristics, then the second one is a Branching flow and third one is known as a Conversion-Transmission heuristic. So, we develop the look at the function structure and then try to try to see what is the most dominant flow in that function structure. So, as you know that the function structure will be having all the functions identified within the box and then we look at

this function and then see what kind of flows are there so we have the material energy and intermission.

In this case, we look for the most dominant flow. So at some point there will be more than one but we will try to identify all the dominant flows in this function structure and then try to combine all those functions which are actually part of this or it actually is connected with this flow as a module. So, that is the way how the dominant flow works.

For example if you take that in the case of a previous case also though it was not based on any rule, we try to see what is happening to the paper and then we try to identify all those functions through which the paper passes and actually comes out and then we can actually combine all those functions as a module. So, that is that is known as the Dominant flow heuristics.

There can be more than one flow dominant flow. We can actually identify all those dominant flows because there will be some flows which are not very important or not very dominant then we do not make modules based on those flows only the dominant flow we consider and then take the identify the module.

The next one is known as the Branching flow. It basically talks about the same kind of flow analysis. We look at one flow coming into the product, suppose this is a material coming into the product and then it passes through some functions and then it actually divides into two and then goes out. So, this can be one way that there can be functions in the structure such that the flow gets branched into multiple uh flows or multiple loops. Then each of these can actually be considered as a module so that is the branching flow heuristics.

So whenever there is a flow branching into multiple branches, then each branch we consider it as a module so that is the branching flow heuristics. Then the third one is known as the Conversion transmission. As the name suggests, whenever there is a conversion of a flow into something else and it is getting transmitted, then we can take that as a module so conversion transmission module we can identify.

For example, when electricity is coming into the product then after some time it may get converted to mechanical energy and then it will get transmitted by some means to some other function block. We put this conversion and transmission as a module. So whenever there is a conversion and a transmission or conversion or transmission can be only conversion or it can be only transmission; in this case if there is a conversion and transmission both can be taken into a single module. That is basically the Conversion-Transmission heuristics.

Using these three heuristics we try to identify all possible flows, possible modules. So there will be lot of overlaps also happening because a dominant flow module may be part of the conversion transmission module or it can be part of the branching flow module also; but we will try to identify all possible modules using the three heuristics, which is the dominant flow, branching flow and conversion-transmission heuristics, try to eliminate this overlaps and then try to identify modules. Based on this we identify all potential modules, we try to identify the overlaps and then eliminate the overlap and then identify the modules that is basically the procedure for heuristics based module identification.

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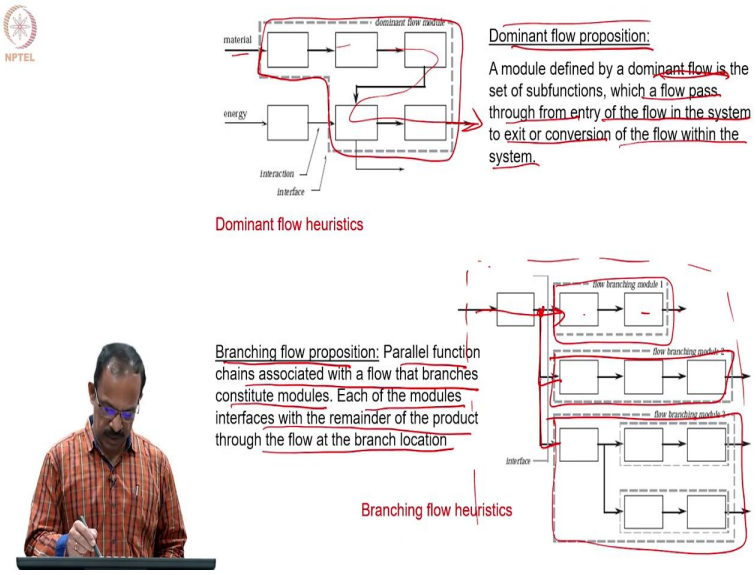

This is what I already explained: the dominant flow defined by a dominant flow is a set of sub functions which flow through from entry to the flow in the system to exit or conversion of the flow within the system. Till the flow gets converted, exits, comes out of the product or it gets converted to some other flow, all those functions which will be part of that is known as the dominant flow proposition. So, all the material is coming here and the material is going out then we consider this as the module so we will consider all these functions as the part of the dominant flow module. That is the dominant flow proposition and now, the branching flow as I told you, the parallel function chains associated with the flow that branches constitute modules. So, you can see that something is coming here and then it actually branches out. This is the interface so it is coming here and then this branching out to different branches. We will take all this as the modules so potential branching modules 1, 2, 3 like this will take. This is known as the branching flow heuristics or branching flow modules. So, each of the modules interfaces with the remainder of the product through a flow at the branch location. So, this location will be the interface for these modules with the rest of the product. The product may be the outer box, will be somewhere here. But this, each module we can see that has got a common interface with this product or the rest of the product using this one becomes the common interface.

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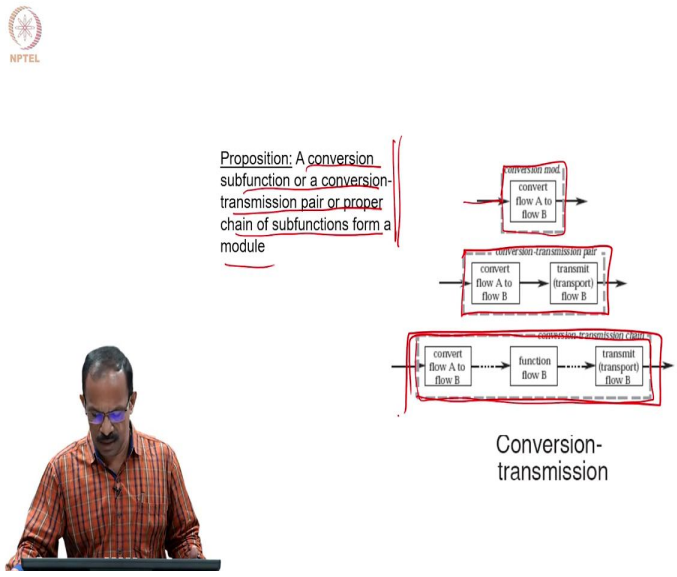

That actually identifies the common interface and then we can say that these 3 modules can be considered as modules which have got a common interface with the rest of the products. That is known as the branching flow heuristics. And the last one is the conversion transmission, a conversion sub function or a conversion transmission pair or proper chain of sub functions from a module. So, that is basically the conversion transmission.

So, you can see that there is a conversion only then you can say the conversion module converts from ‘flow a’ to ‘b’; that is converted electricity to mechanical energy or electricity to torque, etc. So, that becomes the conversion module or there is a conversion and then transmission that is you convert ‘flow a’ to ‘flow b’ that is, from mechanical electrical energy to mechanical energy and then transmit torque.

That will be the conversion transmission pair or you can actually have a combination of these converts then another flow then again transmits that also can be considered as a conversion transmission chain. So, you have conversion then it flows I mean passes through some functions again it gets transmitted then also can be considered as a module. This is the conversion transmission chain. This way you will be able to identify the modules using these three heuristics. So you have the dominant flow, you have the branching flow and the conversion-transition.

So, most of the potential modules that can be identified in a product can be identified using these three heuristics and as I told you there will be lot of overlaps between these modules, identified modules and then as designers we need to sit together and then identify the overlaps and then remove the overlaps and then look at the interfaces and accordingly decide these are the potential modules that can be there in the product.

Again that decision depends on many other factors like the number of products you want to introduce and generation portfolios that you are planning to have. So, all those things also affect

the final decision but potential modules can be identified using these three heuristics. We will see this or we will look at some examples to see how this can be implemented in a practical case.

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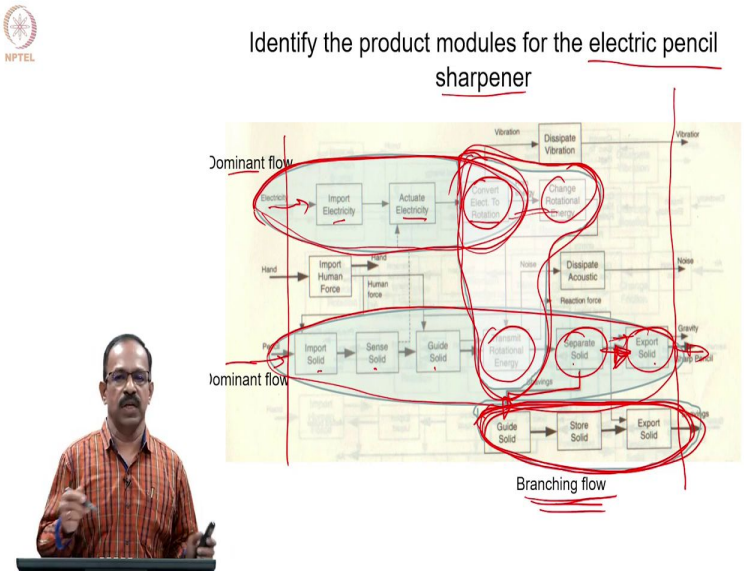

This one again we already saw as an example earlier using the first method where we try to combine the function which has got something in common. We will use an electric pencil sharpener so now we can actually look at whether there is a dominant flow, branching flow or conversion transmission. So, you can see this electricity as a dominant flow here. Electricity is coming, import electricity, actual electricity convert to rotation, so up to here it is electricity.

So, we will actually put these 3 functions into a model saying that this is the electricity module and after conversion it just becomes something else so we do not put those functions a part of this one. Then similarly, we look into the pencil. So, the pencil is coming to the product then import solids and solid guide solids then separate solid, export solids. So, all those things transmit rotational energy, of course the energy passing is given to the solid so it actually becomes part of it and exports solid.

So the solid is coming out so till the pencil is coming in and till it goes out it has got many functions so we put all those things into the dominant flow module. So, these are the 2 dominant

flows that you can identify in this product and of course, there are many other flows actually and other things are there but we do not consider but we can actually consider this.

This actually contains another module potential module that you have the guide solid, store solid and export solid which is actually a storage module for the shavings of the pencil. So, that can also be another one because this also a potential module. Now, there can be other opportunities also. This actually becomes a branching flow module because it actually branches out from here. So, this actually goes out from here and then it comes, this material solid one branches here and one branches out here.

This can actually be considered as a branching flow and therefore this becomes another module branching flow module and this actually becomes another one. Since we only found one function there we need to see whether it can be taken as a separate module or not. Otherwise this becomes a part this becomes part of the branching flow model. So, these two are the dominant flow modules and this one is a branching flow module.

Now, this can actually be considered as a conversion. Here you have a conversion to convert to electrical rotation and then change rotation energy and transmit rotation energy. This can be considered as a conversion-transmission chain and this would be another potential module a conversion-transmission module.

Now we can see by using the dominant flow you will be able to clearly tell what are the potential modules that can be I mean, using the heuristics we will be able to tell what are the potential modules that is possible within this product, not that we will make everything as a module we look into this and then see what can be a model what cannot be a separate module and will decide how to go about identifying the actual modules in the product.

For example, this dominant flow module imports electricity, actually electricity then converts transmission and transmission so there is an overlap here. So, you need to decide whether you

want to make this conversion transmission as a module or you want to make this as a module part of this. So, that actually is left to the designer based on the requirements of the product as well as the concerns and other considerations they can decide which one to be chosen.

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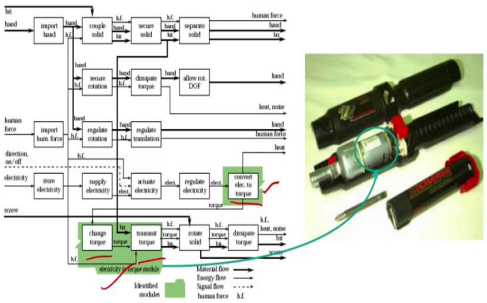

We will take another example here which is again a power screwdriver. So we saw this function structure earlier inputs like these are the inputs you can see the hand human force, electricity, screw these are the inputs and then these are the outputs that you can see. Now, here again you can apply the dominant flow heuristics so you will have one for the electricity. So, it is the electricity based on the electricity you can identify one supply electricity module and then you can have basically here is a conversion transmission module. So, here is the change torque, transmit or display torque. So, convert electric energy to torque.

This is a torque transmission model. This is the conversion so you have conversion and then transmission. You can put it as a conversion transmission model or a transmission module separately and here there is a coupling so solid so the bit tool bit so couple solid, secure solids and of course the separate solid also can be made part of this if you look for the dominant flow. This way you will be able to identify potential modules and another one you can see is that here you can import hands and you can see here actually it is getting branched to different branches.

There are 3 branches for this one. We will see similarly human forces also getting branched into multiple cases here. We can look at the branches here so this can be one branch this can be another branch and this can be another branch. This way we will be able to get the branching modules also. The branching modules can be identified as coupling decoupling modules; because you are using the hand force to do this and that actually gets branched out, so you have a coupling decoupling module and then you have a manual use module.

This actually makes it possible to use manually so we will use that as a manual module and this as a positioning module. And then that is again this coming here so hand force so it is an actuating module. So, this way again the hand force is used here for this application, this purpose so we can this hand force is coming here so there can be a branching module here also is basically the torque transmission module.

On looking at the branching of the hand force as well as the hand, you will be able to identify many modules as part of the branching heuristics. The dominant flow heuristics gives you some modules, then you look at the branching flow module that will give branching flow heuristics that will give you some modules. Similarly, now you go for the convert to electricity, so a conversion module and then transmission module also. This converts and then converts to torque and the transmission. That is the conversion transmission module so convert, change and transmit so conversion transmission module.

We use all the three heuristics separately and identify the potential modules and as you can see here there will be a lot of overlap between these modules and then remove the overlaps and then identify the actual modules needed. This is the way how we use the module heuristics to identify potential modules in a product and this is only potential modules as I told you this is not the final one the final module will be decided based on the by the removing overlaps as well as taking into consideration other aspects of the requirement of the product.

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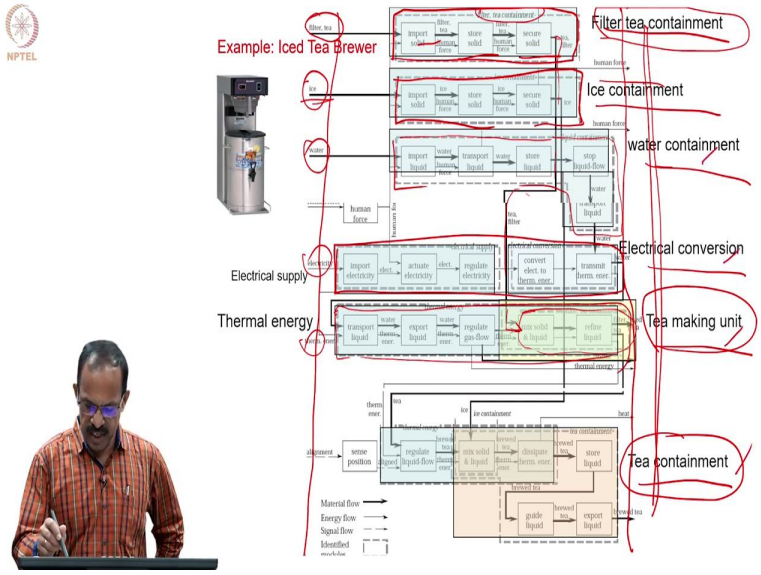

You should be able to look at the function structure and then should be able to apply the module heuristics to identify the potential modules. If you look at the function structure again, this function structure we already discussed in one of the earlier classes. I am not going into the details of how you get this function structure. You will be getting this function structure, so the input will be filter tea, ice, water then electricity then thermal energy, that is thermal energy coming and then alignment other things, that is in information. Now you can see the dominant flows in this case.

You can see that is a dominant flow of filter and tea. All these functions which are actually part of this will become a filter tea containment module. Then this will become an ice containment module import solid, store solid, secure solids that becomes the ice containment module because that is the dominant flow here in this case and similarly of course, that will be actually continuing here also mixed solid and liquid until the come out.

You need to look at those functions which are actually connected to ice and then combine all of them together in that module. Similarly, water so it has a water module here. You can see liquid containment module and electricity, electricity module again it is a dominant flow so you have

an electricity module and this as part of the energy module so you have thermal energy coming from here. The thermal energy is converted to thermal energy so now thermal energy becomes a flow.

You can actually follow that and then try to identify all those modules connected to the thermal module. If you see that this is a filter tea containment module so this is also part of the filter tea containment module so that is why it is mentioned here. It is not stopping here so you need to look at what is happening to this tea and filter so basically coming here and then going here so it becomes again part of the filter tea containment.

Follow the flow and till it gets converted or till it comes out of the product put all those functions in part of the dominant flow module. So this is the module and this is the way how you can identify modules. Again you can actually look at the branching if there is any branching happening or if there is any conversion happening so all those things can be converted and then you can actually have different modules. There will be different such modules identified here, so you can see this ice contained part of ice containment after tea containment and this is the brew tea can be another module.

Once the water is converted to water tea leaves everything converted to brew tea becomes another flow. So, you can actually put that also as a module. So this way, you will be able to identify all potential modules in a product by simply following this module heuristics or applying the module heuristics and then getting the potential modules. Once we have all these potential modules you try to identify the best possible module for the product and that will be like this. So you can see filter tea containment, ice containment, water containment, and electrical conversion tea making unit and tea containments.

Here this talks of only about the filter and tea here it is ice it is water and then there is an electrical conversion and there is a module which actually makes tea and once the tea is made then this module takes care of all those the rest of the thing that is the tea containment module. In

the structure of the product structure now we know that these are the important modules that need to be there in the product.

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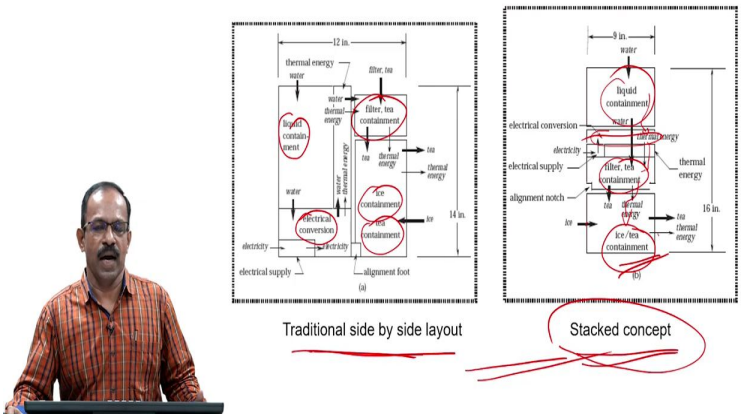

We can now create a structure, product structure or a geometrical layout based on this and you will be getting this as the possible layouts. We identified the liquid containment, we identify the electrical conversion, ice containment, tea containment, filter tea containments so these are the modules. Now, as a designer you can see okay what way you would like to arrange them so that you will get at least a geometrical layout of the product based on these identified modules.

We still do not have any physical form for all these things but at this we know these are the modules that need to be provided in the product and these modules can be arranged in such a way that you will be getting all those functions needed. So, this is one way of side by side layout or you can have a stacked concept also like one over the other. The ice tea containment, filter tea containment, liquid containment like that and then electricity and the thermal conversion here electrical conversion module here.

The water will come through the electrical conversion heat and then it will pass through the filter tea containment so that the tea can be added and you will be getting the tea then you can add ice

and you will be getting this as the tea ice tea. This is again another concept or stacked layout that can be proposed for the product.

Now you see how things are progressing. We started with looking at the customer's requirement and then looked at how to satisfy the customer requirements, what kind of specification to be provided and what kind of functions to be provided and then from these functions how can we identify different modules in the product and how these modules can actually be arranged so that we can get a product layout.

This is basically the architecture of the product and if you want to have multiple products in the family, we can also do this by changing some of these modules to a different module you will be getting a different product in the family. That is basically what the product architecture is all about. I hope you understood the basic idea of how we identify the architecture of a product.

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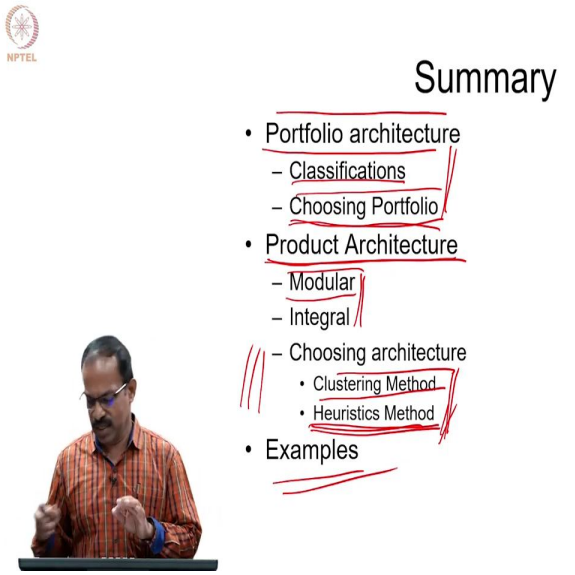

To summarize whatever we discussed in the last few classes, we started with the portfolio architecture and then we saw what are the different portfolio architectures existing and the classifications of portfolio architecture basically based on the modules or the integrated one or I

mean unshared architecture or modular architecture in within the modular architecture what are the different possible options like modular family, modular generation, etc.

And then we saw how we choose the portfolio based on the customer's requirements by looking at the population distribution as well as the segment distribution. We will be able to identify the changes needed within the products and therefore we will be able to identify a portfolio based on that.

How many products to be offered and what should be the way in which the product should be architected can be obtained in this case. And then we talked about the product architecture, the product that is how an individual product needs to be identified or its architecture can be identified. So, how do we actually convert those function blocks into physical chunks and then how these chunks can provide the necessary functions and here also we identified two important architectures one is the integral one the other one is the modular one.

Integral all the one physical blocks provides you multiple functions and there will not be any clear distinction between the functional blocks as well as the physical chunks and in modular will have different modules providing different functions and there can be clear interfaces between these modules. And then we saw how to choose the architecture. Suppose we have decided to go for a model architecture, how can we identify the modules within the product that was the choosing the architecture.

And we saw one that is the basic clustering methods where we use our intuition to come up with some modules based on the flows and how it is actually arranged in the function structure. The other one was the heuristic method where we tried to apply some heuristics to identify the modules within the product that is known as the heuristics method. And we identified there are two methods or there are three major heuristics we use and they are known as the dominant flow heuristics, branching flow heuristics and conversion transmission heuristics.

So, using these heuristics we try to identify the potential modules and then we look at the overlap of these modules and based on the design team's understanding and the requirement of the product finalize the modules. So, once the modules are identified then you can create a layout of

the product to see how these modules can be arranged so that you will be able to make a complete product to meet the customer's requirements.

So, that is what we discussed and we saw a few examples. Also how do we convert, how do we use these principles to identify modules. So, with that we come to the conclusion of the product architecture. So, the next step is basically to see how we can give shape to these modules. So, we identified this pro architecture, we identified many modules for a product saying that we need to have a tea containment module or we need to have a conversion transmission module or we want to have a water containment module.

Now, as a designer you need to see how we can have a tea containment module or a water containment module which is not the same as what everyone is providing. You want to have a new design for it or you do not want to copy somebody or you want to have your own design so that it can actually meet the specific requirement of the customer and that actually comes from developing concepts for this product or the modules.

So, it can be a concept for the overall product or it can be a concept for a particular module or more specifically for a particular function also. So, that is the next stage where we go to the development of concepts for these functions or modules or the products. So, we will go to the concept development as the next step or probably the final step, that final thing that we will be discussing in this course. We will look at how concepts can be developed for each one of these. So, we will move to that topic now.

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So, as I mentioned we will be going to the concept generation stage now. So, from the functions to the product architecture into the concept. So, that is the stage we have reached now.

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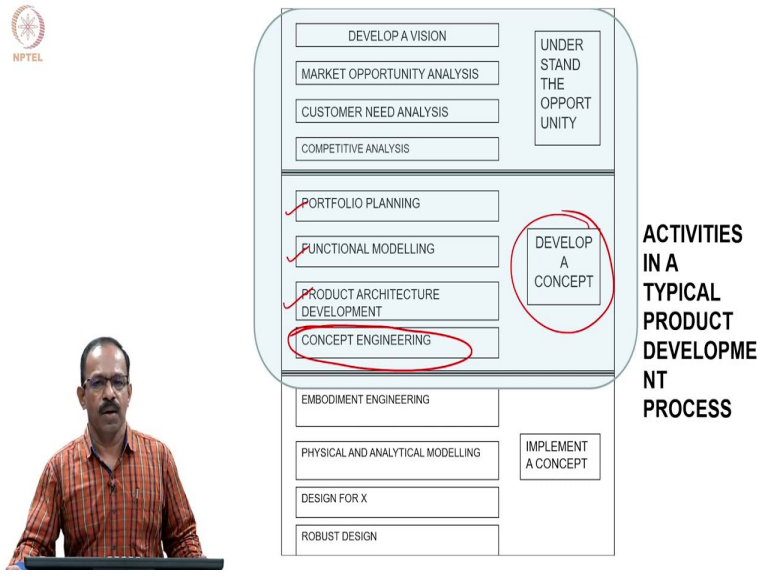

So, in this section we can see that we are in this stage of product development, in the concept development stage and we mentioned that activities in a typical product, that is all activities needed to see what the product should be, that is to develop a concept. Now, we have completed

this one portfolio function modeling and product architecture so the last one is the concept engineering. So, we are at the stage of concept engineering in product development.

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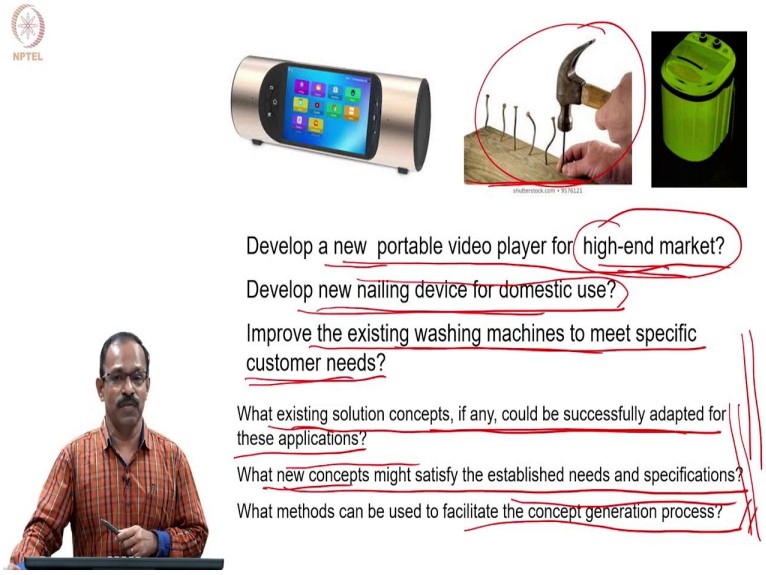

So, most of you must have done a lot of design in many applications, whether it is a very small one or a slightly complex one we will always be doing something related to design. So, whenever we try to solve a problem that actually is a kind of a design. Now, as a designer you will be encountering many such design issues. For example you want to develop a new portable video player for a high-end market or a company is interested in developing high-end video players or you want to develop a new nailing device for domestic use.

So, you can see this kind of nailing, this is the normal way of nailing a hammer and it will always create a lot of issues where you want to convert this into an electrical nailing tool or you want to improve the existing washing machines to meet specific customer needs. So, these are the starting points for a new product development and then what we will do if you want to develop this one you need to look at, you need to go through all these steps and then identify the critical areas where you can contribute to the design.

Because when you do a function decomposition you identify the product architecture, you identify the modules and you are not going to change everything in the product. When you are

bringing a new product it is not that everything is new or everything is completely different from existing.

You will be using lot of existing things but something which you want to contribute or some area where you want to improve that is the for example here it is saying for high end market so you have a specific focus a mission and you want to see to satisfy this high end market what should be provided what module to be provided and then you try to develop concept for those modules that is the way how you start.

Similarly, if there are no existing products then you probably need to think of many things and then you need to think of how you actually provide the necessary functions and then how these functions can actually be given some physical shape and to do that you need to develop concepts. So, this is the way how we normally start with the design of the design process.

So whatever it is, this washing machine to meet specific customers needs some customers; say that, I want to reduce the water consumption that may be a requirement of some customers. Then you need to look at the function blocks which actually use water and how the water is being used in the product, what kind of functions are there and then you try to identify a module which can actually be redesigned to get the customer specific needs.

And after all those analysis you come to the stage where you can develop a new concept to meet this customer's needs. Then you start developing constructs for that particular module. So, that is the way we proceed in the design process. So, now let us take this example for this nailing device and see how we can actually go from one stage to the next stage in the design process.

But most of the time we need to look at existing solution concepts, if any, could be successfully adapted for these applications. It is not that you need to have everything new, as I mentioned it is not possible to have everything as completely new in any product and no product will be 100% completely new also. There will be a lot of things which people try to adapt from different fields.

Before going for the concept development, you need to look at what existing solution concepts can be successfully adapted for your product. Similarly, what new concepts might satisfy the

established needs and specifications? So, you have established some specific needs and you identified the specification or develop the specification you have to see what kind of new concepts can actually satisfy that and what methods can be used to facilitate the concept generation process.

So, how can we actually do the concept generation? If you need to develop new concepts, suppose you need to develop new concepts for the product, what methods can be used to facilitate the concept generation process. So, these are the things that we need to look at in concept development or when you try to develop new products or new concepts for a product we need to keep these things in mind.

And then see how we can use the existing concepts or adapt the existing concepts or what kind of new concepts need to be developed and how can we generate this concept in a systematic way. So, these are the things that we will be discussing or we need to be aware of when we go for concept generation.

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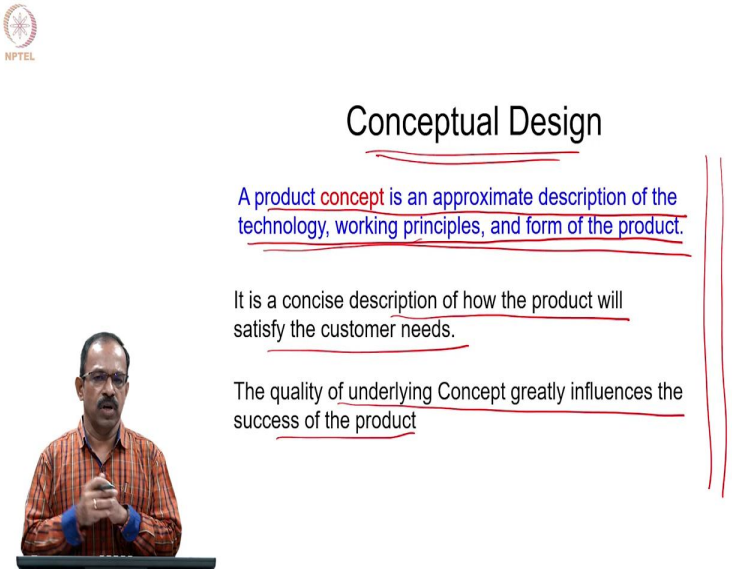

So, conceptual design, a product concept is an approximate description of the technology working principle and form of the product. When we are trying to develop a concept, the conceptual design or a concept is an approximate description of the technology working

principles and form of the product. So, what kind of technology you are going to use and what is the basic working principle and what is the form and how does it look like that is basically the form and that is basically known as the concept of a product or a model whatever it is.

And it is a concise description of how the product will satisfy the customer needs and the quality of underlying concept greatly influences the success of the products. So, that is conceptual design. So, we will discuss this in the next class. I do not want to continue now. I will stop here and we will see how the conceptual design can be systematically approached and quality concepts can be developed. So, we will discuss this in the next class. Thank you.