Design of Mechatronic Systems
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Lecture 1
Introduction

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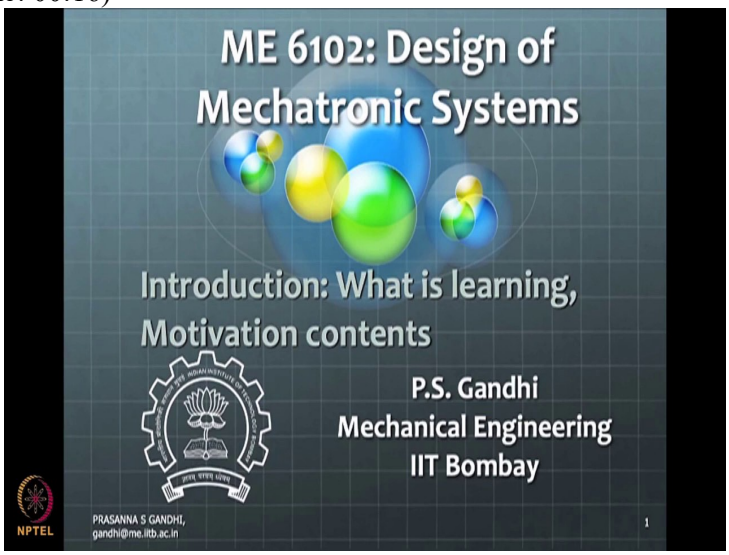

Hello, welcome to this course, ME 6102 and Design of Mechatronic Systems. What we are going to see today is mainly the introduction, part of that is what is learning, we will see what it opens up for us and then motivation for this learning and the contents of this course. These are mainly things that we are going to see today. So, my name is Prasanna Gandhi and I will be there as the instructor for this course with you for this semester to go. So, let us begin here. Let me switch to the slide mode again.

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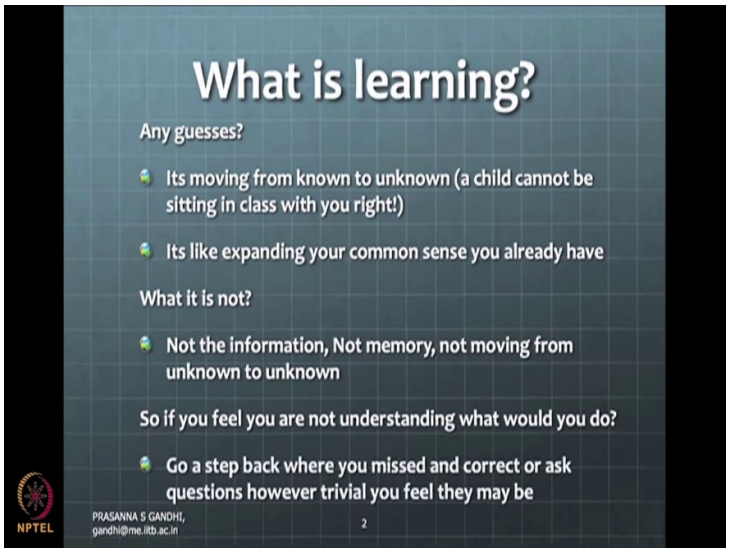

Now, first let us ponder on this thing. Have you ever understood this mechanics of learning? How the learning happens? What is this learning? So, any guesses, can you see, think about, how exactly when we see or you read something or you listen to somebody, what is a way, the learning happens in the process.

If you kind of ponder over closely, you understand that it is not about just some information; it is actually taking you to what you already know and adding something more to it. So, it is something, moving from something known to something unknown. So, that is why you need some a background for learning anything.

So, child cannot be sitting in this class with you. I mean, he or she may not understand anything talked about, but there is basic, some a background if you have, then you can connect with that background to some something unknown and you grasp a little more than what you have unknown already.

So this, we understand this process. If you understand this process very well, then it is very smooth journey for enhancing your knowledge, you will not have a situation of panic, because for understanding something, you need some background. So, it is like, in some way, expanding your common sense.

So this is again, another part of learning. See that from childhood, we have this a common sense. For example, when you are driving a bike or when you learn first to ride a bicycle, you

do not need to know the fundamental of mechanics or force or kinematics or dynamics of the systems. You learned it by some way, with that kind of common sense.

If you tend to fall on one side, you need to do something to not make that fall happen and somehow you kind of mastered that skill. So, you do not need really these fundamentals to get a sense. So this common sense, is what I am talking about here. We should not lose it. I mean, I found like over my experience, many people, they tend to lose this common sense instead of expanding during the process of learning the engineering courses.

Especially deep mathematical courses, you tend to believe math more than your common sense and then that is where things start a little bit moving away from doing any useful things out of whatever you are doing. So, you need to be aware about this two things, the learning process is going from known to unknown and this is a common sense that we already have some something within us, we want to expand it more. Another example I can give for this common sense kind of a thing is the sense or feel for numbers.

So, if I say 1 meter or 1 mm, you understand what it is. You have a feel for what is 1 mm and what is 1 meter, but probably if I say the same thing for acceleration, 1 meter per second or no that is very a little bit too hard to get a feel for that. So, we are to develop this feel and that feel is very important for designers.

So, we will see a little more about that as we go along. What it is not; it is not just information, it is not your memory and it is not moving from unknown to unknown. So, if you are something is being talked about and you are not able to connect it to your prior knowledge or it is just making no sense to you that means probably you need to go back a little bit one step and do read about the prior background necessary to understand that.

So, that if you understand this then you will not have a difficulty, so when you do not feel that you are understanding well then you go back and to do some background and come back again to this. So, this is what we will do. Then let us move on to the next question.

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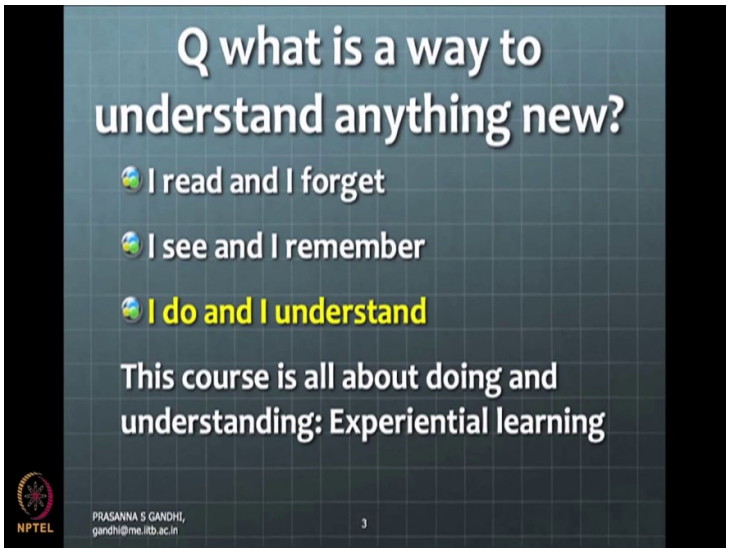

Now, what is a way how do you understand things? See typically what you do, while to do study, you start reading the books. Then maybe some of you may be seeing something about some concepts, you see there is some practical thing happening or some experimental thing happening about that concept and then go on to understand the concept.

But does it get they give, really, really great understanding. So, just see this some kind of Chinese saying, whatever you read, you tend to forget in time, this time maybe a little small for some people may be little large for some other people. But whatever you have read, you will tend to forget eventually as time progresses, then whatever you see, you will remember.

So, if you have observed some phenomena happening that creates a much deeper impression in our mind than just reading. Then actually, when you do the stuff, then you understand if you are building some setups or rebuilding, you are actually working out that experimental phenomena yourself, while doing you understand much much better, then that understanding is some somewhat irrefutable.

Anytime even in the middle of the sleep, you are awaken and ask something about it, you will not have any problem in telling that. So, that is a way you say, that is way, that is a point you have understood things really well. Many times we say, we have understood, but actually reality, somebody asked some questions about it, then we understand oh, no, we have not yet understood.

So, like that you need to know, see what you call understanding and how do you get to the understanding thing and we will do in this particular course, is all about doing and understanding thing. So, we will do a lot of stuff, maybe simulation, maybe some small experimentations at your home, we will do with the experience, experiential learning, experiment, to experiment, we will start learning lot of new things. Of course, there will be mathematics to back up the things and understand what part of mathematics are really important and not we will see as we move along.

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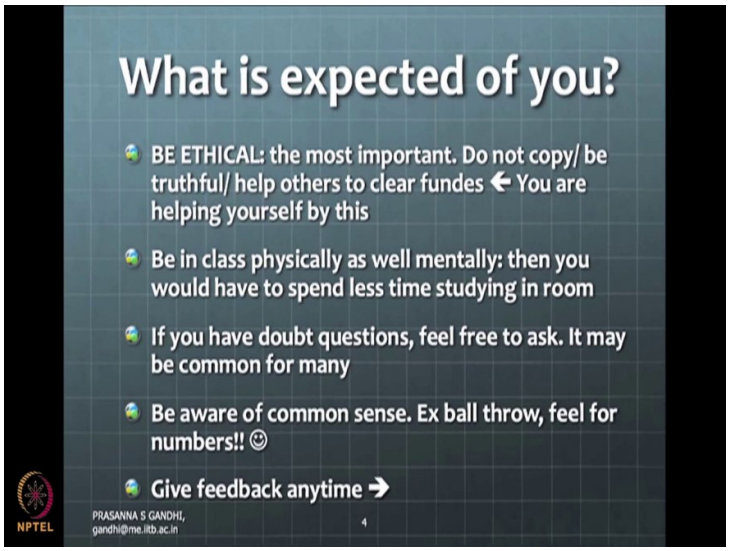

So, for this course, to have you rich experience what is expected out of you? The first and foremost is ethics. So, this is something we should not compromise at all. It is for your own a rich understanding and learning experience. This will very important not to tamper with your ethics and you can help others to clear fundamental that actually helps you to enhance your clarity of understanding.

Somebody asked you questions it is, it is much better a way to think over and give answers while answering you will find that your clarity about those fundamentals become much better. At least, as instructors, we have this experience every time we teach, the same course even if it is the same course there are some things that new that we learn from the question that the students ask.

So, it is good to do that a small processing small way as possible for your friends. Then, now, we cannot be in class physically, but at least you can be physically there during the class

hours. So, that we can have whatever possible, best interaction possible when we are having this interaction session during our class time.

And very important that if you have doubts or questions you can you will feel free to ask, it may be common for many people and you need to be aware of this common sense feel I was talking about, that I know you have say for example, you throw a ball from your, inside your house you throw ball to touch your terrace, I mean touch your ceiling and it comes back you have a feel what is the velocity it will hit the ground.

And again after hitting, what is the velocity it is bounce back, depending upon the material of the ball, there will be a lot of different things that are happening there. Can you can get a feel for this phenomenon. Of course you know how to do the number crunching on that and to get to those numbers, but without doing any number crunching, without getting into equations too much can you get a feel, oh this will go by this velocity of 1 meter per second or 2 meter per second, what is the velocity?

Or when you are riding a bike what is the speed that you are going in meter per second for example. So, those feel for numbers is what will help any designer, to get the design ideas, conceived in a way that they will be more feasible. Otherwise we conceive a lot of ideas but then just some simple top hat calculations we find those ideas that are not really workable.

So, to get to the ideas, multiple ideas, innovative ideas, but they are well workable, in the at least somewhat workable, you need to do a little more thing to make them perfect, but you will not waste too much of a time in conceiving ideas as a designer, which may not see the light at the end of the day.

So, that is a idea for getting a feel for different phenomena in different numbers and also, you should you are free to give feedback anytime even anonymous or whatever way you want to give you can post it anytime. So, this feedback will help to tune the things for your particular a test of learning.

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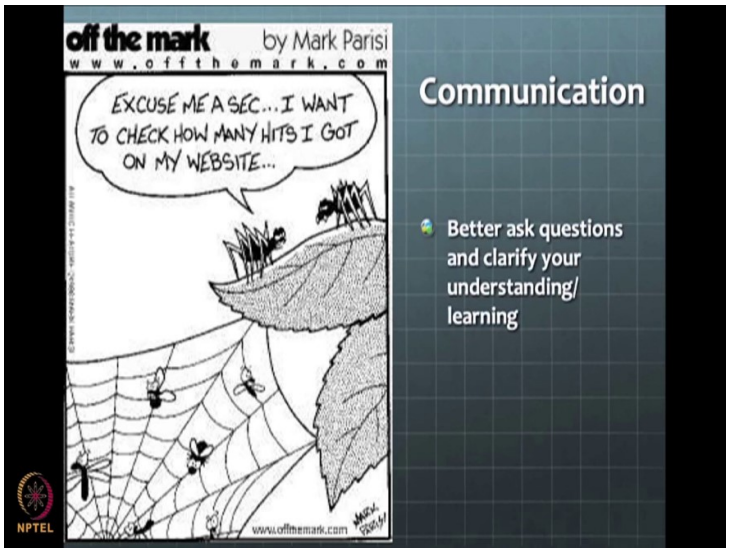

This is a slide about communication. So, when I am saying some words or saying some something you may listen to these words multiple times then make some a picture or sense in your mind, but what actually what I wanted to speak that intention behind may be different. So, we will become aware about this fact that okay, the picture actually is different, but the words are saying something different. So, we can ask questions and clarify these understanding and learning here. So, let us move on.

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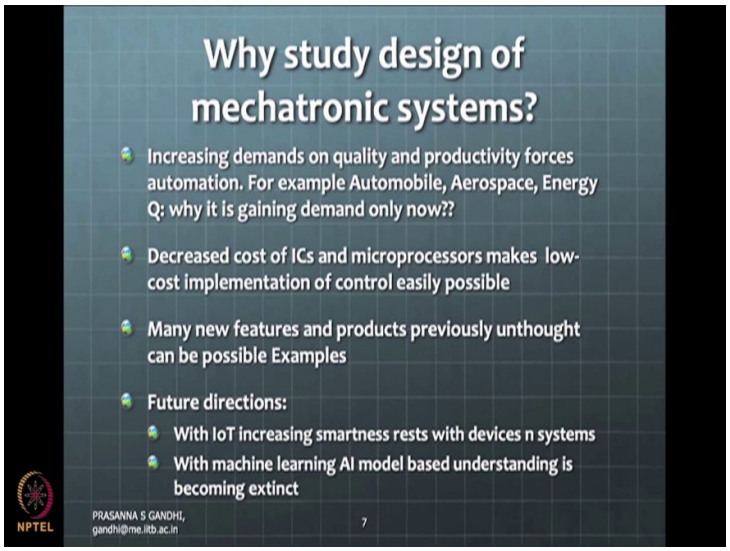

Now, the question here is why study design of mechatronics systems. So, you can ponder over this, why do you think, you are here, for this course? What prompted you to really come

here and maybe at least get introduction lecture attended or feel for the, for the course? What do you think?

Just ponder over this, you may have some answers with you, you may be writing them out or thinking them out. But so, let us think from, just general philosophy perspective, what are the things that get importance in the different periods of time, in terms of this technology? So, you will find that the technologies that drive the markets, economics, market economics, in some way, they start getting more and more important and then the old technologies which are, they are, they fade away and so this mechatronics is doing that kind of difference.

So, the technologies which are giving you higher productivity and at a lower cost that are going to get this the market better. So, you can see that the increasing demands on quality and productivity that forces any technology, that drives any technology and in this particular case it is mechatronics or automation.

So, if you see all the things that are happening in these different, different domains, like automobile domain, energy space, aerospace applications, they are all now getting drastically changed by this developments in the area of mechatronics. They are getting more and more mechatronics systems into them and the next question is, was it not known before why it is getting demand only now?

The answer is, if you see the over the period of years now there is a decrease in the cost of IC and microprocessors and they are available now at a throwaway price, you can even buy a lot of microprocessors as a sample ports without paying anything and you can work with them. So, this low cost implementation of control is what is possible very easily now and that is what it is main game changer in all these activities.

Then other thing is many new features and products that were previously unthought can be possible, there are a lot of examples one can sight, I mean you can start with ATM machines or your car lot of systems in the car, modern cars if you see. So, many small small control systems, which are in place right from the fuel injection, electronic fuel injection to auto drive mode or this hands free drive mode.

A lot of new, this new features are coming in the automobile industry, which are a previously people might have been 30-40 years before people might not have thought that this could be possible and there are many future directions, which are very exciting in this domain, I would

say, with the internet of things that are increasing, smartness now, rests with devices and the systems themselves.

You do not have to repair the system, but the system will say know that, it needs repair or you do not need to do the maintenance of the system, but system will maintain itself. That thing could be possible with the developments in IOT sector that are happening and other thing that is happening is in the machine learning domain, which is very interestingly changing lot of ways in which the things are done previously. So, you might have seen them already, but maybe we can have some examples of these as we go along in this course.

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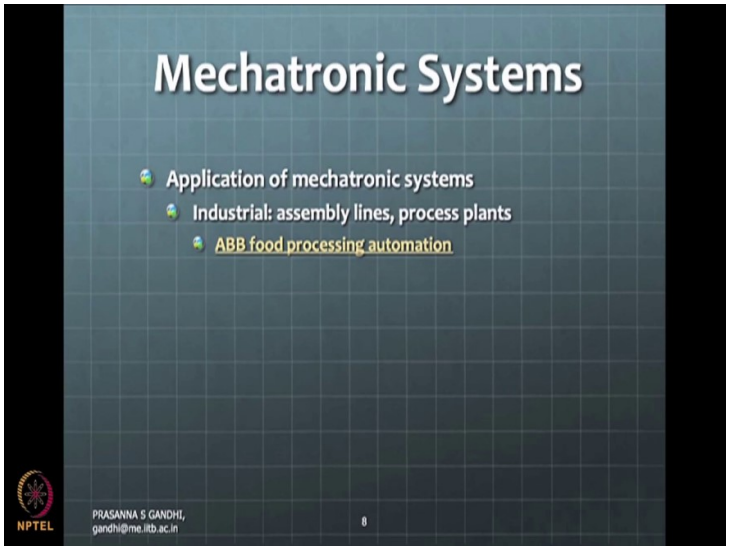

Now, if you see what are the different, different applications of mechatronic systems. You can see the some of the industrial applications, there are many assembly lines process plants which run with mechatronics at their heart. So, maybe let us observe this video.

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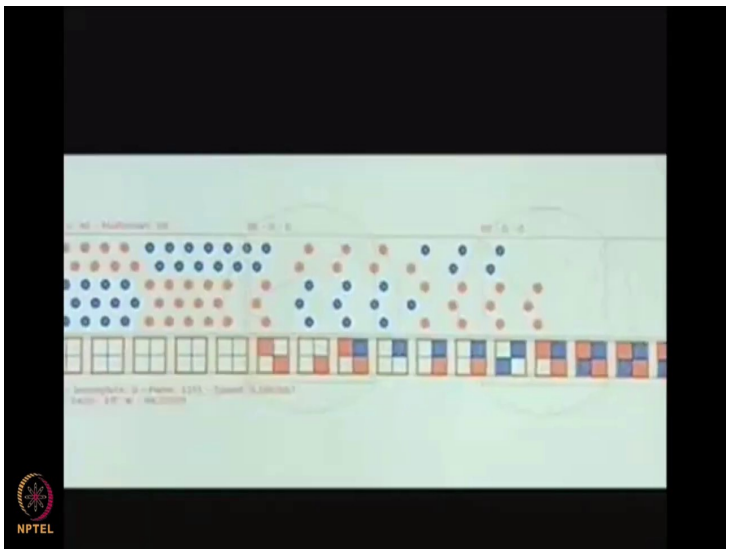
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You can see so many robots which are working in coordination with each other, there is sound behind we cannot hear the sound. So, you see that it is doing some quality inspection and segregating components based on the quality of the products that are being running on the line. So, this is assembly line for different, different products actually.

So, if you imagine this operation to be done by a human being, it is going to be too much of a what do you say drudgery kind of a job, doing the same thing over and over again and that is completely being saved by this process. So this very interesting way, this product lines, this is ABB industry, courtesy to them.

So, you see this, the way this robot is made to work, it has a flexible links there. I mean, they are not very flexible but are somewhat flexible, but they are working it is like a parallel kind of configuration and because of that it is, this robot is working very, very fast at very high

speed actually that can be possible for such a system because of the lightweight, flexible linkages.

And it comes with so, here there is a additional image processing application going on. So with this image you are identified some a products and then they are placed into their packages in a very interesting way. Some algorithms being worked out, you can see that here. So, how these packages are fed with proper products in a place inside them and handling these soft objects, very interesting technologies would have gone in designing or developing this products and processes and further the complete mechatronic system around the process. So maybe we will pause here for this video and come back to our presentation.

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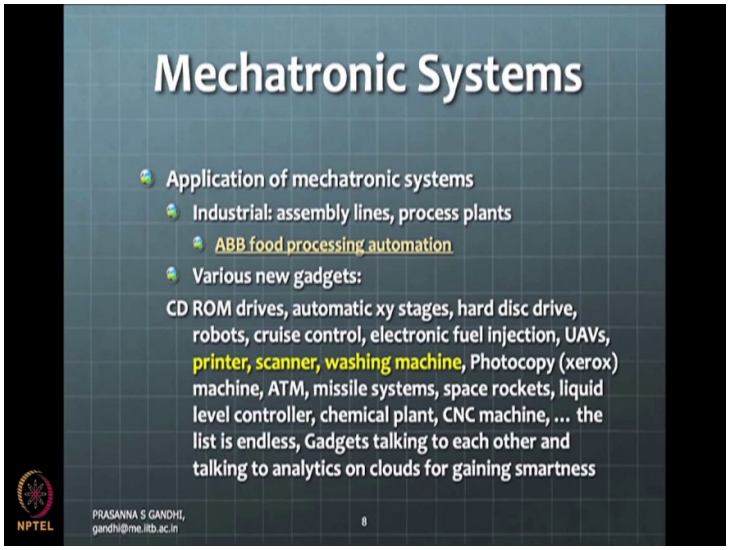

So, what do you have seen is one of the industrial applications, we have such a lot of such applications in industry and there are a lot of domestic or consumer applications for these systems as well. So, a lot of these new gadgets that you see around, I mean, you have must have used plenty of these yourself. So, I am leaving some list of some gadgets here.

So, CD ROM drives, for example is very one of my favorites, it is very interesting technology sits there very refined kind of Opto-Mechatronics system is a CD ROM drive. So, it has to read the data from the surface of a CD, which is placed in one single spiral which runs over kilometers on a CD ROM drive.

So, we will talk about this little more in details in some classes to come. Then maybe we will look at some more products. This looking at these actually designed products will help us like

know tune like know what is way or thinking philosophy of developing these kind of designing these mechatronic systems ourselves for some different applications. So, from that perspective, we will look at like know many different existing applications.

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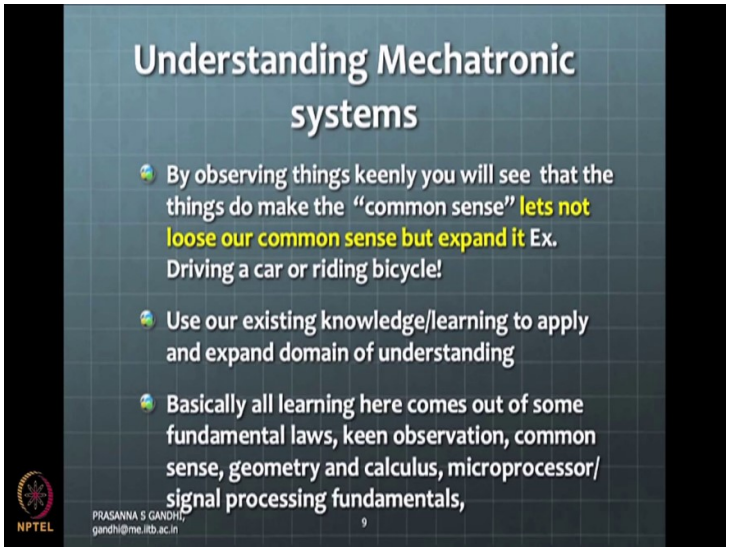

So, that is what the point I was coming to now, how do you understand, these systems. For designing we need to have this understanding of the systems first. So, see the there are multiple ways. So, one of the ways is going through entire fundamentals and doing a lot of different allied courses or different topics related with these, mathematically or theoretically studying them all and then come back to a system and see how that is fundamentals are taken into that system.

And other approaches, you can directly go to these system's extremely practical world and learn from nature, you just see how these systems are designed, observing keenly and carefully and you will see that the things too make this common sense. So, we will look at the systems from that perspective.

We will observe keenly, why this particular feature people might have put in this system, for example, CD ROM drives. Why they have something compliant mechanisms? So, these are the questions that you can ask yourself. Once you see how this is placed, how this is designed, what are the component that are used? Why those components only why not any other components?

These are the questions you typically tend to ask yourself and observing this, keenly finding the answers to these questions, then you will get to know some very interesting fundamentals

that commonly will be difficult to teach in any of the, formal theoretical kind of a course. So, that is what our approach should be, that we understand the mechatronic systems from their already existing knowledge that is in there in the domain in the form of many different products.

We will learn from that and then while designing new products, we make use of the fundamentals that are learned from already existing kind of products. So, we use our existing knowledge of learning and apply to whatever this observations that we are carrying out and then expand our domain of understanding that is a process that we will go through.

At least for to begin with we will do that for a couple of systems and then know, we will get a feel of that and then we will see how do we know apply these now to a new a system what products that we want to develop.

So, this all is learning here we will come out of some fundamental laws some basic laws that you must know, then some keen observations of existing stuff and things around and then of course, the common sense and simple kind of geometry and calculus fundamentals that you need and microprocessors fundamentals is what again we will have as a prerequisite here and a signal for processing fundamentals will built in this course. So, all these things put together will be is sufficient for getting a really interesting mechatronics application going.

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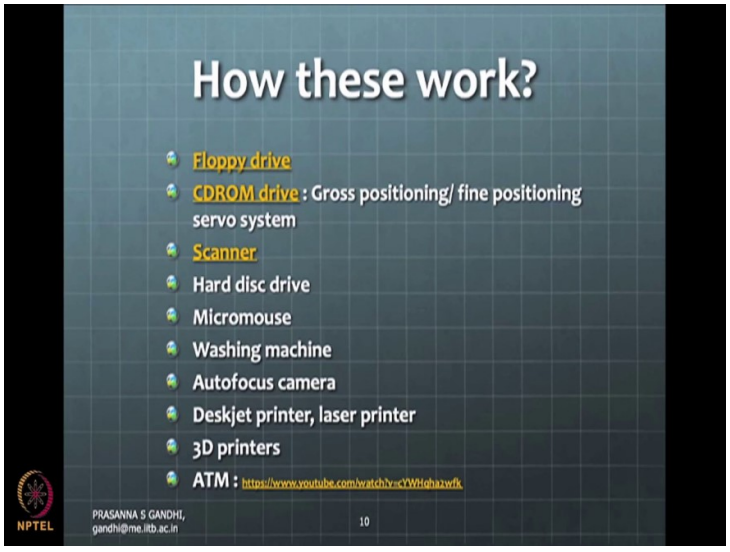

Now, I would to like you to look at take some of these systems, so you can take one or more of these systems and think how they would be working and I want you to not directly go to

see right now, there is so much of our information is available on the net and we tend to know immediately go, this and find out, how things happen?

I do not want you to do that, I mean you I want you to first think about, how what you think suppose your whatever knowledge right now you have, you are to design some application such as these, what will, what comes to your mind first, what is that you will do? See why we need to do this? Because that is when you see now, after this thought you knew a lot of questions will be raised in your mind and now when you see this, let me switch on to myself.

So, when you can have look at this, think about this systems yourself, so for example CD ROM drive, I take a CD and see, these are the tracks that might have, so I want to read them tracks, what is the system that could be there inside that will have a head or something to position to read the track? It is touching or maybe non-touching, I do not know. But what kind of system would be existing.

So, if I want to design will I designed the system which will touch the CD surface and then get the information or I will design a system which will not touch the surface and get the system the information out of the CD. Like that you think about all that is possibility for based on whatever knowledge that you have to begin with, you will start you may be wrong in doing whatever things does not matter.

Your thinking is what is more important here, the thinking will generate a good mindset inside you, that will be now very ripe for accepting or registering the solution that are existing, when you actually go to the website and look at these solutions that people have actually given and so if you go to this website of howstuffworks.com you will find the most general information about how these systems work.

They may not have very particular information but we will find essentially what is needed to see, how people have designed such systems in order what technologies are in place to get this thing working. So, this is an exercise that I would like you to do. So, I am switching back to the slides again. So, you can look at all these systems or maybe as many possible systems and some of them will take actually for more detailed of a study as we progress in this course.

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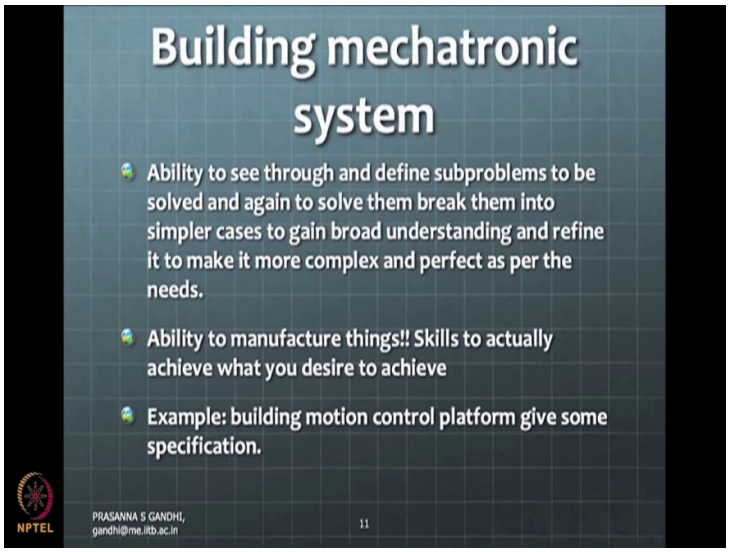

So, what building mechatronic system what you need? So, first and foremost is conceiving idea or given the abstract problem you first conceive idea in terms of defining what is exactly problem that is to be solved and can I divide it into many sub problems to be solved and for each of the sub problems I will give or conceive new some idea or solutions for that and so, this ability to kind of given a bigger a problem to break it into many smaller sub problems is very, very important.

We are not tuned to that a thinking so far because many courses whatever you are going through have typically given this a problem defined completely and when the problem is defined completely you solving it is easy, but how will you define a problem in the first place. To solve some abstract application, how do you define what is the problem to be solved, in terms of mathematics or technology problem that needs to be solved?

That is a task is we are not used to that task, I would say. So, we should look at how do we can develop the skill to see through, what is the problem that needs to be solved and then other kind of skills that is needed for this ability to build or manufacture things. So, in both in the domain of mechanical and electronics, we need to have this a, some a skill set to know what kind of manufacturing ideas can be used to develop some certain things.

And so, we will take this example later, like a building, you have to build some a motion control platform for given some specification, that is an example we do for many different kinds of specifications, what are different technology? How does specifications change the technology for development of such things and so like that we will study from really a

different perspective that you might not probably have been exposed to it so far. So, that is what we will look through in this course.

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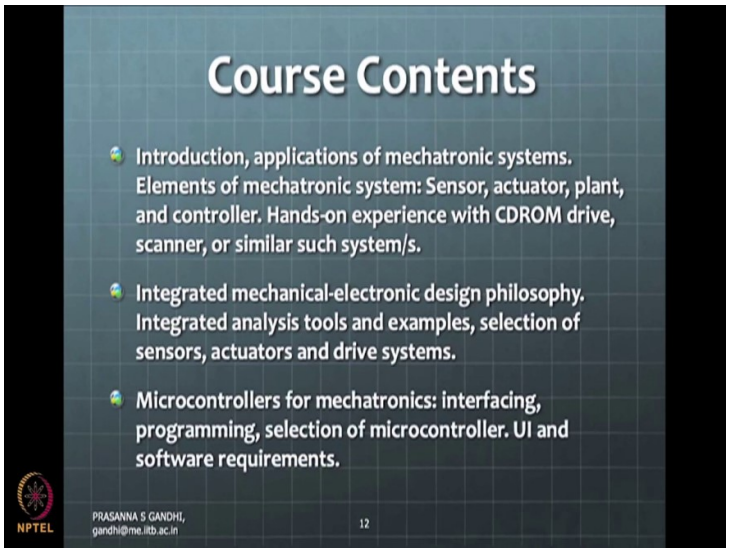

So, now coming to course contents, as you might have read in the syllabus also, that we will look at first this applications and the different constituents that are necessary to build these mechatronic systems. So sensors, actuators, your plant and controller, so you need to have a fair understanding of these, each of these elements and then, you will understand how they can be put together to drive any interesting application or solve a problem.

So, will have some hands on experience, now we will see how this hands on experience can be built. So, for this we may not have much we will do mostly, some video based understanding here or some kind of a, I have some actually open stuff here. I will put some slides about this and then we will, we will discuss what we observed. So we will do that with a couple of such systems like CD ROM drives, hard drives or some kind of systems like that.

Then, we will study a very important aspect of mechatronics which is integrated mechanical and electronics design philosophy. So, typically we are accustomed to thinking only in mechanical domain or mechanical engineers, all electronics engineers only in the electronics domain they will think, but now if you want to put together mechatronics system, your decisions in mechanical domain may get affected by what is possible or not possible or what is easily possible in electronics domain and vice versa.

So, these aspects is what is, very important for mechatronics engineer to be to understand or mechatronic system designer to understand so that he or she can put together a system which

has plus of both the sides like or you are not compromising on too much into, for demanding some kind of a way of the way, you know mechanical things to be done you are demanding too much on the electronic side, no that is not, they should be well balanced design or somewhat optimum design from both the domains perspective, that is what we will learn then. Then microcontrollers we will get into much more details about.

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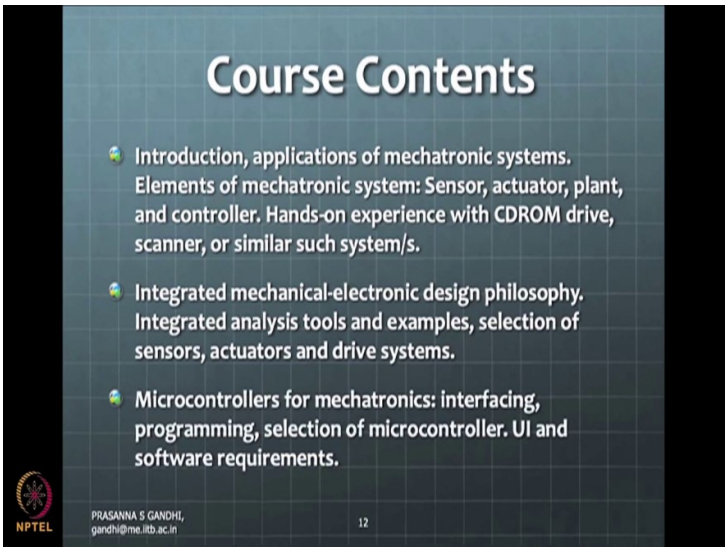

Then we will look at quite a good amount of details, time will spend on how do you design control for practical working of system. See control traditionally will have a lot of mathematical control algorithms if you open if you just search this area of control tons of several papers on many, many different kinds of controllers people have developed and designed, out of them only some subset would be actually worthwhile to look at from the practical implementation perspective.

All others are theoretically working fine, but in practice they may not have any possibility or feasibility one to kind of implement or even if the feasibility is there, it is at such an additional cost that, it is prohibitively restrictive. So, we will look at these controllers which are mainly practically feasible for controlling. Say for example to control linear system or nonlinear system with a rigid body, which is fully actuated what are the, what is the best controller, those are questions that we deal with in this, in these discussions.

Or if you have under actuated kind of compliant system, what is a kind of control that we will do so that we achieve our application without having too many disturbances or vibrations

coming out because of the compliance in the system. Then there are nonlinearities such which are practically unavoidable which like friction, backlash and noise.

So, how do you deal with them and finally, some fundamentals about digital control. The way the control is implemented. See whatever mathematics that we do is, is all continuous in nature and even what you are learning in mechatronics course or you have learnt in mechatronics course is all in the continuous domain.

Suppose now, but actual practical implementation is a micro controller which is doing in a sampling time implementation. So, what is happening to the system dynamics because of the sampling that is a domain of discussion in the digital control. So, we will touch upon some of the aspects there and finally, what we need is the signal processing for mechatronics.

So, these are the things that we are going to look at. So, these signal processing is an integral part of any of the mechatronics system, you need to have a good understanding of signals that sampling rates and how do you process them to make sure your application is running in a best possible way.

And then maybe if time permits, we can touch upon some of the advanced topics there. Apart from these if you feel, that is something that you would to look at in this, maybe you can propose and we will take a look at.

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These are the course goals set. So that's what, I have been talking about trying to conceive these new mechatronic products is what we will have this skill that it is to be take away from

this course, how do you conceive this and develop that idea further to realize into a product. So, you will be able to control actuators like motor, voice coils, in a closed loop and understand, these are more details kind of small sub goals, sub parts of these goals or skills that you will learn as a part of this course.

Then how do you interface sensors with microcontroller, using various different kinds of interface that are there. So, you may not have closed loop control application, but you just have some a observation of some phenomena in the nice way to be done, this will be very helpful or if you want to develop conclusive control of course, this would be definitely helpful.

Then develop skills to choose controller I mean the sensors and actuators and microcontroller for a given application. So, this is again another very useful practical skill that you must have is to get a good mechatronic system working.

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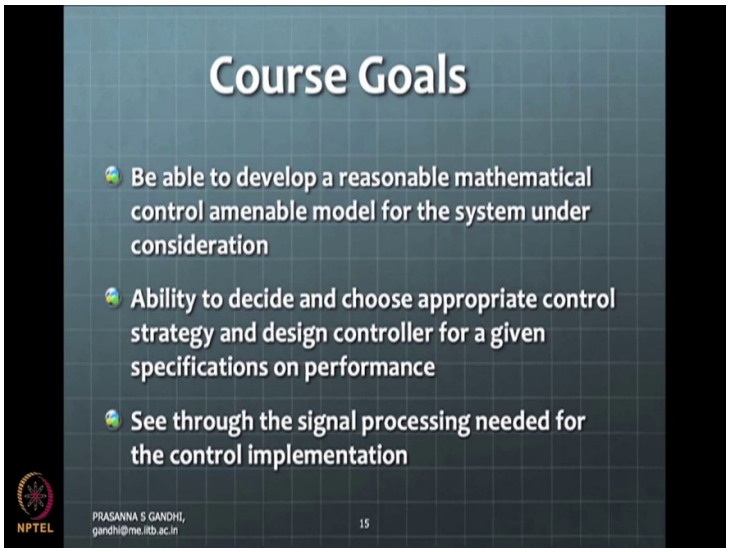

Then next skill is about developing reasonable mathematical control or model first and then the control or control amenable model here I am saying per system and condition and then the ability to decide design a control and once you have designed controller, then you need to see through some signal processing aspect for control implementation to kind of the smooth working of the entire system going.

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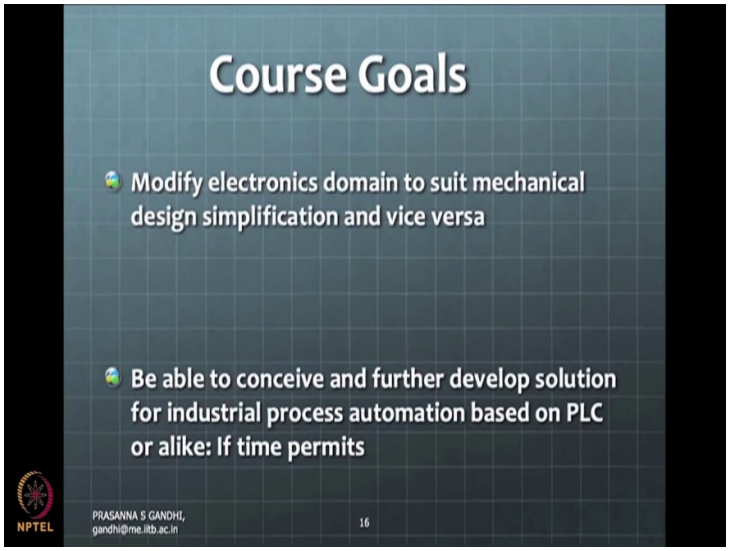

So, these are more skills that is a part of this course, these are goals that we set for our course.

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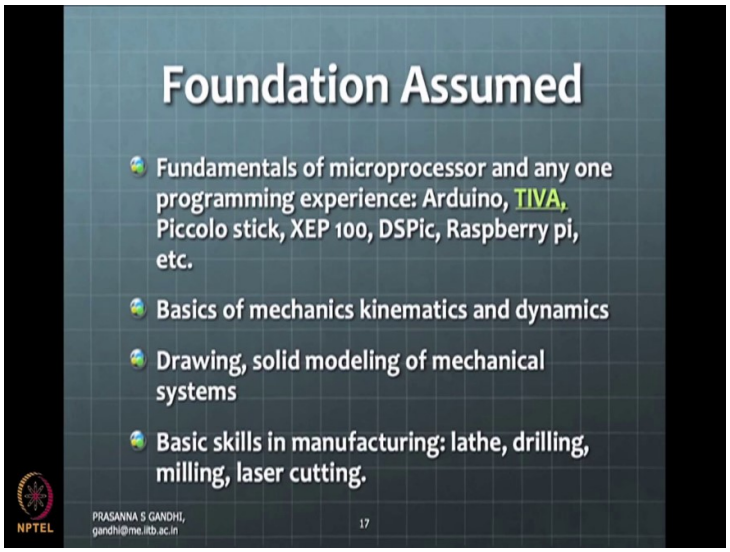

Foundations that I am assuming here is fundamentals of microprocessor and any one microprocessor programming experience or any other kind of system is okay, but you need to have a good experience, at least you should have a, when I say good experience you should have driven motor by using one of these controllers and microcontrollers.

If you have done in a closed loop mode that that is great, but even if you have not done, but you have interface some other sensors it is okay. So, that is what a base foundation I am assuming is okay and we will work in this course on this TIVA board, which is from Texas Instruments and it is an ARM Cortex, series microcontroller.

So, that is what we will use in this course with a code composer studio as a emulator or as a software to program it basically. Then you need to have basics of mechanics, in terms of kinematics and dynamics of rigid bodies and particles. That is what again, will be foundation that is assumed and your skills in drawing and solid modeling is what we will assumed here.

You have enough fundays in terms of drawing, if you make drawing, you make sense of it, and, if you have some a way to do the solid modeling to 3D print some of the parts for your project you should be able to do that and then basic skills in manufacturing, these are the kinds of fundays that are assumed.

Of course we may not, have a chance to demand or depend upon when the things situation get better. What things that you have locally depending on that one, these machines may not be

used in this course, probably too much. But we will see how we can do some of the things without even having or having getting some local access to these things to do some stuff.

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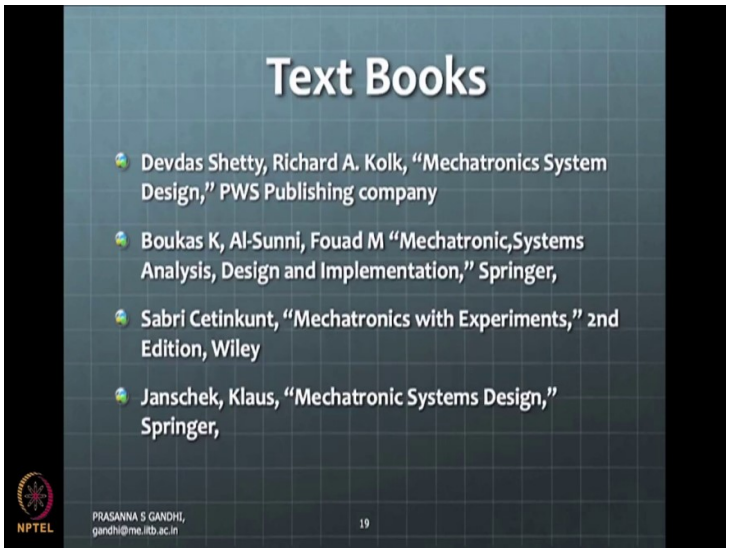

These are some of the textbooks for the course and there is no one single a book, unfortunately. So, have fun in learning this new exciting course on you know, I would say the latest application, this technology is driving this latest application. So, you can enable yourself know by doing this course, to be in the forefront like know, some of these many of these applications. Thank you very much.