Foundations of Cognitive Robotics
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Lecture – 01

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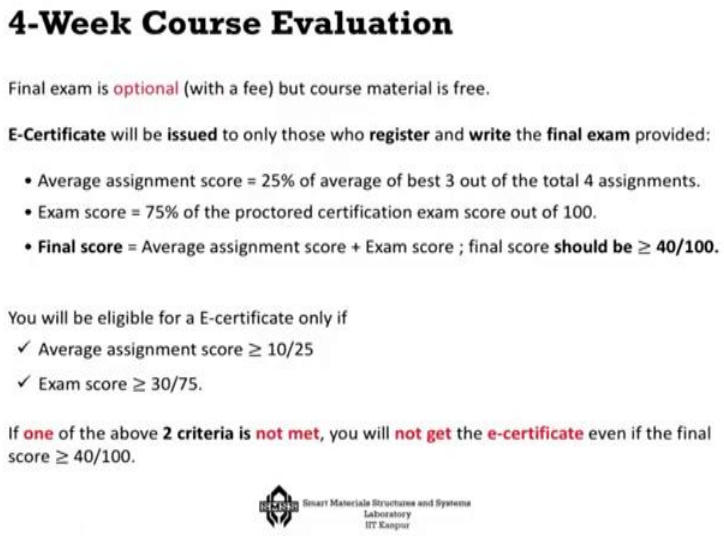
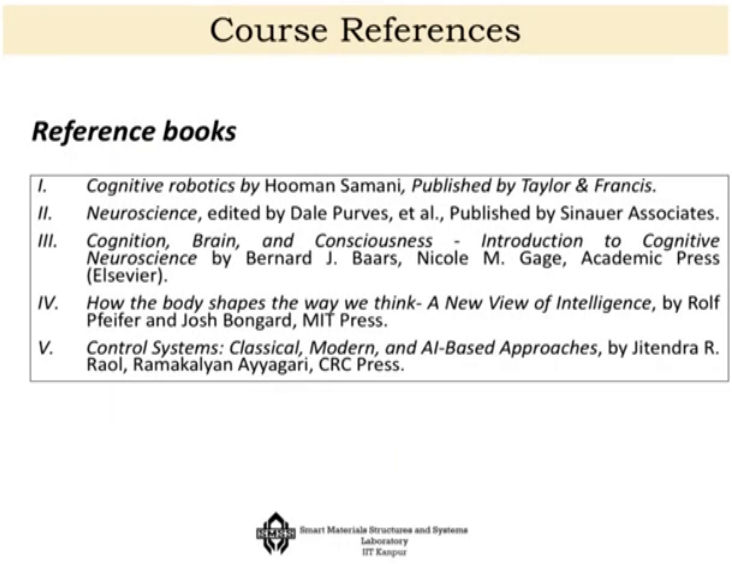


Welcome to the course on Foundations of Cognitive Robotics. I will first tell you about the course evaluation procedure. You will have a final exam, which is optional, but with a fee, you can actually go for these. E-certificate will be issued to only those who would register and write the final exam provided the average assignment score will be 25 percent of the average of the best 3 out of the total four assignments. The exam score will be 75 percent of the proctored certification exam score out of 100. The final score will be the average assignment score and the exam score; however, it should be greater than or equals to 40 out of 100.

Now, you will be eligible for an E-certificate only if the average assignment score is greater than equal to 10 out of 25, and the exam score is greater than equal to 30 out of 75. If one of the above two criteria is not met, you will not get an E-certificate even if the final score is greater than equals to 40 out of 100. So, having said the course evaluation procedure, let us start the course on cognitive robotics. (Refer Slide Time: 02:01)



I will first talk about the reference books that I will be using in this course. The first important book is by Hooman Samani, which is published by Taylor and Francis; the title of the book is Cognitive robotics. And then we also would follow the basics of Neuroscience from a standard book like Dale Purves. And Cognition, Brain and Consciousness some Introduction to Cognitive Neuroscience by a beautiful book from Bernard J. Baars and Nicole M. Gage, which is from the Academic Press.

And the other important book is from Rolf Pfeifer of MIT Press and Josh Bongard that is on How the body shapes the way we think – A New View of Intelligence. And also, you need some basic knowledge of Control Systems, particularly the modern controller AI-Based Approaches. So, you can follow books like the book of Jitendra Raol, Ayyagari, or other similar books in this direction.

I will now tell you a little bit about the motivation beyond these subjects of cognitive robotics. As you can understand, cognitive robotics is an interdisciplinary subject so, it draws inspiration from computer science, from psychology, and, of course, from robotics. How this intermixing has created this new subject, cognitive robotics, and the primary motivation of it what we have new in this particular course, I will give you this basic introduction in the first lecture. (Refer Slide Time: 04:11)

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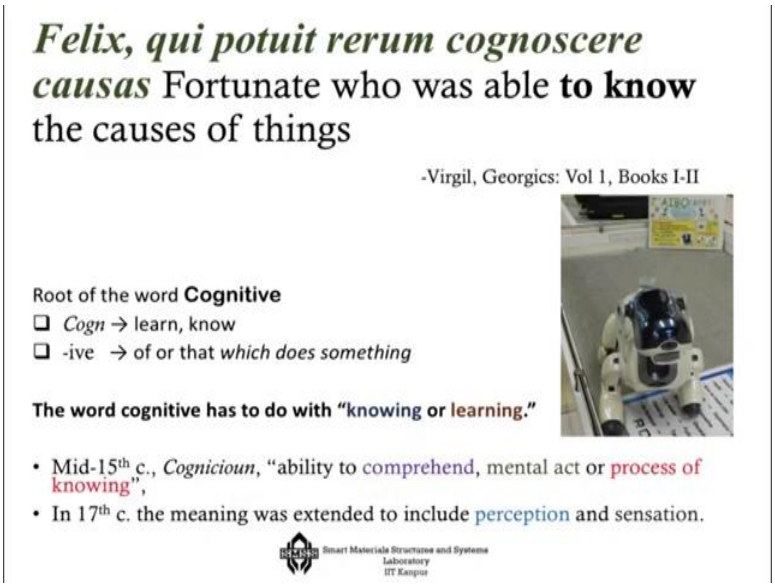
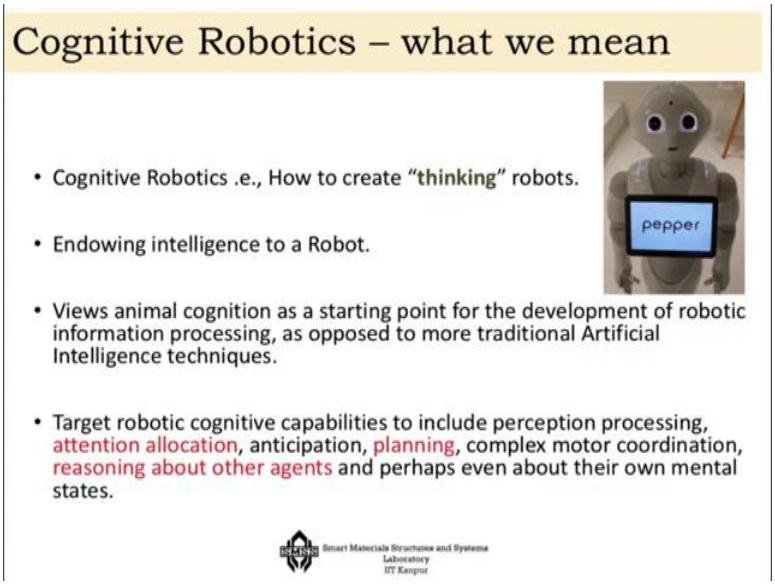


The motivation behind this cognitive robotics would come from this very famous quote from Virgil, which is *Felix, qui potuit rerum cognoscere causas*, which means fortunate was able to know the cause of things. As homo sapiens, you would little understand the significance of how fortunate we are that we can know or we can pursue to know the cause of the things.

Now, if you watch carefully that these to know something in Latin, it is called ***cognoscere***, the root of the word of cognitive, which has two parts in it that the ***cogn*** part of it is the learning knowledge and the process of it. So, cognitive referred to the process of knowing or learning something. In fact, until the mid-15th-century ***cognicioun*** usually

would mean the ability to comprehend, mental act or process of knowing. In 17th century the meaning started to get extended to include things like perception and sensation. (Refer Slide Time: 05:49)



Now, when we talk about cognitive robotics, what we mean by these? Well, cognitive robotics would actually mean if we literally try to translate, would suggest that how to create the thinking robots. Alternatively, if you try to, the word thinking will sound a little bit vague to you. So, if you try to dilute it, it would mean how to endow intelligence to a robot.

Now, while doing it, we would not only consider homo sapiens. We would consider that there is this process of thinking presently even in animals. So, as a starting point, while developing automated information processing, we will consider how this cognition can happen in animals and the interesting characteristics of that cognition that we can actually impart in robots. This is opposed to a more traditional artificial intelligence technique.

The other important aspect here is that when we say about the robotic cognitive capability, it is not only in terms of some sensing or some actuation; we aim to include characteristics like perception processing, attention allocation, anticipation planning, and complex motor coordination, reasoning about other agents. Here, this word agent would mean broadly about living and nonliving things you know nonliving say robots and perhaps even about their mental states.

That is our objective: Can a robot comprehend its mental states, and can a robot have these kinds of you know the animal or human-like capabilities of attention allocations? So, that is what is the goal of how we can develop such a thing in cognitive robotics. (Refer Slide Time: 08:10)

Now, I would just like to show you a small video. Many times we think that intelligence is only possible in higher-order animals; I mean mostly mammals, and even among the mammals, I would say primates and the homo sapiens, but that may not be the case. Let us look into the simple example of a much lower order animal biologically that is about an octopus and let us see that how this octopus can have attention can have a perception about a problem, and can think about a strategy to escape.

So, you see here is a bottle where we have kept an octopus, and you can see that I have taken it from an interesting YouTube link, and you can see that the direction is showing that if there is a movement from these angles as you can see already that movement is

happening. The tentacles of the octopus are moving; it has understood which direction it has to move, and it is doing some reverse direction also.

So, to understand that which way it has to apply the torque and it has wholly understood it is applying it perfectly now if you wait and see that how it is now going through this entire process of unlocking itself, it is fascinating. You can see that it is moving its limbs, and it knows that this unturning is over. So, it can take the whole lid out, and you see it is taking out all its limbs, and it is fascinatingly escaping.

Can a robust AI robot plan for such a fascinating escape? I will give you a one more fascinating example. This time it is about the fish, and it is about the spawning of the fish eggs. This particular example I have taken from an Amazon rain forest and just observe the amount of intelligence. In this case, there are two fishes, the male and female, which are cooperating in order to make the spawning of the fish possible not in the water, but outside the water. Let us look into that example.

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This will tell you that intelligence is not just the property of higher-order animals. So, this is *copella arnoldi*, commonly known as splashing tetra, which lays its eggs outside of water, and the advantage of doing it is many. Like you know, the eggs can develop faster in outside water where you are getting more oxygen supply; because the many times in such rain forests, the oxygen demand biological oxygen demand will be quite low because of algae covers. Also, it helps to avoid predators.

Now, let us see we know the advantage of how it is actually executing it. So, you can see that this water this splashing tetras the spool of these splashing tetras you can see both males and females. Now, you see how this spawning is happening in them. So, they are still inside the water and then looking for a target, they have to jump out of the water. So, they are looking for a suitable target with a fisheye view. They are searching which plant will be suitable for spawning.

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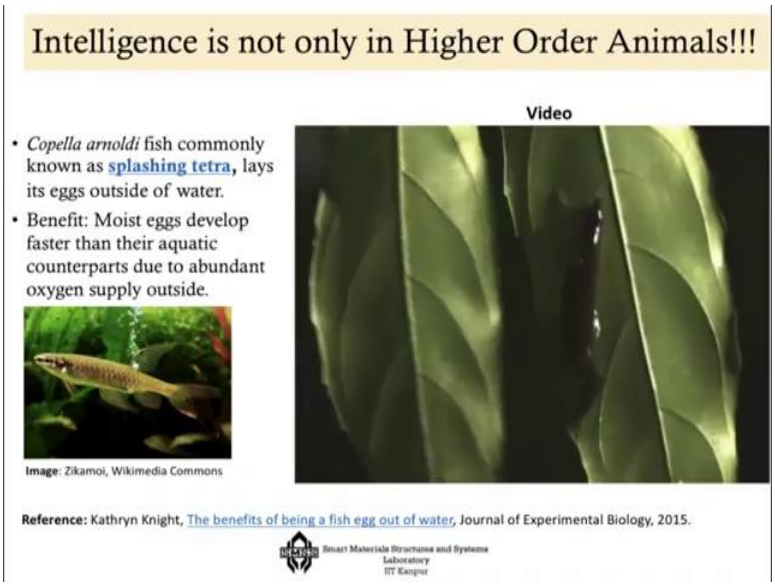

And, after some movements, various directions, they have fixed it fixed the leaf. You can see both the male and the female are spawning their legs are spawning their eggs. The male would remain for little more time. They will go back. Some eggs you can see already. Again they will be back. They will be spawning the eggs and you can see how they are actually spawning the eggs phase by phase; they are populating it on the leaves.

So, they have chosen the target, they have come out of water and they have spawned the eggs all over the leaves. Now, that is not all, you know a fish cannot live without water. The same thing is true for the eggs. You have to keep it moist, atleast. So, what it is going to do is that it is going to find out the position of these leaves precisely and you see how it is splashing water. So, that all these eggs would remain moist and they can nicely grow inside. You can see already the life has started.

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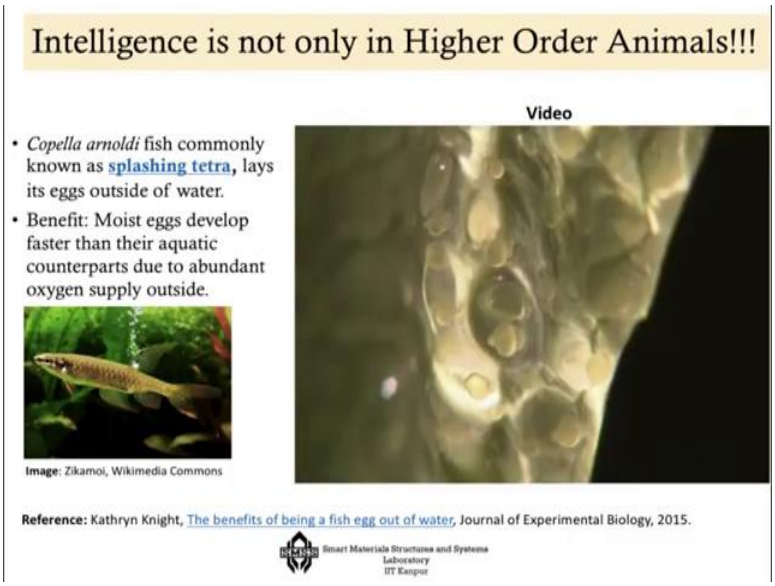

You can see these small small the fishlets are actually inside.

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The moisture is helping them, and these male tetra is continuously moisturizing until these fishes as growing to the extent that with the help of further water, they can start their journey back into the stream. So, do we not call it as an excellent example of intelligence, but this is coming from fish from a relatively biologically lower-order animal.

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So, that is the basis when we say that when we talk about intelligence and when we are talking about imparting intelligence, it has to happen from the animal level itself. Now, let us talk about some basic definitions of cognitive robotics that you will find in the open literature.

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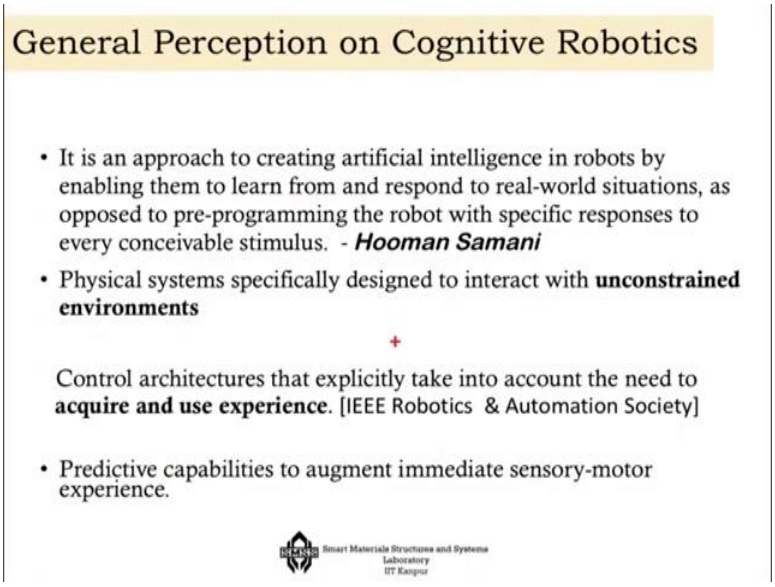

The general perception of cognitive robotics is given very nicely by Hooman Samani, and he has said that you can consider it to be an approach of creating artificial intelligence in robots by enabling them to learn from and respond to real-world

situations. You are not preprogramming the robots that, if this happens, you react in this manner. You are giving it some clues that are based on the real-world situation about how you can make your decision.

So, this is sometimes also called that how to interact with the unconstrained environment, and you need, of course, a suitable control architecture in order to interact with such an unconstrained environment, acquire knowledge and use this experience for your further action. In other words, you should generate predictive capabilities to augment the immediate sensory-motor experiences. So, what kind of control structure can actually give us this?

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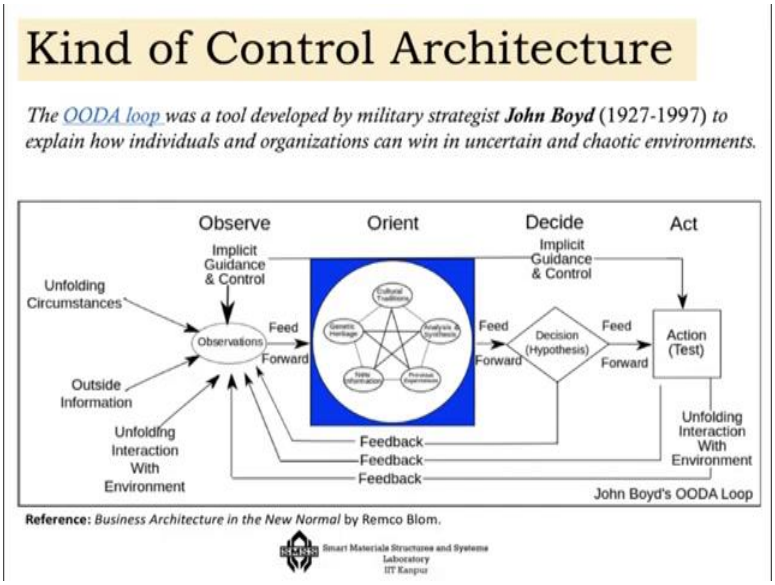

Well, one very famous control structure was proposed by John Boyd which is based on observe-orient-decide-act; in other words, the OODA loop. If you look at these carefully that there are these four sections observed section in which you are carrying out observations unfolding the circumstances. Check what is the information that is coming to you and then take this information's take it forward.

Do a feed-forward and look at it from the prism of various say cultural traditions, various analysis, and synthesis that is available with you the previous experiences that you have understood, any new information whether you perceive, whether if there is a genetic heritage of this kind of information is that you have already acquired. Based on these orientations, you feed yourself forward, and you take individual decisions.

Now, whatever decisions you take, you also feed them back in the observation process. Let us say you have decided that this is observation is more like a cultural observation. Then you modify your observation towards the cultural direction, or you want to correlate it with your previous experiences. So, you observed more keeping your previous experiences in mind, and also, based on your decision, you feed it forward further and take some actions.

Now, as soon as you are taking the actions that also you have to feed it back so that you are having more unfolding of your interactions with the environment. As you are unfolding your interactions with the environment, you are learning more, and you are getting newer observations, and you are feeding it through this entire circuit. And, doing this process, particularly in the orientation phase, you continuously give the implicit guidance and control that are there based on the system you have.

Now, these are some of you know control architectures that can help you in an unconstrained environment. We will talk more about this type of control architecture in the future.

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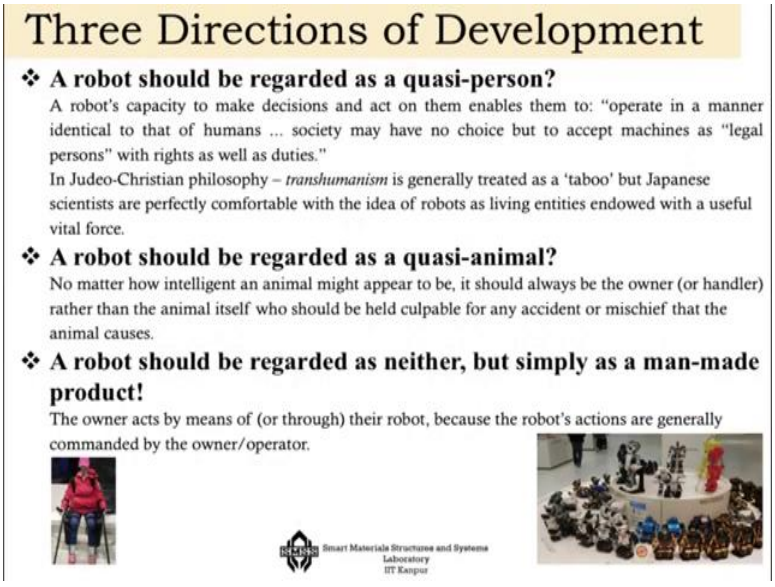

Now, there are three directions of development for the robot. The first question is that can we consider this kind of cognitive robots as a quasi-person? Many people think that since these robots have a short of intelligence, thinking process, perceptions, in other

words, they operate in a manner that is identical to that of humans. So, should they not have some legal rights, and should they not have some duties?

You know, even though in certain philosophies like Judeo-Christian philosophies, this kind of humanism outside the homo sapiens we call it transhumanism is generally treated as a taboo, but certain other cultures like Japanese scientists they are perfectly comfortable with the idea of robots as like living entities. You might be knowing that in Japan and the robots have participated even in social marriage. So, this is a concept that is coming up that with the increased level of intelligence, human-like properties like attention perceptions, you may consider a robot to be a quasi-person.

Some people are a little less optimistic they can they are ready to consider it like a quasi-animal, and they consider that well we need to give an intelligence like animals. However, the robot must have an owner, and the owner will be held responsible in case of any accident or mischief, just like if you have a dog and this dog creates some problem and is the owner of the dog who is held responsible, similarly is the owner of the robot who will be held responsible.

Now, some more people think that it is neither an animal nor a person, but it is simply a product, and hence like for other products, the manufacturers are responsible; similarly, for the robots, the manufacturer or the operator will be responsible. So, there are these three different viewpoints towards the direction of the cognitive robot. I will now show you one example of one of the latest humanoid robots, which has been developed by Honda, also called the ASIMO robot.

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Now, look at this particular work, which is reported by Honda very carefully and think of it that in which category you can place this robot based on this action that you are going to see. You see, the robot here ASIMO is bringing something that looks like a flask, which is having some drinks in it and a glass. Look how carefully it has come to the unconstrained environment without any human hand went to a proper position.

And, then, without falling, it was taken a sidewise movement and you standing in front of the table that he has brought the cart with the drinks that he has brought. Every time you will be now seeing this, you should also compare the performance of it with the octopus example that I have shown. You see how it has held; it now knows how to unscrew the bottling process; it is opening up the bottle perfectly, keeping in mind that it may have some fluid that should not spill out.

So, it is applying just a good amount of torque to open it up. It has opened up and kept the lid first very safely, and then it has (Refer Time: 24:12) picked up that glass. Now, it has to decide about the proper angle proper orientation and gradually fill the glass. That is what it has done with the help of its fingers and the visual scanning and the touch sensors and the actuators. So, now that it has filled the glass, it is doing a social duty. So, it has given this water or the drinks to a person.

So, based on these interactions, you have to tell me that in which class you will be keeping this ASIMO robot? Would you like to give it a right just like a homo sapiens,

transhumanism, or would you like to treat it like an animal? Suppose, if it does anything wrong, suppose if you know, spill off this fluid on the lady when it is serving.

So, you know, would you help the operator the people who have actually developed the robot responsible? Or would you help the person who has designed who is running the robot the operator to be responsible? Or you would think no, you know the robot is autonomous on his own so, it has his own personality so, it is the ASIMO robot who himself or herself is responsible for that?

So, this as the intelligence is propagating. As we can embed more and more human-like behaviors into the robots, these are becoming our fundamental legal issues.

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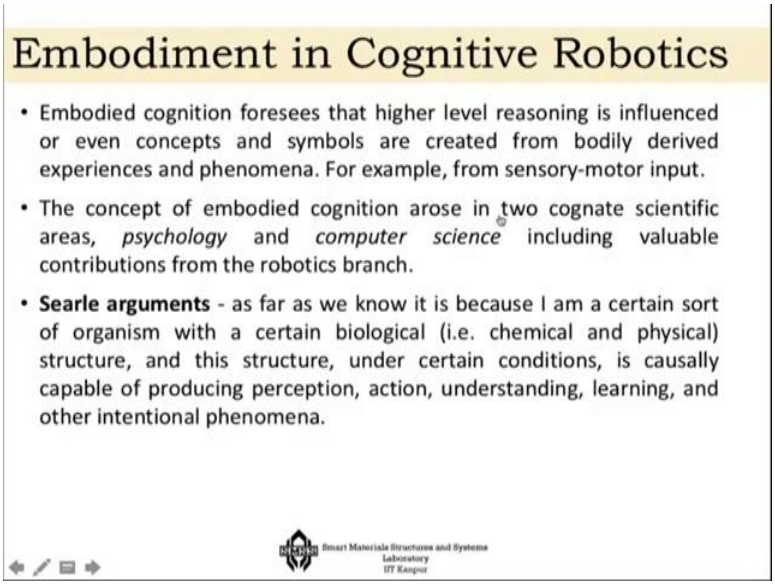

Now, as you can see that in the last example of the robot, some embodiment has taken place in the robot. This word embodiment is very important because there was a group of people who are from the strong AI group, and for them, the artificial intelligence does not necessarily require any hardware to be present. Let us say if there is a network of computers according to the strong AI group, it can be an intelligent agent.

However, according to the embedded group, this embodiment is very very important in order to impart intelligence to the system. So, here the psychology and computer science people have to merge with the robotics brand in order to give this embodiment into the

cognitive robots. Now, there is a very famous scientist Searle, was given a strong argument in favor of this type of embedded AI's which is also known as weak AI's.

And he has proposed a sort of a Chinese game in which he has considered that let us say there will be a person in the Searle's Chinese game. He has considered that let's say there is a monolingual person who only knows English and he is in a closed room, and you are supplying him with all the Chinese letters and some Chinese scripts and some instructions which tell that the syntax says that how each one of these letters is part of the script.

Now, if you write something based on these Chinese symbols in the form of a script, can we call him to be a Chinese writing person? If he speaks something based on such instructions, can we call him to be a Chinese speaking person? Because the person does not know anything about these symbols. He only knows that the syntax says that is given to him.

So, the fallacy is that if you have a robot which is having these symbols as the first batch and these script as the second batch and these third batch as how to join them the instruction set, based on that, we cannot actually call that the robot has some Chinese personality or similarly the robot has intelligence.

Today you have, for example, Alexa with us, very popular. Now, can we call Alexa to be an intelligent being because, in the back end, it does not understand each one of the symbols with which it is trained? So, Searle's weak AI logic is that in order to have an intelligence you need to explore with the environment. So, you cannot call this kind of instruction based intelligence to be a proper intelligence, you need embodiment in order to have intelligence.

So, if you look at Searle's arguments, you can put it in a way that every organism with this intelligence should have a particular biological structure, and this structure, under certain conditions, is causally capable of producing perception, action, understanding, learning and such other intentional phenomena. So, this is the significance of embodiment in cognitive robotics.

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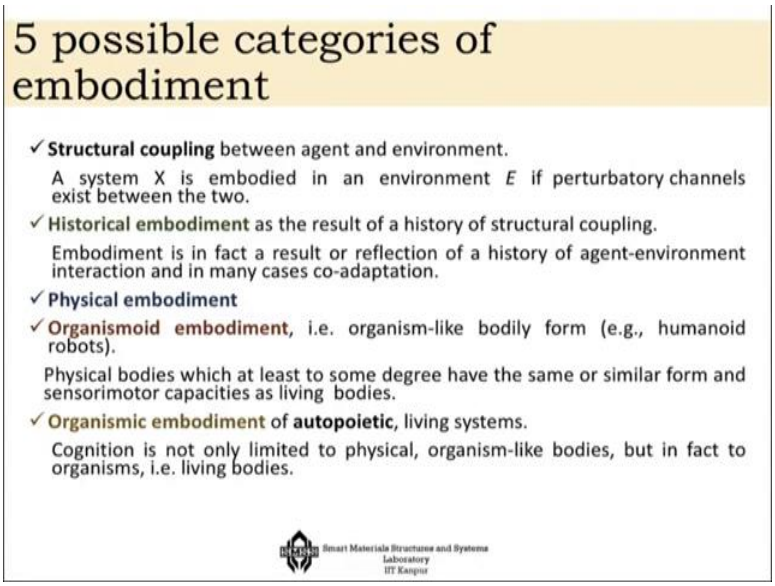

Now, there are five such possible categories of an embodiment; the first one is just simple structural coupling between the agent and the environment. Moreover, when I told you when I would talk about an agent, it can be any living or nonliving thing which has the capability of interactions. So, in this sense, if you consider Alexa so, there is a structural coupling between Alexa and the environment because if the environment changes, you give some instructions, Alexa understands and changes its behavior. So, there is structural coupling.

There can be further improvement of structural coupling in terms of historical coupling. So, you can improve your AI up to that level that you can keep a track record of a history of agent environment interactions. So, you can learn from it, and it can adapt itself based on it. But, with that Alexa example, there is no physical embodiment; on the other hand, for the ASIMO, there is a physical embodiment that is there.

Now, this physical embodiment can have a sort of an initial group of embodiments like organismoid embodiment, which is not precisely an organism, but organism like bodily form like the humanoid robot. So, here the physical bodies have at least to some degree it has a similar form like an organism and it has the sensory-motor capacities with it. So, that should be the starting point of cognitive robots.

And, the ultimate point is like organismic embodiment, which is like autopoietic; autopoietic are the systems which can self create itself which can maintain itself on its

own, just like a living system. So, that is the final goal of developing this kind of cognitive robots. However, in order to have cognitions, you must have a physical embodiment, and it must have organismoid embodiment, and the final goal is to develop an organismic embodiment.

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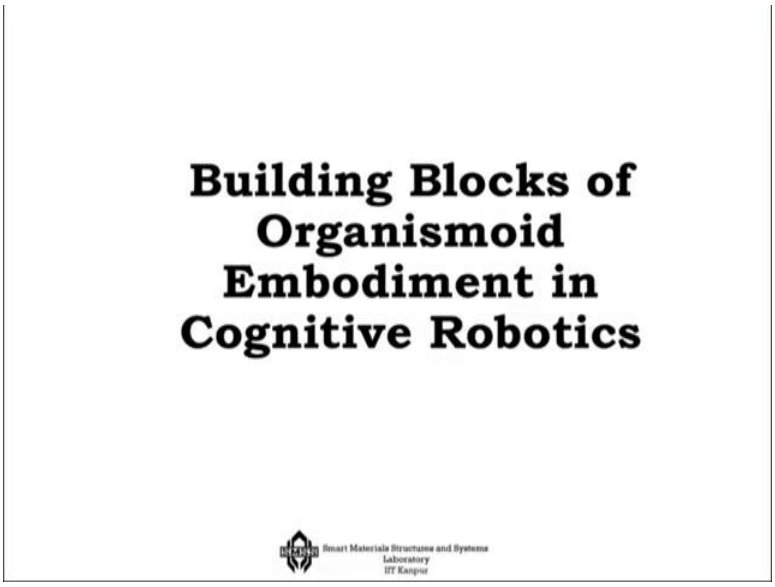

So, this is what we will perceive in our course; that means this building blocks will be discussing the organismoid embodiment and how to develop each for cognitive robotics.

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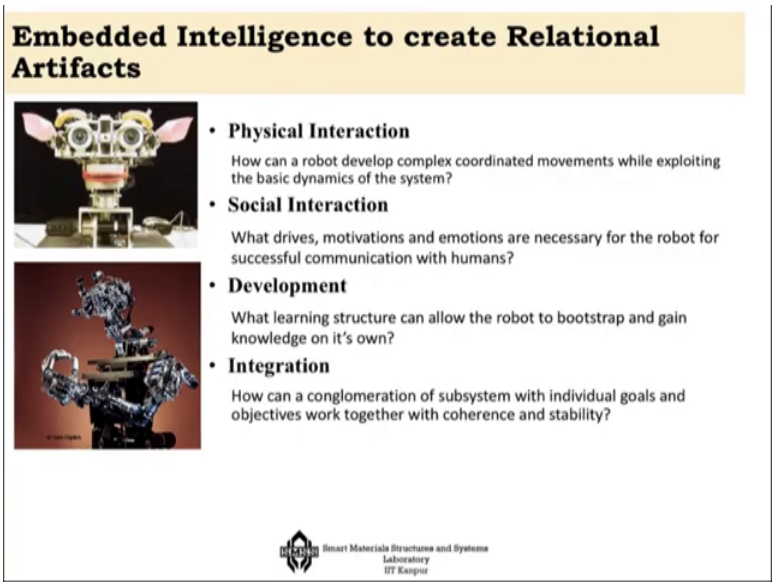

Now, for the cognitive robotics development, we will talk about three different types of strategies like physical interaction of the robot; how can a robot develop complex coordinated movements while exploiting the fundamental dynamics of the system, the robot has to be aware of its basic dynamics. Furthermore, then the social driving factors and can provide a robot bootstrap itself and try to know on its own.

And, finally, all these three properties how can you integrate them in order to get a kind of a complete system out of it which is capable of having physical interactions, social interactor and actions, and developments. So, this is what we will be exploring in the course as we will have the future lectures in these directions.

Thank you.