Foundations of Cognitive Robotics

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Lecture - 12

Welcome to the course of Foundations of Cognitive Robotics. We have reached the final week and in this final week in the first lecture I have talked about the various theories of intelligence particularly from the psychologist's point of view. Now, there is also another perspective to intelligence which is very important for us from the robotics point of view and that is the perspectives of artificial intelligence.

There are distinctly two groups of artificial intelligence perspective. It starts with the soft AIs, where the AI is the Artificial Intelligence is described in terms of soft rules. And, then there is a further development towards the hard rules of AI where the AI is embedded in robotic system.

So, we will see that how this theory is developed and with that perspective we will see that what are the different theories of artificial intelligence, a glance of it. We will not be able to have all the things in this lecture, but a glance of some of the important theorems of artificial intelligence; we will see it now.

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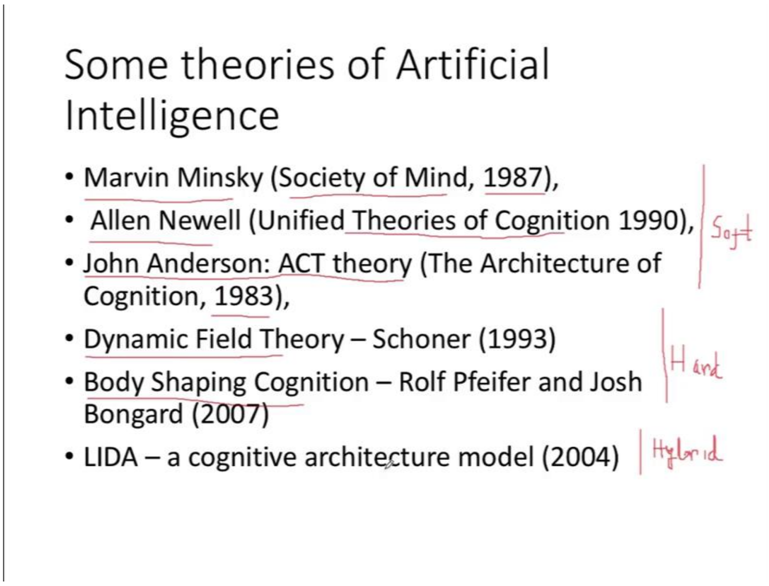

In this lecture we will cover these following you know famous personalities and their theories related to artificial intelligence. We will first talk about Marvin Minsky's contribution in terms of Society of Mind that is the book that I have chosen and that is in 1987.

Then we will talk about Allen Newell's point of view that is the Unified Theories of Cognition, that is after the Minsky's work and also John Anderson's ACT theory. It has undergone several evaluations, although the first part of the theory, the first initial architecture was in 1983.

Now, up till these this will be mostly computationally dominant artificial intelligence. So, I will simply call it as the soft AI and then we will discuss about some of them which are like hard AI. So, this will encompass the Dynamic Field Theory from Schoner and also a very important book that I have covered many times in this lecture series that is Rolf Pfeifer and Josh Bongard's Body Shaping Cognition.

So, both of them and they will be towards the hard domain and finally, we will talk about something which will be mix of the tool that is the LIDA and the cognitive architecture corresponding to it.

So, let us call this to be a mix of soft and a mix of soft and hard rules and maybe we can classify it as the hybrid technique. So, that is the hybrid technique ok. So, this is what we will be covering soft, hard and hybrid. Let us first start with the soft theories of artificial intelligence.

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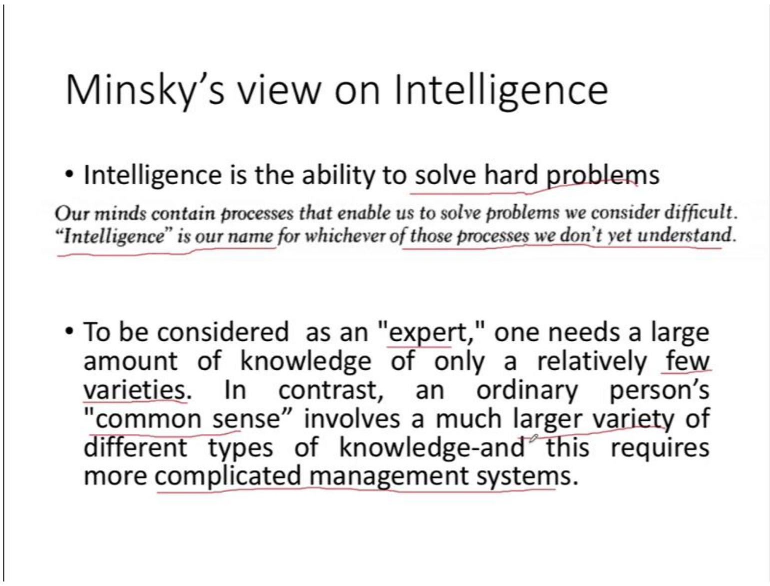

Now, I will start with Minsky because no theory of artificial intelligence can remain complete without any discussions of Minsky's view on intelligence. And, in a very simple manner Minsky has covered intelligence as simply the ability to solve hard problems. Now, the question is that what are these hard problems? Well, our minds contain this exactly in Minsky's words contain processes that enable us to solve problems we consider difficult.

Intelligence is basically a term it is our mind for whichever of those processes we do not yet understand that you know why these are the things that we are able to solve. So, that kind of hard problems for which there is still lack of understanding Minsky wanted to say that this is what we actually refer to the term through intelligence. Now, here also he has made a division between an expert because as an expert he said it is essentially an agent which needs a large amount of knowledge of only relatively few varieties.

So, it is a large amount of knowledge with relatively few varieties. Something like if you consider that an intelligent chess player that is or an intelligent chess agent a robot. Now, this kind of agents will be only expert of chess that intelligence we will not get reflected in other problems. So, in contrast if you consider an ordinary person's common sense you would see that would involve a much larger variety of different types of knowledge and that requires more complicated management systems.

So, according to Minsky that instead of an expert point of view of development of the agents, we should, if we want to look for intelligence we should broad our scope and we should start to see how these you know larger variety of different types of knowledge can be actually tackled under one umbrella.

In fact, many times Minsky has mentioned that it is more difficult to emulate a you know some of the children's actions in a robot than to do something which is a very industrially standard dexterous kind of a work.

So, that is what you know is related to the common sense and what is so easy for us may not be at all easy for the robot; because what looks so easy may actually involve a lot of complicated processes inside it.

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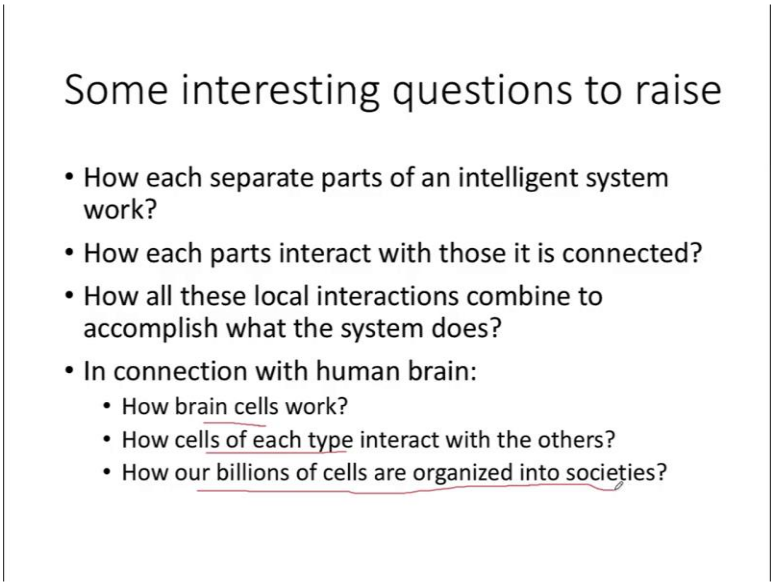

Now, some of the interesting questions here to raise are how each separate parts of an intelligent system actually work? If you consider the brain itself as a source of intelligent system each one of the parts of the brain how does it work? And, how does each part interact with the other parts? And how all these local interactions is going to get combined to accomplish what the system does?

So, there are three questions that if there is a subdivision then how each subdivision works? How the subdivisions interact among themselves? And how these interactions finally get combined whenever a system has to do something which is like a final deliverable from the system?

In connection with human brain this will also raise the questions like how the brain cells work or how cells of each type would interact and how our billions of cells are organized into societies? Which he has mentioned as the society of mind, how they are organized in terms of doing some work?

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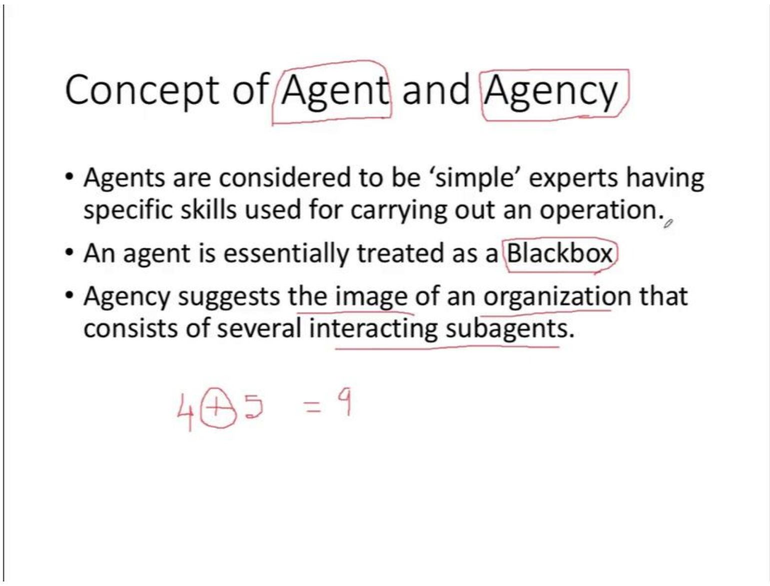

Now, again and again there are two concepts that has been used by Minsky and that is very important even in today's context of artificial intelligence which is agent and agency. Agents are considered to be simple experts having specific skills used for carrying out an operation.

So, they are essentially treated like a black box, let us say that you have to add some numbers. So, if you have an organ which carries out this addition. So, it carries out this addition of any number you give say 4 and 5 and you immediately get an answer that the answer is 9.

Now, we do not know how exactly the brain is working in order to get this number 9. We will simply say we know and that we know is because of an agent who is carrying out this addition operation inside the brain and that works pretty much like a Blackbox. So, this is one important concept related to the agent.

Now, there is another part which is called agency. Now, agency term is has a very broad convocation in English. For example, you want to plan a travel, then where do you go? You go to a travel agency or let us say you want to plan some savings. So, you go to some savings agency.

So, agency suggests the image of an organization that consists of several interacting subagents. Now, whenever it is a question of agency then there is an image map that is available for us, but for agent it is a black box; that means, we do not know how the whole thing works.

So, essentially the society of mind according to Minsky or any intelligent system consists of several agents and agencies. And, maybe some of these agents work under an agency in that case it will be like a black box and sometimes there can be independent agents. But, these are the two things which is very important in order to understand how an intelligent mind or on how an intelligent system could be developed.

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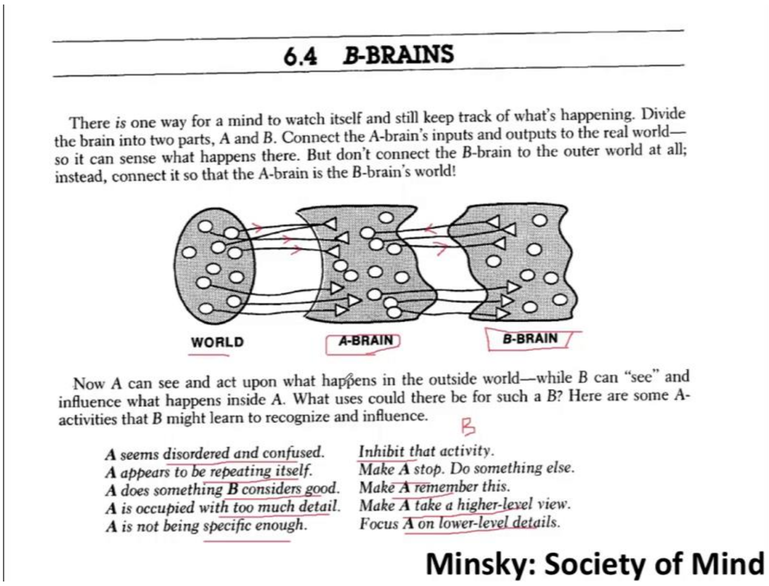

6.4 *B*-BRAINS

There *is* one way for a mind to watch itself and still keep track of what's happening. Divide the brain into two parts, A and B. Connect the A-brain's inputs and outputs to the real world—so it can sense what happens there. But don't connect the B-brain to the outer world at all; instead, connect it so that the A-brain is the B-brain's world!

Now A can see and act upon what happens in the outside world—while B can "see" and influence what happens inside A. What uses could there be for such a B? Here are some A-activities that B might learn to recognize and influence.

B

A seems disordered and confused.	*Inhibit that activity.*
A appears to be repeating itself.	*Make A stop. Do something else.*
A does something B considers good.	*Make A remember this.*
A is occupied with too much detail.	*Make A take a higher-level view.*
A is not being specific enough.	*Focus A on lower-level details.*

Minsky: Society of Mind

Now, another important point is that there almost invariably exists a kind of an interface between the deep brain and the brain that interacts with the world. So, with the brain that interacts with the world we will call it as A brain and the brain that is that can only interact with A brain is known as the B brain. So, we have for example, different somatosensory systems and this somatosensory system interact with the environment and pick up the information.

Now, that is done by a brain which would actually have some knowledge of what they are looking at, but mostly they themselves are actually controlled by the B brain. So, B brain looks at that what is what are the informations that A brain has brought and B brain simply kind of guides the A brain to look for the informations, to change the resolution, to change the perspective and everything. So, you see that is what is the kind of the work of the B brain.

Now, some of the activities that A activities and B activity; for example, A it seems disordered and confused while carrying out an activity. Then B may inhibit that activity or A appears to be repeating on some activity.

Then B may say that make A stop, A does something B considers good, make A remember this or A is occupied with too much of detail, make A take a higher level view or A is not specific enough focus A on lower level details. So, this is what the B controls. So, this is the B's role over A.

Now, this kind of a hierarchy according to Minsky can actually help in terms of developing an intelligent system. We have seen the Minsky's view on artificial intelligence. Now, almost contemporarily there is Allen Newell who had also looked into this problem and helped to flourish the field of artificial intelligence. And, Allen's point of view was in terms of developing a kind of a unified theory of artificial intelligence.

Because, there is this group of psychologists and there is the group of computer scientists and Allen kind of worked as a binding agent between the two. And, he has developed the first framework under which according to him this kind of integration is possible. So, there are certain demands from his unified model and let us look into those demands.

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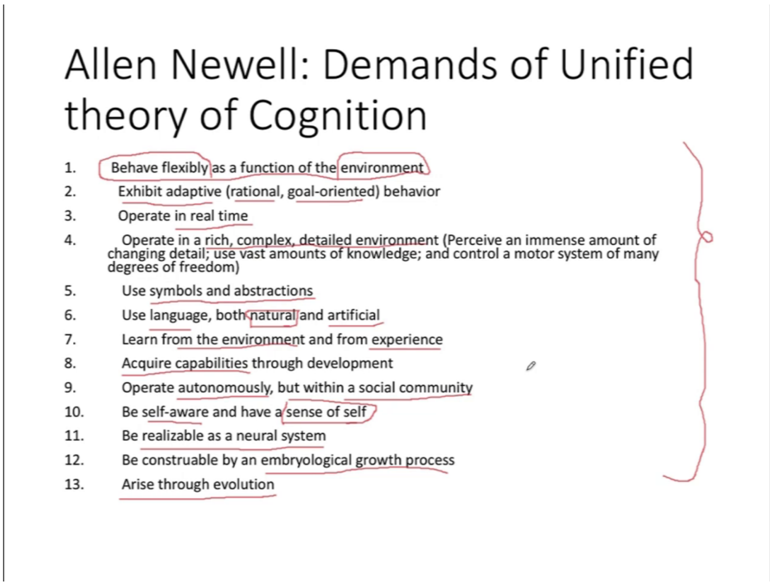

Well, Allen Newell's Demands of Unified theory of Cognition. There are actually 13 of such and he considers that if these 13 demands are fulfilled, we can consider that the system is intelligent system or the prerequisites of the intelligent system has been taken care of. Now, this starts with first of all behave flexibly as a function of the environment; we will come to this point again and again that how the analysis of the environment plays an important role for any intelligent system.

So, there is something called an ecological niche and every intelligent system is to find out what is that niche, where it can prosper. And, in order to do that it has to be adaptive; it has to behave in a flexible manner. So, that is what is the very first and important thing. And, the second one is also correlated with these exhibit adaptive rational and goal oriented kind of a behavior. The third important thing is that the intelligent system should operate in real time.

It should not you know happen in a virtual world, it should happen in the real time and it should operate in a rich, complex and detailed kind of an environment. So, the environment should be a kind of an environment which for example, a living system you know faces. It should be complex, detailed environment. This system, the artificial intelligent system that one has to develop must use symbols and abstractions just like the living counterpart.

Use language which should be both natural and artificial. Natural language is particularly very very important, because we will see later on that that increases the power of communication immensely. Learn from the environment as well as learn from the experience. Acquire capabilities through the environment, operate autonomously, but within a social community where there is a group of some you know things which are working together.

Be self aware and have a sense of self. This is a big philosophical task of course, that how can one be aware, how can an agent any agent, any robot be aware of itself and can carry a sense of self. Be realizable as a neural system. So, it should be you know one should be able to physically realize such a system be construable by an embryological growth process. This is something which is also something which is not achieved till today; that means, can a robot generate a new robot, procreate a new robot.

So, that is the embryological growth process and the other important point that is arise through evolution. So, if all these 13 points are met, then actually we can say I mean according to Newell that you can say that you have developed a truly cognitive intelligent robot. Now, we will see that much of these cannot be actually fulfilled in one shot. But, the next important milestone towards this is actually John Anderson's ACT theory. ACT refers to Adaptive Control of Thought - Rational.

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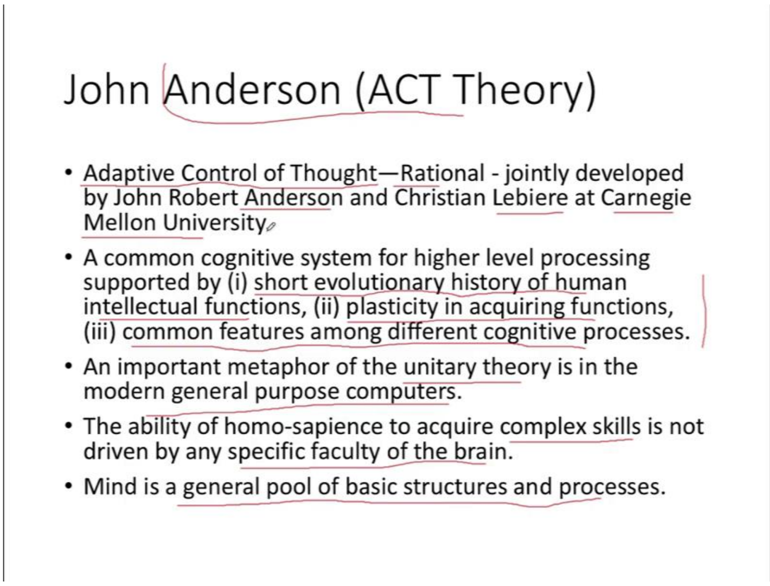

So, sometimes it is called ACTR or ACTs are stars at different levels it has been developed jointly by: Anderson and Christian Lebiere at CMU or Carnegie Mellon University. Now, according to Anderson who’s a very much a proponent of a single theory or cognition; a common cognitive system for higher level he thought it to be very important. Because, it is supported by short evolutionary history of human intellectual functions and it’s also the plasticity in acquiring the functions.

It is the kind of plasticity that we observe and common features among different cognitive processes. So, all these three things that the human intellectual functions have developed in a short evolutionary span only and it has a plasticity in terms of acquiring functions, different parts of the brain. It has been shown many times that even if one parts get injured or get damaged, the other parts come into action and work on these directions.

So, that kind of plasticity it can quickly show and different cognitive processes have certain common features. These are the three things that are actually kind of supported that there must be a unified theory of cognition.

So, an important metaphor of the unitary theory is in the modern general purpose computers for example, because for a general purpose computer it does not take help of different subsystems. One single processor can handle let us say the word processing can handle the internet, can handle the data analysis and things like that.

So, that is something which says that yes unitary theory is possible. The ability of homo sapiens to acquire complex skills is actually not driven by any specific faculty of the brain, that the brain is generic that is why these complex skills are achieved. And, the of mind is a general pool of basic structures and processes. This was the basis of Anderson’s ACT theory.

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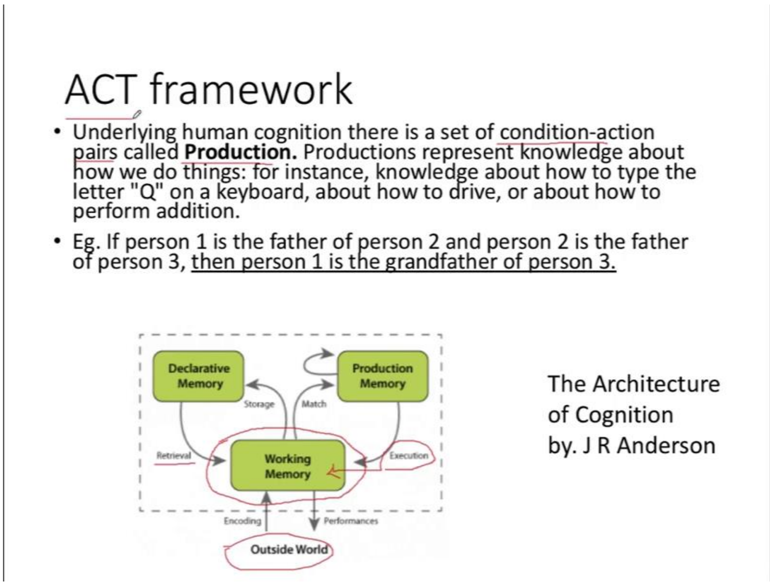

Now, if you look further into it, there is this ACT framework and one important concept of the framework is the concept of production which is a set of condition action pair. And, it is something like once you have this knowledge about how to do a specific thing and then you know this is like an agent it continuously does that very specific things.

So, for example, you know if a logic is included like this, that if person 1 is the father of person 2 and person 2 is the father of person 3, then the definition of grandfather is that person 1 is the grandfather of person 3.

So, finding out the grandfather from this logical relationship is a production process. Now, Anderson’s concepts is that essentially there are always three types of memories with us. The first is the working memory.

So, that is where you know we essentially interact with the outside world, but the working memory is limited in scope. Now, if something is too big then the working memory stores it in the declarative memory, where the items category wise are stored. And, whenever needed working memory can actually retrieve from the declarative memory.

And whenever some function is to be actually carried out then the working memory sends these to the production memory and the production memory has all these kinds of condition action pairs. As I told you so, the production memory goes to that and it say it executes it and it sends the data back to the working memory. So, that is what is the structure that this three memory interaction with the outside world and that is the architecture, the basic architecture of the ACT framework.

Now, we have talked about the soft rules in terms of developing intelligence. So, we have seen Minsky's point of view, we have seen Newell's demands and we have also seen some algorithm that Anderson had developed you know in terms of the ACTRs.

Now, the soft intelligence has limitations because, it is if you look at Allen Newell's logics that it is not interacting with the real complex world. In order to interact with the real complex world, a system must have sensors, must have motors, must have processing systems and a body.

That means the system the intelligent system must look like a physical robot. Now, this the moment you develop this kind of a physical robot; what you will not be able to avoid once this physical robot starts to interact with the environment is the dynamics of the robot. So now, I will talk about some very fundamental work by Schoner and his groups on the dynamic field theory. So, let us look into that.

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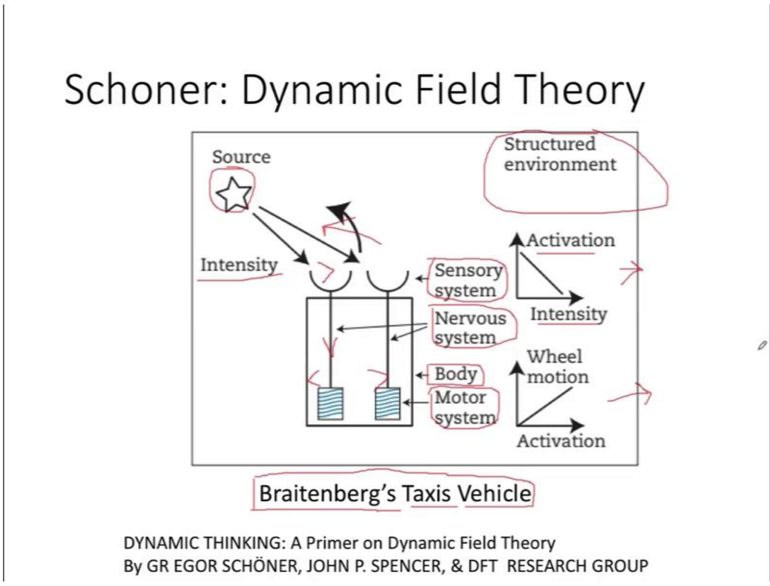

We will now look into Schoner's: Dynamic Field Theory and a very easy example because we are just introducing the concept view that has been done by Schoner is by taking the examples of Braitenberg's taxis vehicle. Now, you know that taxis is something which is very popular among the biologists like phototaxis for some of the flowers or chemotaxis for some other plants.

So, taxis denotes that a gradient based movement. Now, we are considering here a Braitenberg's taxis vehicle and as I was telling that this vehicle is having some sensory system. So, this embodiment is there then it has some nervous system and then it has some motor system. Now, all these things are not hanging in thin air. So, it has a body which actually you know kind of houses all these three things: the sensory system, nervous system and the motor system.

Now, let us say that this sensory system has to move towards a particular source by measuring the intensity through the sensors and because the two sensors are placed at two different positions.

So, they will be having different intensities because one which is nearer to the source will be having higher intensities. One which is away from the source will be having lower intensities and you can see that the activation and the intensity in any structured environment. So, it is actually inversely related in the sense that as the intensity is in increasing the activation is going low.

So; that means, that here the intensity is more. So, this is higher. So, if we this is higher here the intensity so, the activation will be actually lower here. So, the motor system here will be actually you know if the same signal is brought here; then these motor signals will be less here, there will be a less turning. On the other hand, if the intensity is lower here then the activation will be more and that means, that the motors will be turning here at a higher speed.

Because activation is directly proportional to the wheel motion; so, the higher the activation the more will be the wheel motion. So, what will happen is that this whole system will then rotate because in this side they will be having higher activation. So, the motors will turn faster and this side they will be having lower activation. So, the motors will turn slower and as a result they will be driving towards the source. So, this is you see a simple Braitenberg's taxi vehicle model.

Now, the interesting thing here is that from the vehicles point of view the only logic that is given for the vehicle is these two logics; that if you get high intensity you should activate low and if you get low intensity you should activate more. And, also this motor logic that if you are having high activation of the signal then the wheel motion should be higher, if you have low activation then the wheel motion should be lower.

But, if you look at this system from outside you will see that just simply following this logic how interesting is its behavior. Then at that as soon as there is a source it understands that how to target itself towards the source just by through this kind of a thing. And of course, there is a structured environment here, we have not talked about any presence of disturbance or multiple sources etcetera. So, the dynamics of the system if we can actually develop then that itself then we will guide us towards the behavior of it.

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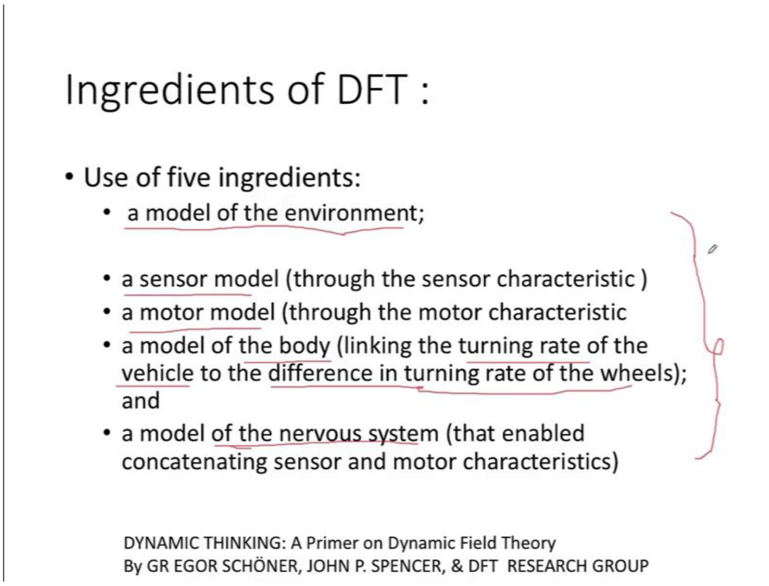

Now, what Schoner has found out is that there are some very important ingredients for these kind of dynamics. And in the dynamic you know field theorem first of all you must be having a model of the environment available with us, environment is very important.

Then based on the environment you should design a sensor model through the sensor characteristics, a motor model through the motor characteristics, a model of the body because the body is housing the sensors and the actuators and imposing certain constraints on it.

It is linking for example, the turning rate of the vehicle that is the rigid body dynamics in this case to the difference in turning rate of the wheels. So, that is where is the significance of the body and also a model of the nervous system which is needed because from the sensor the activation is going to the motor through the nervous system. So, these are the five very important ingredients that you must have in terms of developing a dynamic field theory based intelligent robot.

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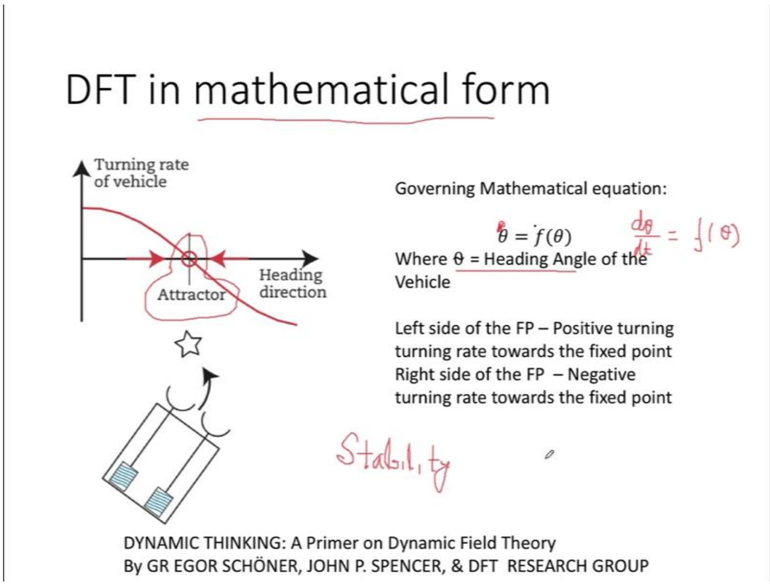

Now, the DFT can be also that is the greatest you know advantage of DFT that it can be also expressed in a mathematical form. So, a higher degree of abstraction is possible. For example, in this particular example that I have shown you that the robot turning towards the source, if the heading angle is denoted by theta then one can actually write it like a theta dot, this is theta dot or that is so to say d theta d t that is the rate of change of the heading angle. So, theta dot is equal to some kind of a function of theta.

So, theta dot is some kind of a function of the heading angle. So, rate of change of heading angle is a function of the heading angle itself. And, if you look at it that for example, in this equation this is a non-linear this can be a non-linear equation.

And, in this equation there is a fixed point here and if the robot goes towards the left side of the fixed point then there is a positive turning rate which will take it towards the fixed point. If it goes towards the right side of the fixed point then there is a negative turning rate which will take it towards the fixed point.

So, the turning rate of the vehicle will be such that it will be always guided towards an attractor, this attractor is very important. So, this is for a single source system, this kind of a taxis vehicle model has one attractor and it has to always go into that attractor. Their presence of the attractor also tells us that there is a presence of stability in the system.

Stability is a very important concept for any intelligent system and for a system to be enormously intelligent; we will later on see that it has to have multiple attractors which should give multiple stability configurations to the system. So, this is an important you know kind of mathematical abstractions that is possible through the dynamic field theory.

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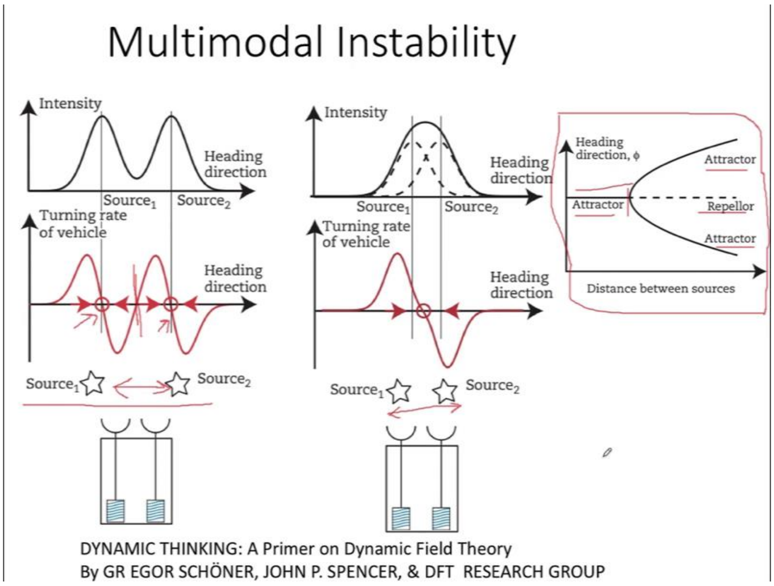

Now, let us consider a situation where you have not just one source, but you have two sources. Again in this case because you have two sources; so, you will be having essentially two fixed points. And, the logic will be such that depending on the initial orientation of the robot you will either go to one fixed point or you will go to another fixed point and there exists a plane in between which will work like a repellor.

So, it will drive the system towards one of the fixed points. So, that is once there are multiple sources then there are multiple points of stabilities. Now, what if the source 1 and source 2 are very close? In that case it may happen that these two bimodal system will be so close that you can apply a mean field theorem and by using the mean field theorem you can actually consider a unimodal system. Again in this case you will be having a single fixed point towards which the system will be driven continuously.

And, this whole thing can be beautifully described with respect to this kind of a you know bifurcation diagram which I had earlier discussed with you, that there are such non-linear bifurcations that are telltale signs of an intelligent systems.

That if the sources are too close then there will be a single attractor system; this is a single attractor system. So, we will be in this range and the moment the sources are far apart the distance crosses a critical point that critical point is of course; this is the critical point of bifurcation.

Then you are we will be going to get two attractors and in between there is this repellor plane which is this repellor plane I have talked about. So, and it will become a bimodal kind of a solution. So, depending on the separation distance between the sources we are going to see this intrinsically complex behavior from an apparently very simple system that it is either going to go to one single solution or it is going to go to two solutions, two points of stabilities. And, in this case it will be depending on the initial orientation of the system.

So, this is you can see that how this same model can develop more amount of behavioral complexity. We have seen the Schoner's model of dynamic field theorem and we have seen that in these field theorem how the embodiment is absolutely important; you must have the environment, you must have the sensor, you must have the actuator, the nervous system connecting them and the body in which the whole thing must be dwelling.

Taking these further we will see Rolf Pfeifer's and Josh Bongard's and they are those point of view from MIT that how the body can control the mind itself or so to say the intelligence itself how that can be governed by the body. So, let us look into their propositions in terms of intelligent system.

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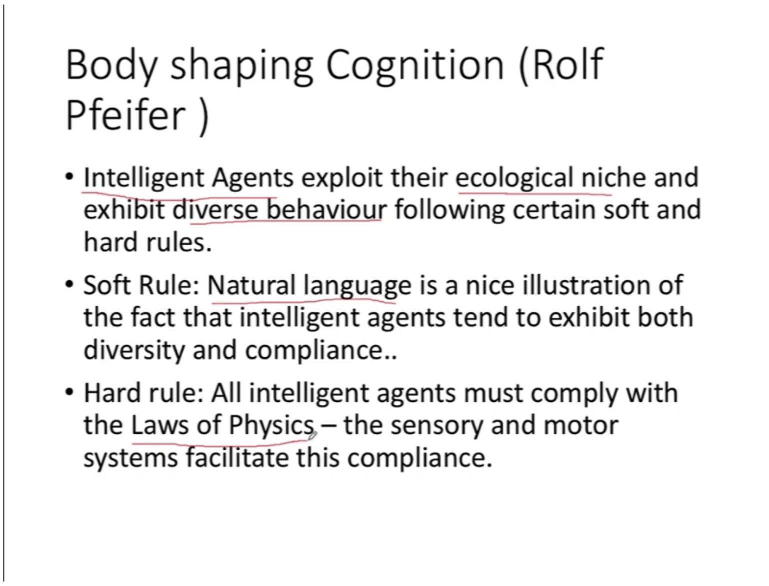

We will now look into the body shaping cognition which was developed by Rolf and Rolf Pfeifer and Josh you know in MIT. Now, here said that the intelligent agents as I told you that agent would mean any intelligent system living or non-living. Now, they should exploit their ecological niche that is what one of the proposition of from the Allen Newell and they should exhibit diverse behavior following certain soft and hard rules. So, the compliance to the diverse behavior is something very important for an intelligent system.

Now, these diverse behaviors a part of it is actually the earlier soft rules that Minsky, Newell's and Anderson's their can. And, one of them is that the robot should be able to use natural language and because that gives enormous flexibility in terms of communications and interactions. So, soft rules are that the mode of interaction should be as diverse as possible and the hard rule is that all intelligent agents must comply with the laws of physics.

Now, this directly means that there must be this intelligence embodied in a real system which is subjected to the laws of physics. For example, the robot is subjected to the laws of gravity. It is subjected to the laws of you know whenever we will be talking about motors etcetera, laws of electromagnetics or other laws like for smart materials we have discussed the piezoelectric laws of piezoelectricity.

So, all these laws of physics it has to comply; there is no escape from it. You can only escape it in a virtual world, but for a real robot you cannot escape it. So, that is the first important thing that we have to keep in our mind.

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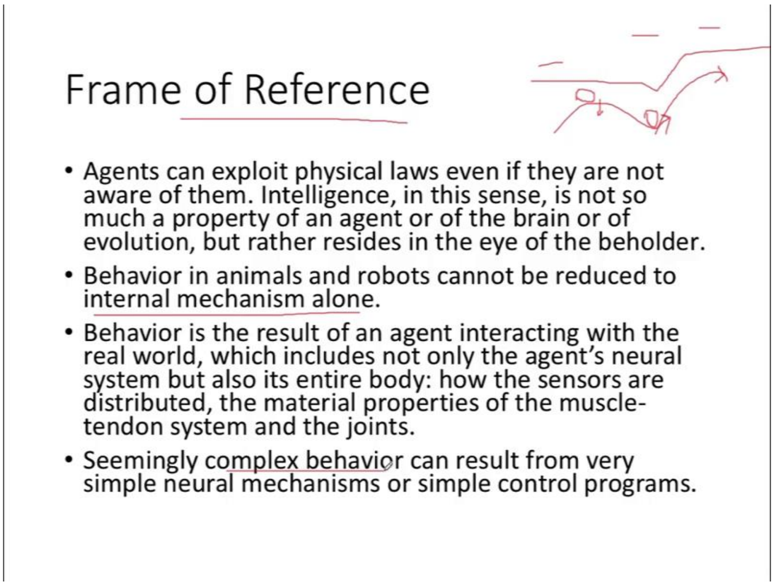

Secondly whenever we will talk about these robots, there has to be a frame of reference that is important for us the frame of reference. The agents can exploit physical laws even if they are not aware of them. In this sense intelligence is something which may not be a property of an agent, but the person is observing the agent.

Now, there is a very famous analogy there that if you consider a ant moving by the side of a beach which is having lots of poodles and small mouths etcetera. Now, you may see once the ant has moved you may see that it has at the end when it reaches from destination a to destination b; you may see that the ant is having a very complex path, this is by the side of the sea.

So, you may see a very complex path, but you know all that the ant must have had done is that if there is an obstruction at a particular position, it has always turned to the other direction, it has changed itself just like this Rolf just like these other Braitenberg's taxis device. So, just by following the algorithm of the obstructions it must have had actually develop this kind of a complex path.

And, hence the intelligence in the ant from the ant's point of view may not be that high, but it is from person is watching this ant path it is a very complex path. Behavior in animals and robots cannot be reduced to internal mechanisms alone.

When you are looking at the behavior you are looking at their complex interactions with the environment. So, behavior is the result of an agent interacting with the real world which includes not only the agent's neural system, but also its entire body because without body it is not interacting.

How the sensors are distributed, what is the material properties of the muscle tendon system and the joints. Remember that is why I told you that for the new age robots you need to know how the smart materials, the smart muscles are going to behave; you cannot exclude that fact if you have to develop an intelligent robot.

And, seemingly complex behavior can result from very simple neural mechanisms or simple control programs. In fact, I have shown you the taxis vehicle example where a kind of a complex behavior is actually happening; although the logic was very simple. So, the frame of reference is important that are you watching it from the robot's point of view or are you watching it from outside.

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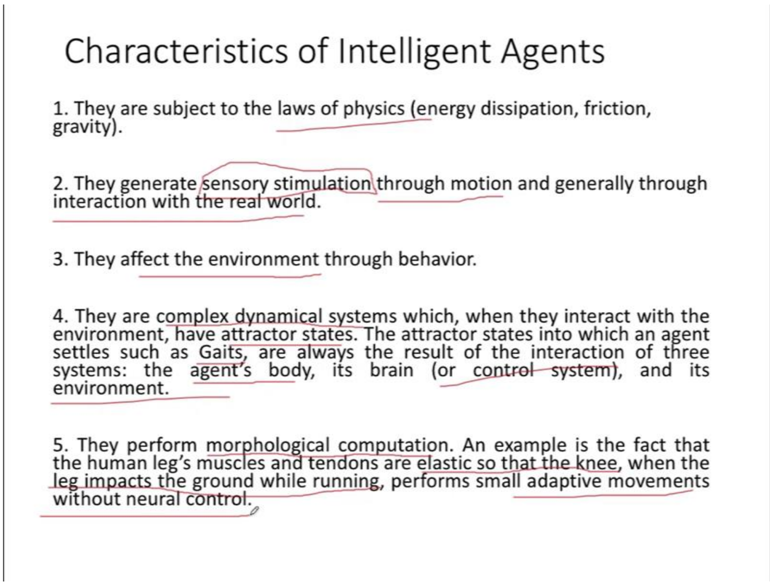

Now, there are certain characteristics which rob said that an intelligent agent should be having. First of all, it must obey as I had told you many times that it must obey the laws of physics like energy dissipation, friction, gravity. It generates sensory stimulation through motion and generally through interaction with real world. This generation of sensory stimulation is very important and through interactions it should generate it. And, this we have to also keep in mind that suppose there is a living system, suppose there is a living dog moving on your lawn.

Once the dog has moved then there are the footprints of the dog on the lawn. So, there it will affect the environment also that we have to keep in our mind. And, these are complex dynamical systems which when they interact with the environment it will have attractor steps.

I have shown you simple abstractor steps right, if you remember in terms of that unimodal system. So, there can be many attractor steps. In fact, for animal locomotion this is also known as gaits. So, there can be many gaits on the system and these are always the result of interaction of three systems: agents body, its control system or brain and its environment.

So, that would define what are these attractors are and the more the number of attractors the more complex is the system. The other important thing is that they must perform certain morphological computation. Now, by morphological computation what we mean is that for example, if you consider the human leg; the muscles and tendons are elastic so that the knee, when the leg impacts the ground while running performs all small adaptive movements without any neural control.

So, you know you do not always need neural control, you may say that this is something which is like a behavior which is given to the system a priori. So, that it can actually work without interference by a control system. And, it is the environment which invariably always closes (Refer Time: 44:30) that is the characteristics of intelligent agents. Now, we have looked into the embodied intelligence, the hard intelligence and you know an aspect of embodiment of intelligence and also we have looked into the soft rules.

Now, we are going to kind of assemble these things together and we are trying to propose some kind of a cognitive architecture. So, I will just give you one such example; in literature there are many. I have chosen one which is a very popular example of LIDA, a LIDA system.

And, that is what we are now going to look at that how can be how a cognitive architecture can look like. And, you would see that this is quite different from what we generally do in robotics control, the cognitive architecture system. So, let us look into this LIDA cognitive architecture system.

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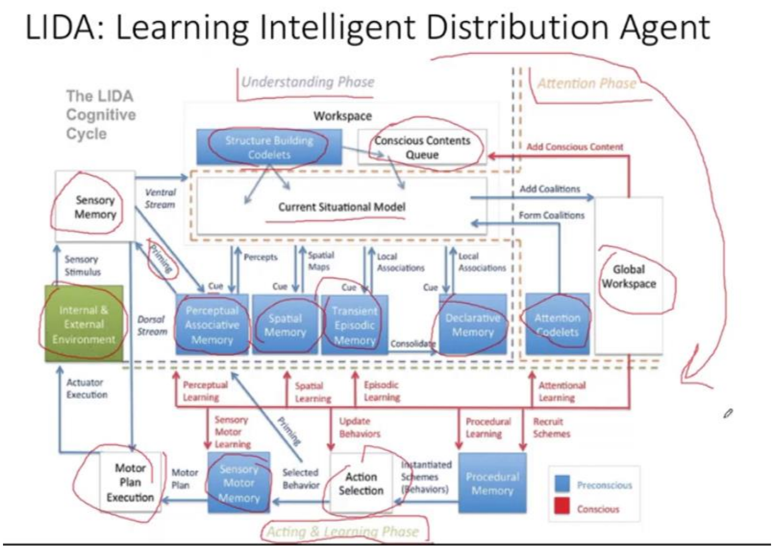

LIDA which is also known as Learning Intelligent Distribution Agent, it is having two important characteristics. First of all, it works in a cycle and it is roughly is like a clockwise way that is shown here, but there is a cycle. You will see in all intelligent systems there is a rough kind of a you know approximate time cycle that always is involved. And secondly, it has three important phases: understanding phase, attention phase and acting and learning phase.

So, it has these three important phases and the entire system is having many so, to say you know the according to Anderson’s these productions kind of you know or the agents you know which carries out many specialized actions. So, first of all such a system would work with a sensory memory and then this sensory memory will send the data, we will call it in form of queues to something which is known as Perceptual Associative Memory or PAM.

Now, PAM also continuously sends its kind of you know directions to the sensory memory. If you remember that A brain and B brain structure if you remember it there that is something similar and this is the priming that is happening.

So, PAM works something like A brain which interacts through sensory memory to the external environment. So, this is where is the internal and external environment and then PAM with the help of certain codelets which are like structure building codelets, it actually develops the current situational model.

Now, when it is developing the current situational model, it also takes care of the conscious contents queue so, that it can update itself. Then from the current situation model and at this stage the current situational model can also get updated by the spatial memory and the transient episodic memories. And, everything can get consolidated in the declarative memory and then certain aspects of these are chosen for the global workspace through the attention codelets. So, this is another kind of a procedural memory.

So, it comes to the global workspace and finally, from global workspace the actions other procedural memory starts to work and the action selection and the sensory motor memory comes into picture. And finally, the motor plan gets executed which works on the environment. Now, there is this blue part which is preconscious level and there is this red part which is happening in the conscious level.

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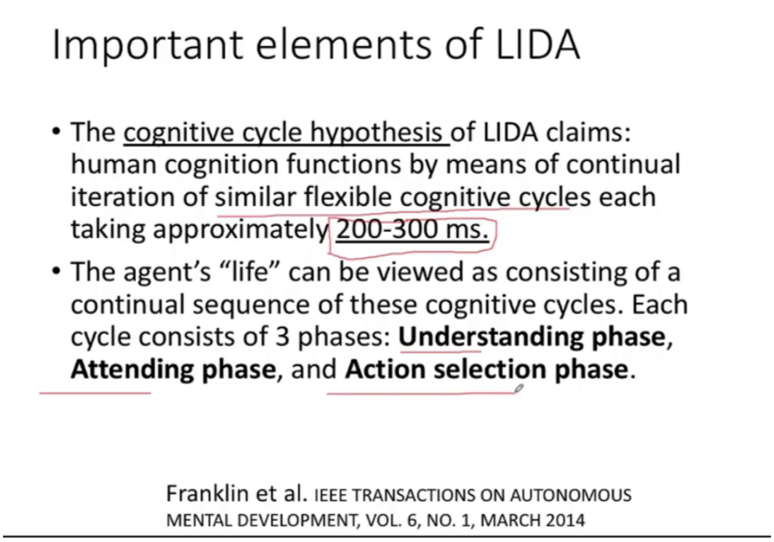

Let us now look into it with a little more details. So, as I told you that cognitive cycle hypothesis is one of the most important feature of LIDA. It claims that there is a continuous iteration of similar you know flexible cognitive cycles which would approximately take 200 to 300 milliseconds.

So, it is not exactly a clockwork of a computer, but it has some kind of a cycle in which it continuously works on. And as I told you that agents life consists of continuous sequence of three activities: understanding, attending and action selection.

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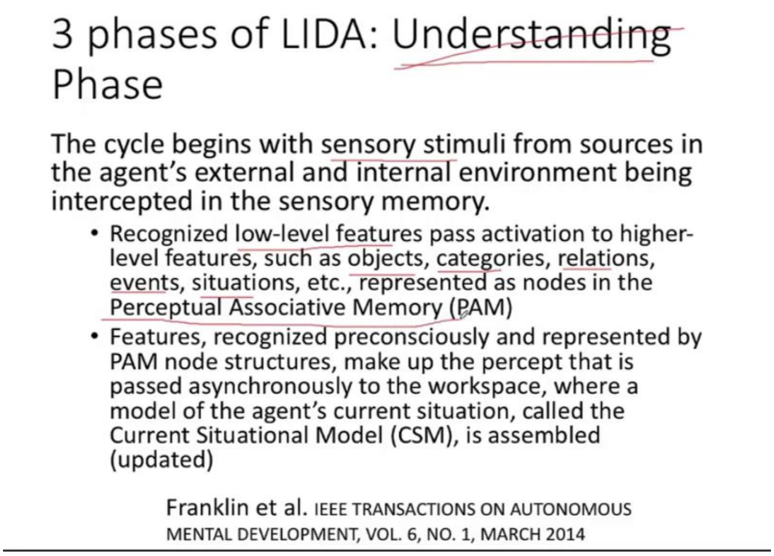

So, these three activities have to happen continuously in the system. Now, these three phases of LIDA; let us look into it one by one again. The understanding phase which we have just discussed; so, in this phase the cycle begins with sensor stimuli from sources in the agents external and internal environment. And, they start to recognize certain low level features and then pass the activation to higher level feature such as what object is it, what category, what is the relationship, what are the events, what are the situations etcetera.

And these are done under the constant monitoring of nodes which are known as perceptual associative memory or so to say PAM. So, you remember the PAM here just this is where is this PAM part. So, this is continuously interacting with the sensory memory.

Now, features recognized precociously, this is the preconscious phase and represented by PAM node structure make up the percept that is passed asynchronously to the workspace, where a model of the agent's current situation called the current situational model is assembled or updated.

So, you remember that this is where is the CSM or the Current Situation Model. Now, at time 0 there is always a model that is present and the model gets updated by the sensory memory and the PAM. So, the model continuously gets itself updated and this is done with the help of the structure building codelets.

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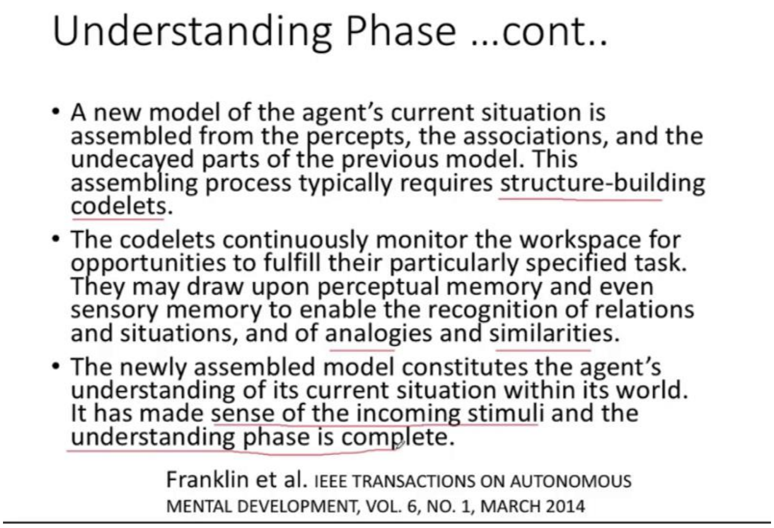

So, a new model of the agents' current situation is assembled from the percepts associations. These associations come from other may come from other spatial memories, episodic memories etcetera. And, the undecayed parts of the previous model and this assembling process typically actually takes the help of structure building codelets. It actually assembles or updates the you know this particular the current situation.

Then these codeletes also continuously monitor the workspace for opportunities to fulfill their particularly specified task, because codelets are something like an agent. They may draw upon perceptual memory and even sensory memory to enable the recognition of relations and situations, analogies and similarities.

Now, this newly assembled model constitutes the agents understanding of its current situation within its world. And, it has made a sense of incoming stimuli that is important whatever is reaching you, it will make a sense of it and the understanding phase is complete. So, that is the first phase.

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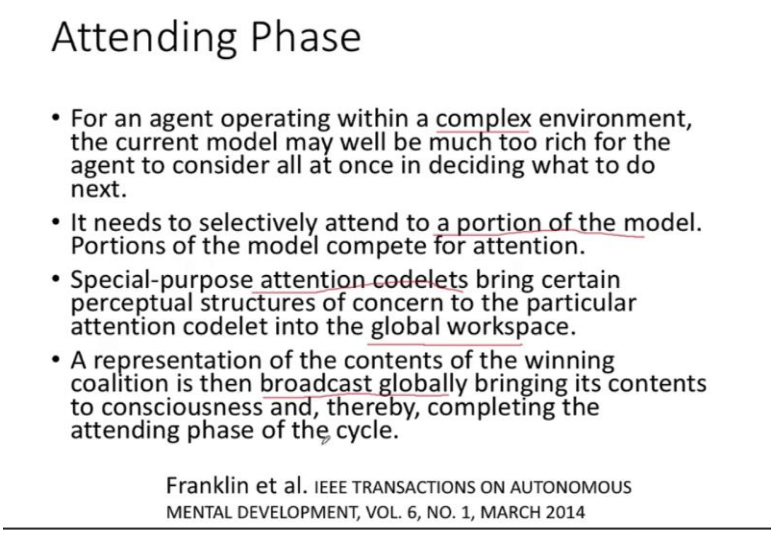

Next we come to the attending phase where the entire model is not presented because the entire model could be very complex or it can be very rich in terms of information. So, one has to choose that where the attention is needed. So, only a portion of the model is actually choosing. And, special purpose attention codelets they bring certain perceptual structures of concern to the particular attention codelet into the global workspace.

And, a representation of the contents of the winning coalition because there will be many coalitions, but the winning coalition then is broadcast globally bringing its contents to consciousness. So, this is where the consciousness starts and that completes the attending phase of the cycle. So, understanding attending is over.

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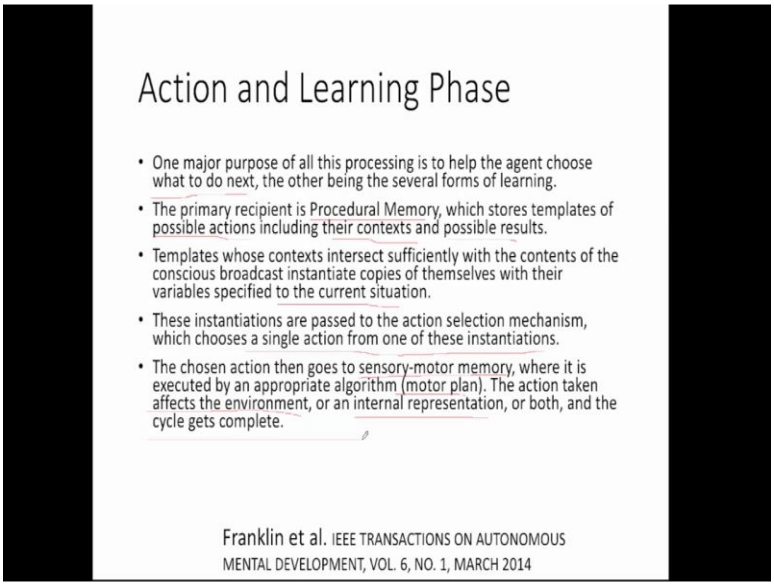

Now, we are conscious because we have to do the action. So, now comes the action and the learning phase. One major purpose of all this processing that has happened so far is to help the agent choose what to do next, the other being the several forms of learning also.

The primary recipient is procedural memory which stores templates of possible actions it is having that if this happens, this action is taken including their context and possible results. So, templates whose contexts intersect sufficiently with the contents of the conscious broadcast instantiate copies of themselves with their variables specified to the current situation. These instantiations are passed to the action selection mechanism which chooses a single action from one of these instantiations.

The chosen action then goes to sensory motor memory finally, where it is executed by an appropriate algorithm or a motor plan. And, the action taken would affect the environment as I told you earlier and also it will affect the internal representation or both and the cycle gets complete, you start the next cycle again. So, this is how the whole system according to Franklin and their group the LIDA cognitive architecture is.

So, we can build similar cognitive architectures for a cognitive robot. So, this is where we will end today's lecture.

Thank you.