Artificial Intelligence
Prof. Mausam
Department of Computer Science and Engineering
Indian Institute of Technology - Delhi

Lecture-65
Introduction: Agents and Environments

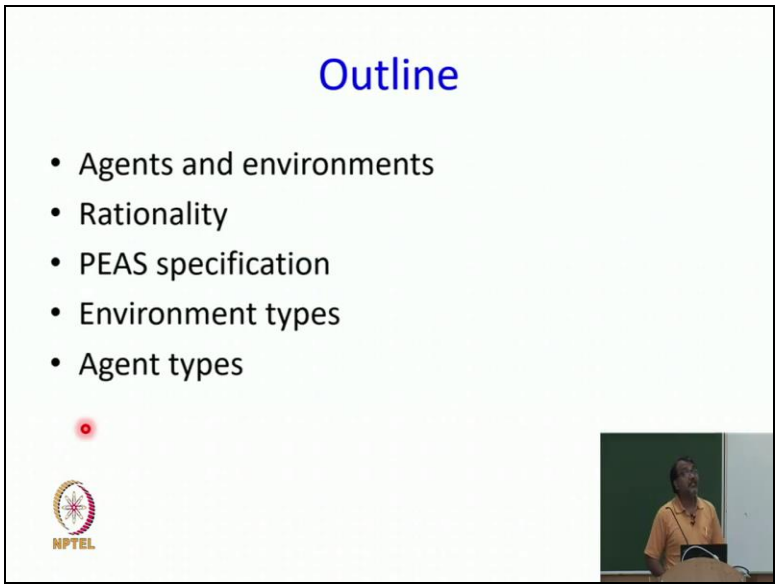
So, where are you in the course? If you think about what we have done so far we started by saying that looks solving a new problem is the cornerstone of AI. Problem solving is the central theme of any Intelligence and so we decided on one general problem representation and we talked about how to solve that particular problem. General problem a presentation was the atomic agent and how we solve it is using a lot of search techniques.

And then we said that is awesome, but we need to build in knowledge in the agent. The agent cannot be starting from scratch every time. If I want to basically used minimax till the very end I will never make a good chess player. I have to give some knowledge. So kind of knowledge, so, we asked question how would we give that kind of knowledge. And to give that kind of knowledge, we learnt 2 main knowledge representations Languages one was the language of logic and one is the language of Bayesian networks.

Bayesian network gives how the various variables in the state interact with each and logical representation also give this how do the various variables in the state interact with each other. Logical representation give you logical way of doing these implications and you know rules that may be true deterministically in my system and Bayesian network give the same in a probabilistic way of thinking in the probabilistic relationships.

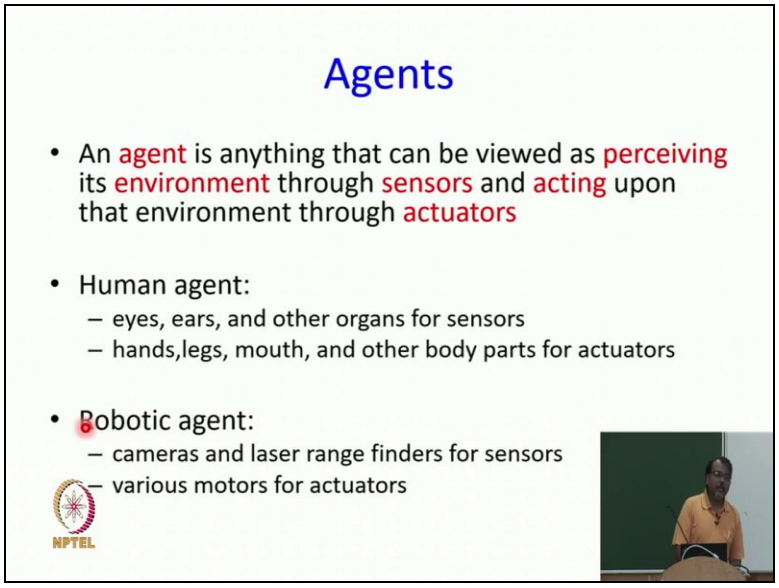
I thought this is a good time to take a step back and think about what we have a accomplished how does it fit together? And how does it fit with the initial philosophical definition of AI that we started with. Typically people teach the set of slides right after the introduction, but I feel that you know the introduction is already too long. And these set of slides are really well understood when you have done some parts of AI to some other so that we can see how they fit together.

(Refer Slide Time: 02:30)



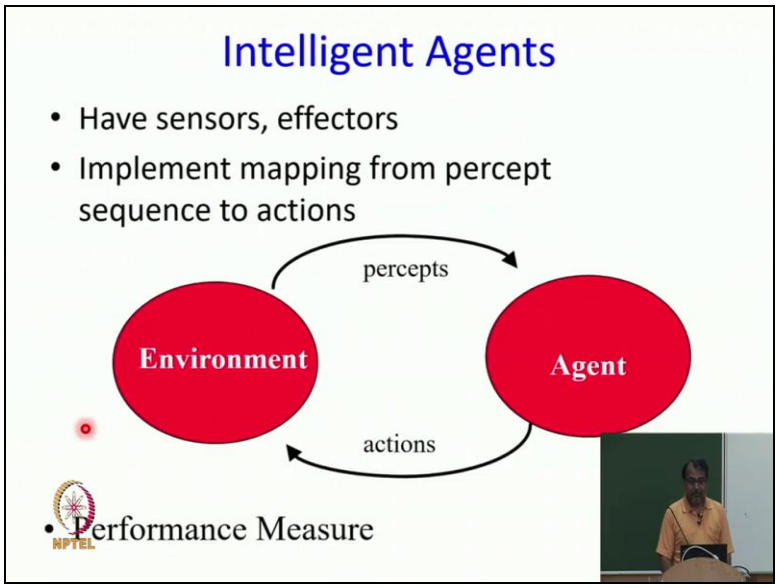
This is what you do today. I will talk again about agents and environments and rationality, which is what we had come up with acid definition of AI. And then we will talk about the various kinds of environment types. And we will try to see what we have studied how it fits together in different environment types and different Agent X.

(Refer Slide Time: 02:49)

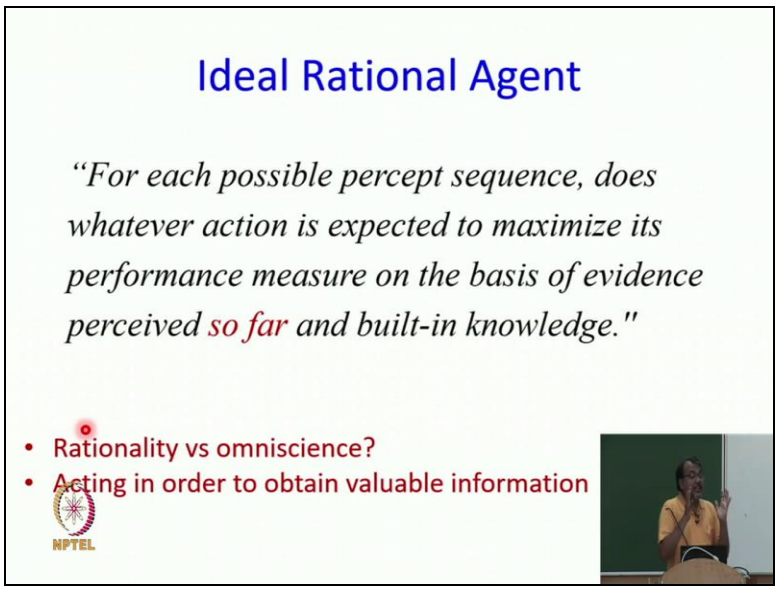


This is our goal it is not it technical lecture today. But it is a lecture where is important to take a step back and think about in a big picture, where are we and then we will come back to again something specific that we will study starting in the next class. Now if you go back how we define an agent? We said the agent is anything that can be viewed as perceiving the environment through sensors and acting upon the environment through actuated.

(Refer Slide Time: 03:17)



(Refer Slide Time: 03:23)



To the definition of artificial intelligence we had even defined AI like this we said acting rationally, remember we said we are acting rationally and our definition of acting rationally was to say that ok I will have a rational agent. It will be observing the world it will be observing in the world through an observation sequence of a percepts sequence. And then it have some opportunity it will take some actions rights.

And this action would be one that maximizes its performance measure optimizes its performance measure on the basis of evidence perceived so far and on the basis of built-in knowledge. So, if

you think about this in this definition of AI the idea that AI is an agent in environment observing the environment and acting in the environment is central. And this observation or observing the environment will happen to its senses through the perception will be observed sensors.

And the actions will be taken to its activator. So if you think about humans we are agents to in this world. What are our senses? Sense organs eyes, ears, skin, and tongue, smell nose and water our activators. How can we change the environment? Through our limbs, I can hold less Mike through our voice I can say something in the world and so on. This is we as an agent of course we can have a robotic agent.

Robotic agent as different set of sensors a different kind of actuators like it may have various motors for actuators it may have camera and Laser range finder as sensors. So, we can think about an organism on an agent as the central entity that the AI system is the brain for.

(Refer Slide Time: 05:35)

So, many kind of agents AI system is typically controlling, so like physical agent likes and intelligent building. A building which automatically turns is AC off when it sense that nobody in the room. A building that automatically opens the door when it sensors that somebody wants to cross the door. A building that automatically reminds you that you have left your wallet, but you are going into the car service should meet your driver's license.

A building which has all kinds of instruments and gadgets built in which can talk to each other and actually can exercise intelligent. Such kind of intelligent home are getting built not necessarily in India but definitely in the west. You must have heard about nest. Some of you know about nest? Nest is this automatic temperature control device which maintains the temperature of your home and it is sort of senses what to do, it has something built-in, but then increase its temperature, it gets a little bit of data.

Decrease its temperature it gets a little bit of data. It starts to learn that you will leave from office at 11 o'clock to come back home at 7 o'clock you know on the weekends you have this kind of behaviour at etcetera and it automatically maintain those temperature schedules. You do not have to feed it in like this and intelligent temperature control system. Autonomous space aircraft or even aircraft all have this autopilot mode.

Now we have intelligent driving cars they also have an auto drive mode rights. You have spacecraft which are deciding what to do in something in the sense of when something is failing how to deal with it and so on. In fact at NASA some of my old collaborators had done something very awesome where they said that if suddenly there is a problem in the aircraft. Likes this is not working that is not working and so on so forth.

Let say limb is not working. One of its rotors is not working. It cannot maneuver in a standard way. How do you get it to land? Emergency landing how can you create automatic algorithms which can get the aircraft to land and their; they figure out that ok based on the turbulence based on it may not be able to go in straight line. It always be going into curved line based on the specific fault that happened in the aircraft how do you get the aircraft to land.

And pretty amazing stuff but not all agents need to be physically grounded. Some of them can be digital and soft too like just general idea of expert system. You go to the machine say I have this symptom this symptom. This is symptom and the machine figure out what disease is you may have and your course of treatments. Here it is this is not an agent which is sort of acting in the world, physical world is an agent which is just getting the data as you may be speak in terms of a signal as you type maybe in terms of text.

And that is sensors and its actuators. Its actuator is what course of treatment it gives you. Google is one such example. Its sensors are the keywords that we type and its effectors are the 10 blue links it provides. IBM Watson is another example of this, where a new question comes in and it has to give answer. The box or the agents need not be physical they can also be virtual. An intelligent agent not only has sensors and actions it also has a performance measure.

It should strive to do the right thing and a performance measure is the objective criteria for the success of the agent behaviour. And that let us to the definition of AI where the agent wants to maximize optimise its performance process. But it can only optimise it based on what has been so far. It does not need to know what does not know. We cannot predict the future. The agent and AI system is not an astrologer.

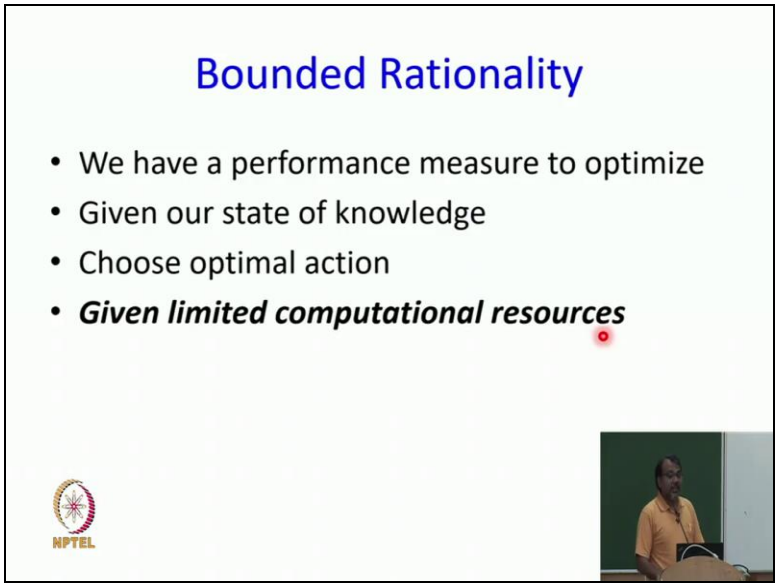
It may have a probability distribution about what happens in the future, but it does not need to explicitly know what is going to happen how the cards are going to played. It does not needs to use some built in knowledge and this built in knowledge will be the present in our knowledge representation language. So, this was the point, it has to be rational but it does not have to be Omniscient right. It does not know something it makes the best decision based on what it knows so far.

It gets to know something new that does not make a decision wrong. It may even act in order to obtain valuable information. It may make an action which does not change its performance measure, but it gives it some information about the world which then leads to its performance by increasing long term. Now this is the ideal rational agent. This rational agent we cannot construct a AI system because the problems are NP hard.

They are problems which cannot have a polynomial solution. Today there are problems which will if we want to have an ideal optimisation of the performance measures. It is just go on and on in all over finish or the memory will be full or something like that. This is the idealism this is the definition of Intelligence. It is the Pinnacle it is the optimisation of the performance metric in a

given setting. But in practice the agent will be what is called bounded rationality. It will have bounded rationality.

(Refer Slide Time: 11:31)



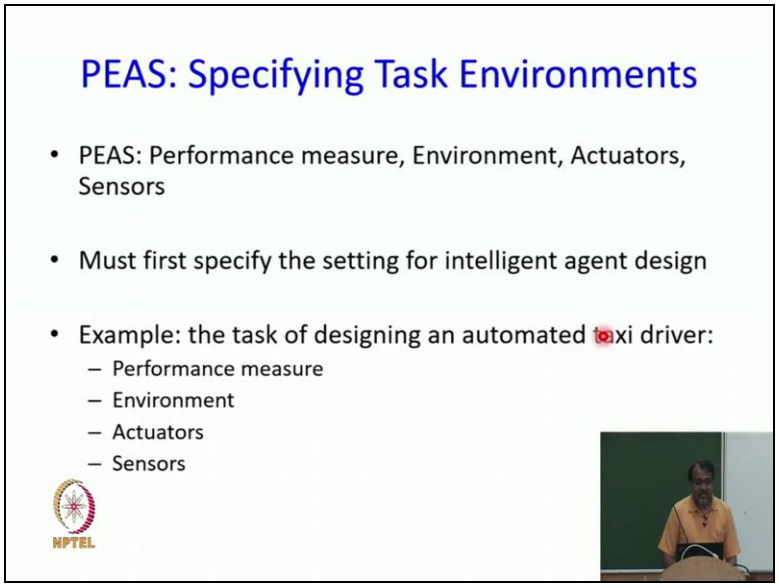
It will be optimising the performance measure given its knowledge and choosing the best action so far, but given limited computation resources. It will have a let say 1 minute of time to play the game. It will have 2 minutes of time to come up with the solution. It will have 4GB memory or 8GB memory. Given some limited computational resources. So, this is sort of how AI system thinking about themselves. Now given limited computational resources we are never getting the optimal in general.

So, a better a more intelligent system will be one which gets to a better performance compared to the other and that is why we will have rankings of AI system. It is no different from the chess ranking. Every chess master, grandmaster, regular player they have some ranking. They have some score and that is what tell us how will they are playing the game. This is also true in tennis. They have ATP rankings so on and so forth. This is the current state of how well the tennis player is playing.

In the same way in a given situation and AI system will produce some performance measure. And based on how well how good the performance measure is you can rank and you can say the system which produces better performance is more intelligent. Now given a new setting given a

new organism given a new agent it is worth thinking about for an AI system what is the performance measure. What is the environment? What are the actuators and what are the sensors.

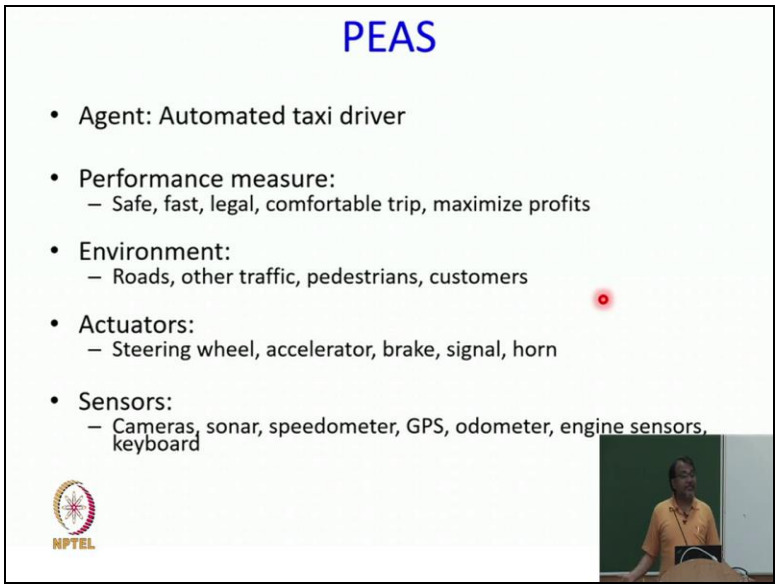
(Refer Slide Time: 13:17)



This helps us in intelligent agents design. Let us think about for example in automated taxi driver what is it environment? For an automated taxi driver, what is the environment? The roads, the pedestrians, the trees, what are its sensors? The camera then it may be the infrared or the laser range finder what else? What else sensors might have? GPS very good. A sound recorder for talking to the customers, just get a sense of how much traffic there is maybe noise can be indicator that is interesting and so on.

What are its actuators? The break, the gear, the signal, the horn whatever it is those are the actuators. Now what it is performance measure? How you human driver drivers? Kashi does that, that is a performance measure that I want but I need to go somewhere also, number of accidents accounts to optimize for those, hopefully not maximize. The total time taken in the trip. How much it follows the traffic rules and so on exactly precise.

(Refer Slide Time: 15:07)

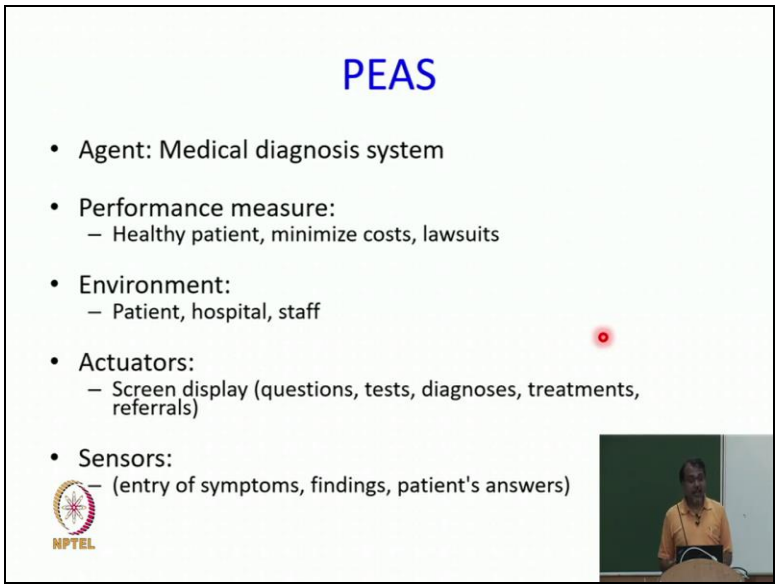


So, you can actually list all these things. And it is easy to think about the diamond actuators and sensors. But for the performance measure you are to be little more careful and you release them anything with a competing. And when there are many performance measures you think about how do I combine all of them to define my optimization problem. And many ways to do this one is to say that I will be legal. I will be safe and those are constraints, but I will maximize my profit or minimise the time and that will be optimization constrained.

That will be constrained optimization another way of saying this is that I have some penalty for being illegal. I have some profit and some dollar value for being in a profit and so on so forth. And I will add all of these and define 1 final objective function. And that will be converting multi-objective into a single unit combined object that compare and that will be another way of doing it. The third way of doing it is I cannot compare I will just try to come up with all solution that have you know that I am non dominative.

It is the third way of doing it which is called multi-objective optimisation we are not talking too much about it. If you do not understand what is non dominated we will have to go and read it but it comes up with the optimal set of solution. So those are 3 different ways have only a single optimization everything else is a constraint have create a single optimisation is a combination of all objective and third keyboard objective separate and try to come up with a set of solutions which are all good and cannot said as one is better than the other.

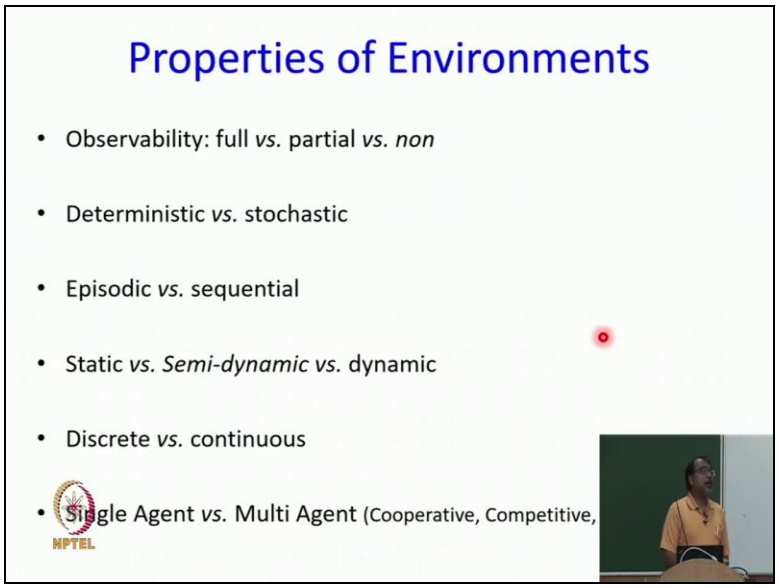
(Refer Slide Time: 16:47)



Similarly you can have a medical diagnosis system. In the medical diagnosis system your environment is the patient, hospital, the staff, activators are the display in which it will give you the treatment and diagnosis or the test. The sensors would be again the same keyboard and so on which where you will enter the symptoms. And its performance measure is for example having a healthy patient, but also minimizing cost and minimizing loss which is extremely important in health setup.

Now let us do little bit in the environment. What are the various properties of the environment? These properties are incredible important because they help us in figuring out what kind of algorithm to use?

(Refer Slide Time: 17:34)



One property is observability let spend a few minutes here. Is my problem is my space fully observable that I know at every point in time completely about everything in the world. Or is it just not observable at all, which is another extreme which is really the case or is it partially observable I can know something about the world, but I cannot know something about the world I do not know something about the world.

So, I know who all students are present today, but I do not know where the students who are absent. That is partial observable for the world for my class. Can you give an example of a world which is fully observable? Chess is observable I know the exact board position at every step of the way can you equivalent think of a game which is partially observable? Poker very good, pokar is partially observable because I do not know their cards. I only know my cards good.

Then environment is deterministic or stochastic? This is self explanatory when I take an action. I know exactly what is going to happen that is a deterministic world. When I take an action different things can happen with different probabilities. That's a stochastic world. Example of stochastic word is the robot trying to pick up this phone. It moves its sensors figure out what kind of shape the phone is, it gets its limbs together, gets its hand fingers and tries to pick it up with the high probability may be it picks it up, if it is a good robot with some probability it misses.

Or maybe it picks up and the phone falls down that would be stochastic world. Then there episodic versus sequential tasks, in episodic task is a one step task. I give you an image and I say is there a dog in the image. That is one step task you are not playing a sequential long-term decision game. Like I will give you a CSP and you solve it. That is a one step task. This is a solution.

On the other hand there are sequential task. Sequential task is I will take one task and then I look at what happened and then I will take next action and I keep playing this sequential action. So, if I have to output sequence of action, if I have to play a sequence of actions in the environment that will be a sequential task. If it is a one step thing, if I am doing face matching in figuring out is their face in there. Is there terrorist in there? That is the one step.

Then there are things where the environment depends on time, or it does not. Static environment versus dynamic environment, a dynamic environment is when things happen by itself without agent doing anything. Overtime the environment changes by itself. It is a dynamic environment. Like I don't know anything I keep standing somewhere and suddenly there is rain. This is the environment changing by itself.

Most physical environment whether the robot has to move around like an automated taxi driver. It is a dynamic environment taxi does not do anything the world still changes around it. The other cars to move, the cars do go the lights go Red and Green it is a dynamic environment. A static environment is when until the agent make such thing nothing changes. 15 puzzle, 15 puzzle is a static environment.

The puzzle pieces do not move until the agent tries to move it. And semi dynamic environment is an environment where the environment is static, but the agent performance measure depends on time. Like chess, in chess have you seen that the player place a move and you know when he hits the clock, stops his time right. Any kind of game give your total amount of time and your performance measure can change if you run out of time.

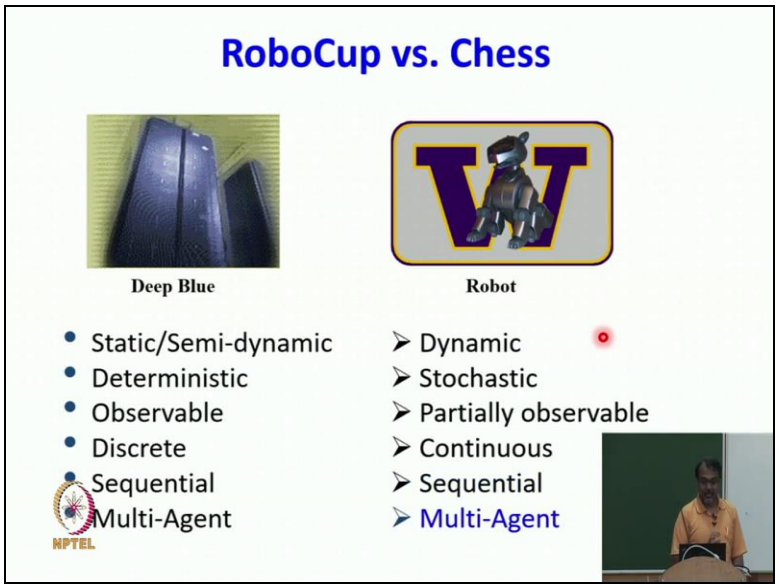
Even the environment has not been changed that is called semi dynamic environment. In such environment is important to do meta reasoning. It is important to think about how much to think. And say that if I think more I could possibly get a better move, but my time is running out. Let me not think more and stop thinking and makeup move and stop my time. That would be behaviour in semi dynamic environment.

Of course the environment is discrete or continuous. Whether it is continuous variable or it only has discrete variable and it has both they are also called mixed discrete continuous or hybrid environment. And last but not the least is there only one agent? Are there many agents? And if there are many agents, are acting together for the same objective or they acting against each other or are they just self interested they can be cooperative or competitive depending upon situation.

What are humans? They are self interested. If you hear the word that humans are always selfish. That means exactly the same thing they have their own optimization function that is what they are optimizing and of course they are doing long-term optimization. Sometimes he will do something for his spouse and sometimes they do not want to do it for the long term happiness of the marriage. You do not have that experience will soon have in few years and I am pretty sure many of you.

Whereas in chess its competitive agents and in; if you have a set of robots who are trying to manage disaster then I think they will be collaborative they will be cooperative.

(Refer Slide Time: 24:17)



Let us quickly thing about it. So, chess versus robot, is chess a static environment or semi dynamic environment? It is semi dynamic environment. It is it a deterministic and stochastic environment? It is deterministic. It is observable or partially observable? Fully observable. It is discreet or continuous? It is continuous. It sequential or episodic? Sequential. It is a single agent or multi agent? Multi agents 2 agents acting against each other, so, that is your chess environment. Now think about a robot which is trying to play soccer.

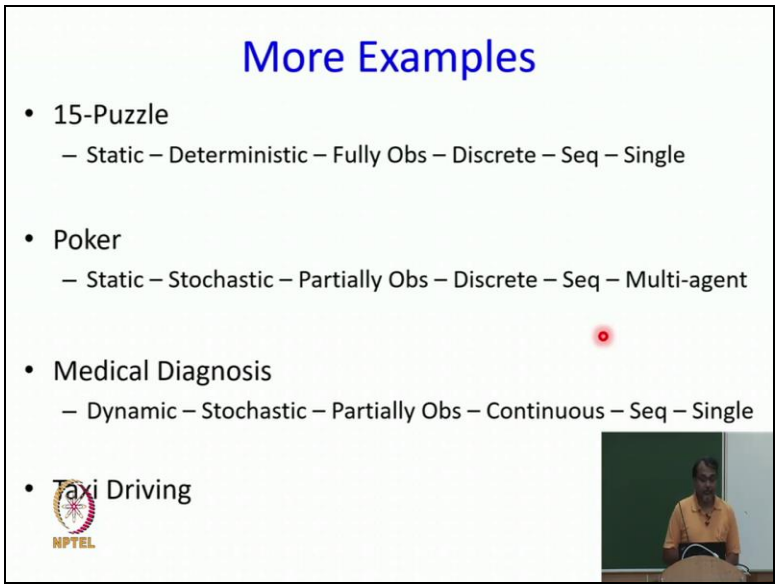
Is it a static environment or dynamic environment? Dynamic environment, the ball is moving. Is it a deterministic or a stochastic environment? Stochastic environment, you hit the ball the ball is gone somewhere else use saw those videos with that was trying to do interesting things. Is it an observable environment or partially observable environment? Partially observable. Why? The ball could be behind you, you may not have sensors.

Even though you may have sensors? You may not exactly know everything because you are answered in the sensors. Is it a discrete environment or a continuous environment? It is in the physical environment so it is continuous. It is a sequential game or a parasitic game? Sequential to take a sequence of steps you want to get a goal. Is it a multi-agent or a single digit? Multi agent. So, now, you can start the see how different environment make the problem more easy or hard.

Chess is a not an easy problem but it is much easier than robot soc. Because it does not have to deal with dynamic environment, it does not have to deal with stochastic environment, it does not have deal with partial observability, it does not have to deal with continuous spaces. It is a much easier environment even though it is a very hard environment. And you can now come up with more examples. So, one of the significantly easy examples of 15 puzzle. 15 puzzle is static or dynamic? Static, deterministic and stochastic? Deterministic

Observable or partially observable? Observables, discrete or continuous? Discrete, sequential or episodic? Sequential, multi-agent or single agent? Single.

(Refer Slide Time: 26:59)

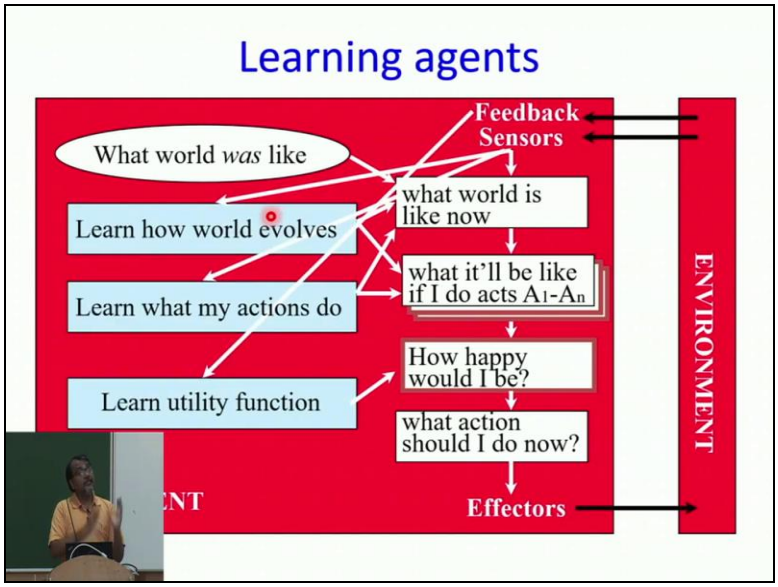


So, the only complexity it has is about sequential and you can keep going further and further medical diagnosis for example is a dynamic environment because a body is constantly reacting to things that are happening even though you are not a new medicine. It is a stochastic environment and you do not know exactly what the effect of a certain medicine would be. You do not know everything about the world but it is a single agent and so on.

Why is medical diagnosis is single agent and depending up on what I am modelling in the world? What time modelling is what should I suggest next to the patient and in that sense I am really agent that is in the human is environment. The next thing we have to do is think a little bit about

how do we make such an agent? And what are the principles and the architecture of making such an agent?

(Refer Slide Time: 28:11)



And each such architecture the one thing that is going to be common is that they will be the brain which is the big red box here. So this is the brain the big Red Square and then they will be the environment. And sensors are going to give us information about the environment and effectors or actuator are going to change the environment. And the agent is going to output taken the sensors and output the actions.

But how we model this brain tells what algorithm we can use? For example let us say I model the only this much in the world. I have the sensor which tells us what is the world today at this moment in time. Let us say I make some rules if this then that. Let us go in the order of the rules. First one fires output the actions. If it does not fire go to the next rule, if it fires output reaction if it does not go to the next rule.

Let us call it a decision list. It is a list of decision based on some conditions this is what we will call a simple reflex agent. An agent which is just reflexive with making taking rest reflex action. Think about how when we take a reflex action does it fit in the paradigm. What is the simple reflex action we can think about? I touch hot plate and without thinking much I quickly remove my hand as a reflex action.

Does it fit into this paradigm? We are not concerned about whether it is the; is it am I making khichdi and am I making roti? I do not care for whether it is on the gas stove or it is on a boil hot plate and many things I do not care for. I only care for this one condition if it is hot. Can I take the action remove the hand that will be a simple reflex agent and this reflexive agent also has a role to play in real robot.

Can you think of one example? I thing I have discussed this sometime back very long. Can you think of an example where you have to put in the small reflexive agent for some specific behaviour? Obstacle of avoidance my robot a drone is moving around and the drone suddenly see something it is going to collide with and the drone say backup. This behaviour is a reflexive behaviour is not a deliberative behaviour.

Deliberative means it is thinking carefully about the outcomes and everything in the making a call. It is a reflexive behaviour and it also has a role to play in the design of a physical agent. Now of course we can make this reflexive agent slightly more interesting. We can say that it can keep some history about what was the world in the previous step and the new information and based on that it can make some inference about what is the world right now?

And that will be a reflex agent with internal state about the behaviour of the history so far. And notice this part which says what was the world like what is the new information and what is the world now is an inference step? This inference step can be done in a logical framework if the world moves deterministically or it can be done using a Bayesian network in the world move probabilistically. Like I get a new sensor reading and I had some uncertainty about whether the obstacle is 2 metres away 3 metres away.

And let see my new sensor reading is 2.1 metre based on that I change my probability distribution of how far the obstacle is? And that kind of reasoning is an inference step which I would do for sensor readings based on what the previous understanding of the world was how the world evolves. In this case it does not evolve obstacle remains at its locations and what the

world is now. It is still a reflexive agent because the choice of taking action still being done by the condition action rules.

By the way this condition action rules are extremely important in the world. I have been told in many government agencies this is what they implement. Like if they want to flag you that you have not paid income tax. They do not want to flag all the people who have not paid income tax. Or they want to flag you for you paid your income tax very low. So, then they will have some rules. Like if your income is greater than this much amount and if your income tax is less than this amount and if income is in this kind of activities like shop owner but not salaried etcetera.

Then they will flag you and say you have paid income tax too little give us all your paper. This is just a set of rules that the system is using to take decisions. This is something that you would apply again and again in realistic settings. But of course, we want to go beyond this. We want to have a high level understanding of what is our objective and have the system come up with the best action based on the high level understanding.

And such agents can be the goal based on utility based. And think about which agent we been working on? So for 15 puzzle is it a goal based agent and utility based agent? Goal based agent. For chess it is goal based agent or utility based agent? We use the utility based agent because we have to do cutoff and we have to come up with the utility of the leaf node or the cutoff load. So, we will have a goal that we want to achieve a goal based agent.

We will also have this understanding of what the world was like how the world was but understanding of what my actions do, if I take a certain action in a certain state what will be the world and you can extrapolated to say if I do a sequence of actions how is the world evolve? Whether I will reach the goal or not and then based on that I will figure out which action do I do now. All the original search based method that we did A star and DFS, BFS etcetera all fit in as a goal based agent.

It is a goal there is a deliberative process which tries to figure out which sequence of actions can take me to the goal based on that I will figure out which action do I do now? We can also have a

utility based agent and in fact in the coming weeks, we will only talking about utility-based because that is sometimes felt like a generalization. In the real world you and I do not have a goal per se.

Our goal is not like we want to be we want to make 1 crore rupees. Our goal is more money we make that is better it is. That is not the goal, that sort of like a utility that the money will make you will get some utility from the money. And then how much happiness we get we get how much health we get everything is a number not; it is not a discreet binary, yes, or no, it is sort of more and less and all of those are the thought of us as utilities.

In fact, there is a lot of psychology theory which says that humans have some reward built-in and we will talk more about when we talk about Markov business processes in reinforcement learning which is going to come up next. So, this would be utility based agent everything the same we do not a goal to reach we have a utility to optimise. Everything else is the same process except instead of saying whether I will reach the goal or not if I take a sequence of actions.

I will ask if I take would take a sequence of action would I be happy or not in fact I cannot say would I be happy I would say how much happy would I be based on the utility that I have and that is my utility based agent. Notice that in everything I sort of know how the world evolves I sort of know what my actions too. This is true for chess this is true 15 puzzle. But you may have an environment where you do not know everything.

You have to learn about the world think of yourself as a baby you do not know the environment. Think of yourself about you have just been put in a new city. You are gone tourism and you have been put in a new city. You do not know all the road. You do not know everything you learn. You try restaurants to figure out where to eat food etc. There you will be a learning agent and agent which not only things about how the world evolves which is given to it but also learn how the world evolves.

Does the action that can observe the change learns about how the world evolves. Learns about what its action do, you know little babies do not even know that this is their hand and they

control. They slowly learn this is hand and they can scratch themselves and learn the utility function, which is very interesting give data so that you can learn what you should be doing in the first place. You know utility function has been formed over time. It is still developing as you come in interaction different people. It evolves a little kid utility function is only I should get food. I should get sleep, my bottom should be cleaned.

That is the only utility function that you have at the time. As you go old that is the utility function still has this three components but has more. So, we learn all the phenomena and that is what makes a learning agent. And we have done two small examples of learning one in the case of learning utility function for Chess or games and one in the case of learning Bayesian networks probabilities based on data.

But you will do more we will do reinforcement learning now in a few weeks and that is when you will really learn what is the transition function of the world? What is my award function would all those would be learnt from the environment. So, in terms of where we are in the course. Now I should end this class in terms of where we are in the course we have done a lot of this goal based agent in a deterministic environment.

We have done a little bit about utility based agent in adversarial deterministic environment. We also talked about how the world was and what my actions do and that kind of reasoning in both deterministic environment as well as probabilistic environment. Now, we will work on building this agent. Utility based agent which know how the world evolves which knows what its actions do has a utility function its a stochastic environment.

And later we will extend it to utility based learning agent where all the things would be learnt. This part will be done through Markov Decision Process which is the next thing we are going to study and this part will be done through reinforcement learning over Markov decision processes. So, that is our part this is the piece of the course that is missing. A lot about deterministic environment and decision-making there we have talked about knowledge representation inference in both deterministic and stochastic environment.

Now you are going to decision making in stochastic environment. Let us stop here and the next class will start talking about decision theory. Thank you.