Artificial Intelligence: Search Methods for Problem Solving

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Lecture – 01
Prologue

So, welcome to this online course on Artificial Intelligence Search Methods for Problem Solving. Now, this course has been running for quite a few years and we have had quite a few participants in this course, but since a last recording was done about 5 - 6 years ago we have started with some fresh recordings because things have change the little bit and also we have made certain things more essentially. This recording that I am doing is in this very difficult times in the times of corona virus and you can see that I have the mask which I use when I came here and so, I hope you are all protecting yourself well as well essentially.

So, what we will begin with now is an introduction to the course which I have called as a Prologue because there is a longer introduction which we recorded the last time which consisted of the history of AI and the philosophical aspects and things like that and that has not changed too much.

So, we will just reuse some videos there in this video I will introduce you to some of the changes that have happened in the last 5 - 6 years because AI as you probably know has become a buzzword in the last couple of decades and specially in more recent times and we will look at some of the issues that are there.

After which we will do about 5 videos of history and philosophy which are carried over from the last recording of this course and when it comes to the technical method the entire course is rerecorded this time I have used slides and animations and to talk about the subjects as compared to the last time when I was teaching a live class and we had lessons on the blackboard and we had students interacting.

So, let us begin with this first talk which I have called as a prologue because it has been recorded in some sense after the rest of the slides have been recorded then this kind of puts a whole thing in picture essentially.

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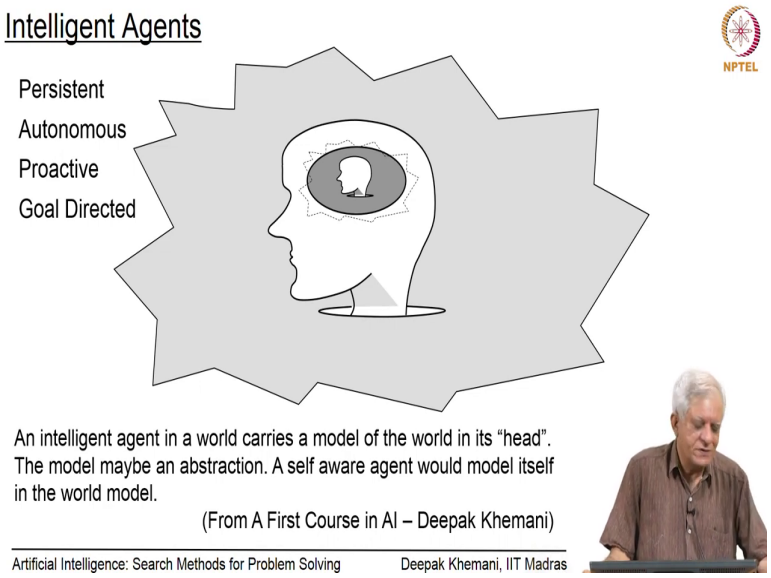

So, we begin with the basic idea that our goal in AI is to built intelligent agents and what are intelligent agents? Intelligent agents are essentially programs as far as we are concerned. The programs may be residing in physical entities like autonomous cars or robots, physical robots or spacecraft or all kinds of things, all kinds of machinery that we use, but our interest is in the programs which control those machines essentially.

And we will use the term agents and programs synonymously and agents are essentially programs which are persistent which means they are alive all the time which are running all the time unlike most other programs where you say you run this program and then you get the output, it is not like that this programs are running all the time. They are autonomous that you

know they do not take too much input from the users and they unless of course, there is some activity in which input is required.

But otherwise they run by themselves, they are proactive they make the own decisions that have to be made and their goal directed in the sense that they have certain objectives that have to be met essentially. Typically these objectives are given to these programs by the users essentially. So, an intelligent agent in a world carries a model of the world.

So, if you have to reason about the world that you are operating in whether it is a physical world or whatever it is a cyber world or whatever the case may be you have to represent it in some way some people call this as domain representation. We will just say use the term that we carry a model of the world in which you are operating and this model of course, may be in abstraction you cannot capture the real world in its entire detail. So, it is always abstraction models are always abstractions and the abstraction is done based on what is the purpose that you want to achieve.

Now, one thing in AI is that we do not often write programs for a specific task. So, there is an entire world which needs to be explore this entire area of knowledge representation which has to be explored which is still in its infancy, but we will not get too much into that. We are more concerned with problem solving here and what we would assume is that an agent a self aware agent would make a model of the world and it would also have a model of itself in the model of the world.

So, for example, if this is the world and this is the agent in the world then inside the agents head if you want to call it the head is a model as you can see the model in this case is an ellipse which is not quite the original world that it is representing, but it is an abstraction it is a model and inside their model it may have a model of itself essentially.

So, a there are areas where in multi agent systems in areas where for example, humans have to interact with robots, the agent should be knowing that it is there in the world in which

activities happening and it should be able to reason about its own actions and actions of other people.

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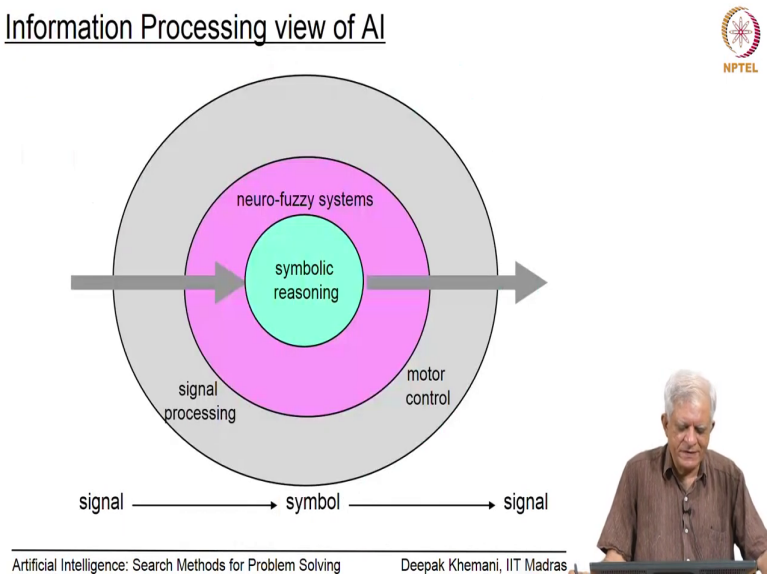

The information processing view of AI which has been around since the beginning of AI is that we sense a signal. So, for example, as human beings we have eyes and we have ears and our nose and our sense of touch and things like that and what we get from the outside world is a signal and at the inner core of thinking of cognition of reasoning is what we call as symbolic reasoning essentially. Our concern in this course is on symbolic reasoning, but to interact with the outside world we have to convert the signal into symbol and very often this is done by neuro - fuzzy systems.

So, for example, neural network 7 example which can for example, recognize characters, recognize people, recognize faces, recognize objects and things like that. So, that once we know what are the objects we are talking about we can work with the might a symbolic level.

So, the whole process is a layered architecture at the outermost layer we do signal processing, then the signals are converted into symbols using a neuro fuzzy process and whatever decisions that you take they are again actuated in some form. For example, you may move an arm or robot may move go from one place to another or you may show certain graphics on a screen and so again you produce signals essentially ok.

So, it is you start with signals you process convert them into symbols do the reasoning generate the desired output and send a output out as signals. So, that is a generally the information processing view of AI.

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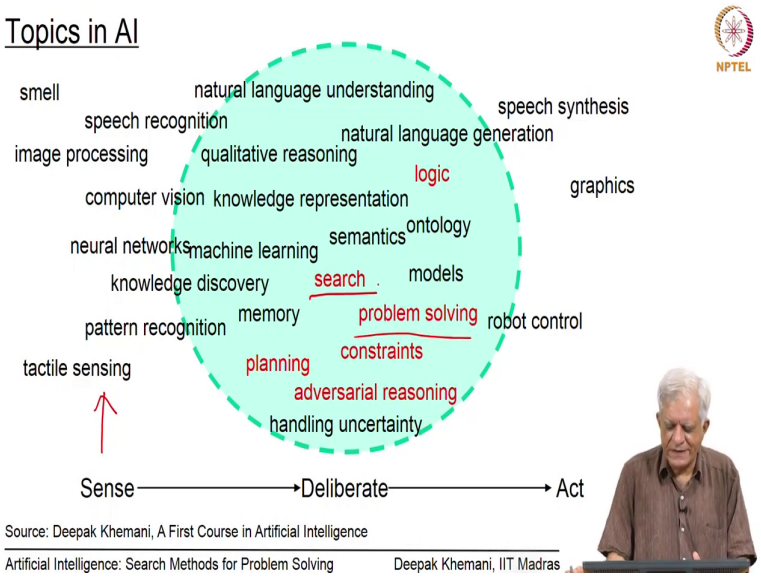

This is something that we will revisit when we talk of the introduction that was recorded 5 - 6 years ago and AI is a very broad field, it contains many areas as of now.

So, this diagram is supposed to go together with the previous diagram previous diagram if you remember we had the signals coming in from the left and the actions going out on the right. So, we follow the same topology here and we assume that all the activity which is to do with signal processing is shown on the left side of the screen.

So, speech processing, image processing, computer vision, neural networks, pattern recognition, all these stuff is in some sense part of AI nowadays and in the in the circle inside here is what we called as the cognitic activities, the thinking activities, the reasoning activities

and so on and that is a focus of symbolic AI it itself has many areas. So, it has thing like qualitative reasoning, knowledge representation, ontology and so on and so forth.

And what we are seeing here in red are the things that we will cover in this course. So, title of the course itself says problem solving using search methods. So, these two are the topics which are there, but there are other things that we will look at for example, planning and constraints and adversarial reasoning which means multi agent reasoning or games as far as we are concerned and a little bit of logic essentially.

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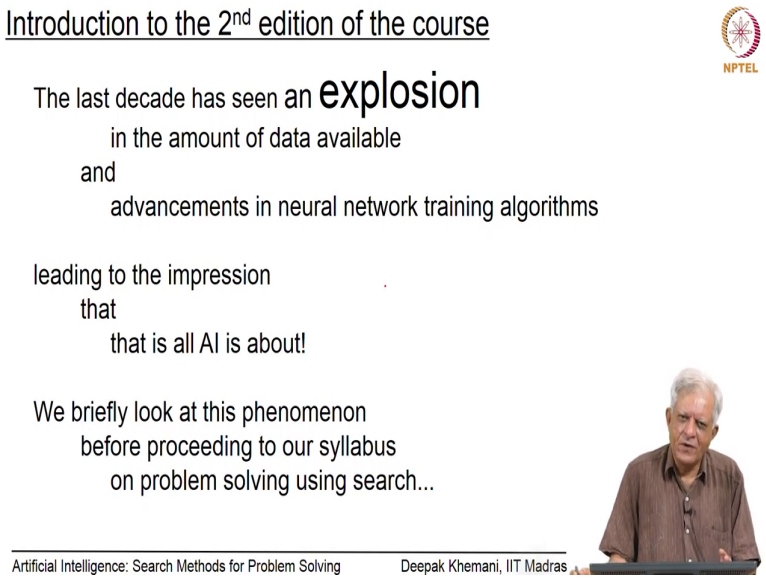

This is a second edition of the course as I said we have already been running this course, but much has changed since 2013 - 14 when I recorded the lectures last time and what has happened is that there is been an explosion of the amount of data that has been available to machines and advancements in neural network architectural training algorithms. And somehow

it is created the separation among some people that is all there is to AI that neural networks or deep neural networks or deep learning or data science is all there to AI.

We will briefly look at this pictures just to put everything into perspective and I must repeat again that this is not the subject matter of this course, this course is to do with symbolic reasoning I am just trying to highlight the fact that symbolic reasoning is an essential core component of AI. So, we briefly look at this what has been happening in the last 6 odd years since we last recorded the introduction. And we will kind of comment on that a little bit and so in that sense this is a second edition of the course that we are doing essentially.

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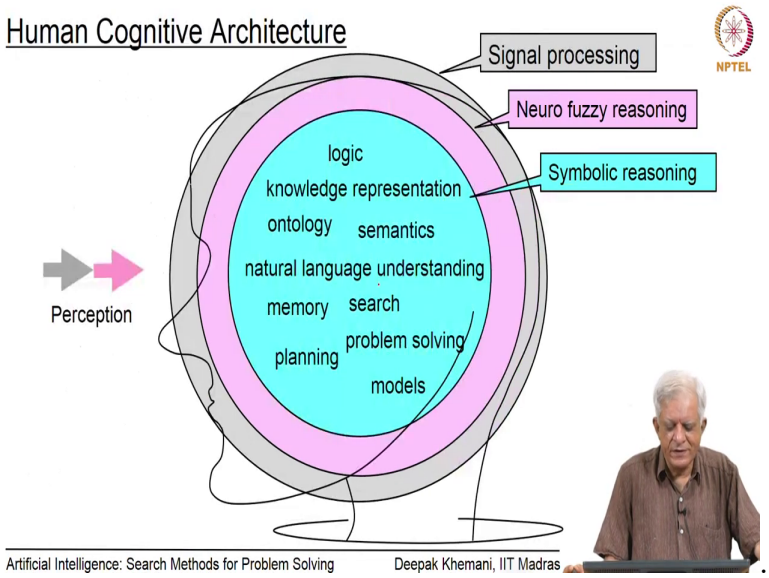

Now, coming back to this the cognitive architecture, if you are thinking of human beings which is kind of suggested by the fact that we have a human face drawn here most of the

cognitive activity most of the thing that we ascribe humans to be intelligent or we say that humans are thinking features are all contained in the inner core of symbolic reasoning.

So, the topics that we can see here logic, logic knowledge representation, ontology, semantics, natural language understanding, memory, search problem solving, planning, models all this is part of the inner core of symbolic reasoning where everything is represented using symbols. We will look at this whole idea of symbols and the physical symbol system hypothesis which Nuel and Simon had given in the introduction which will follow this lecture.

So, I am just trying to put everything into perspective here in human beings the inner core is the most prominent as kind of suggested by this figure whereas, the perceptive activities of signal processing in neuro fuzzy processing for human beings is not the prime consumer of our energies or cognitive energies if you want to use a term like that.

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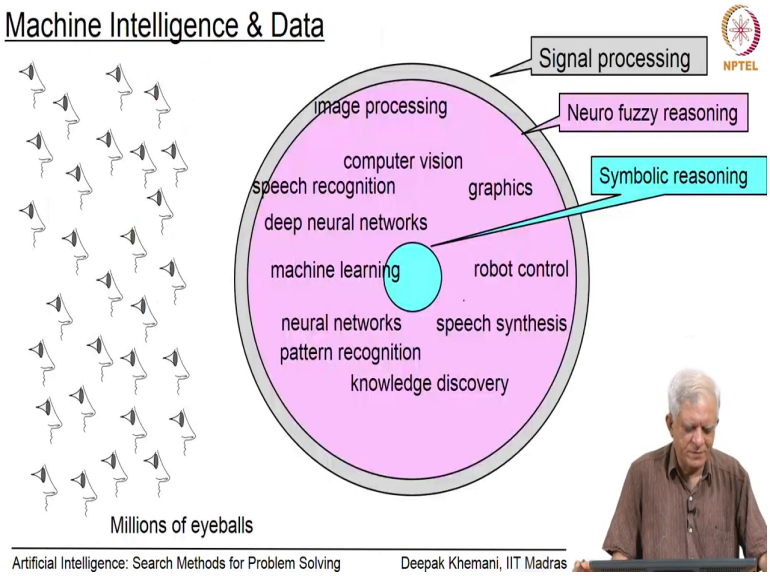

Now, on the other hand what is happen in the real world thanks to the explosion in the internet the fact that we have big fat companies which we interact with that they give us tools to interact with other people we have social media, we have Google, Facebook, Amazon all kinds of centralized entities which we interact with in order to interact with the rest of the world. So, if you are talking to somebody on Whatsapp, Facebook is a wave that that you are talking to somebody in Whatsapp.

So, all these companies are very keen to figure out what are you doing, where are you going, who are you talking to, what are the kind of websites you are visiting, what are the kind of things you are buying and all this kind of stuff. So, that is kind of illustrated in this diagram that you see millions of eyeballs which are interacting with this kind of intelligence, but what this kind of intelligence is doing is essentially data processing, data science, some people call it machine intelligence.

So, it is doing things like using neural networks to figure out what you are looking at you know labeling images and all these kind of stuff. So, what is happening in the world of machine learning and data science is largely neuro fuzzy processing. The internal core is still very tiny they are not able to reason symbolically and we will kind of talk about that a little bit in this talk here.

So, that is a difference between what is happening with humans, we have a large core of symbolic reasoning whereas, machines are prominently doing neuro fuzzy reasoning when they are processing tons and tons of data essentially.

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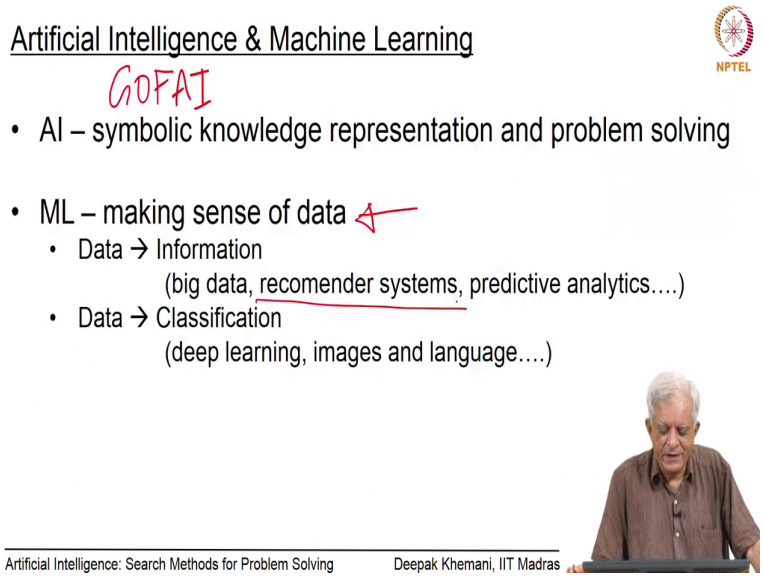

So, we can add this point distinguish a little bit between artificial intelligence and machine learning though of course, machine learning is a part of artificial intelligence because nowadays we use some a term artificials for almost everything that machines do including making sense of data which is what I would like to call is machine learning.

So, machine learning is essentially making sense of data whereas, what we call as AI or some people called as good old fashion AI GOFAI Good Old Fashion AI is to do with knowledge representation reasoning problem solving and things like that essentially. So, we will at least in this course when we talk about AI this we would mean this symbolic AI or good old fashion AI whereas, machine learning is making sense of data so, either you have lots of data and you extract some information from it.

So, for example, recommender systems they if you are buying stuff on Amazon, on Flipkart or something they are watching what you are buying essentially and even then they are trying to see persons who bought this book for example, also bought that other book essentially. So, they are trying to make sense of the data that they are gathering from you remember this figure that we talked about millions of eyeballs.

So, you can imagine this circle here is Flipkart or Amazon or Google or whatever is your favorites web source and they are looking at what you are doing and they want to make sense of what you are doing largely and to kind of drive the advertisement, but sometimes they do other nefarious more nefarious things as well essentially. So, that is one side of machine learning which is making sense of data, looking at data and you know trying to extract information from it.

Another sense is classification, which is also trying to extract information on data, but it is most specific in the sense that you want to give a class label to thing, you are looking at an image and you are saying this is an image of a horse in a meadow. So, you should be able to label it by saying that this is a kind of image that we are talking about or that this is an image of traffic in a urban environment.

So, these kind of labels which of course, the originally get from human beings because human beings are constantly labeling images on Instagram and Facebook and all kinds of places where we share images what these programs are doing is harnessing those shared images and learning from them. So, the kind of learning they are doing is classification that they can look at a new image and they can produce a class label which is consistent with what they have seen in the past essentially.

And largely deep learning which has been the buzzword in the last 10 years has been successful with image labeling and language and so on and so forth language processing.

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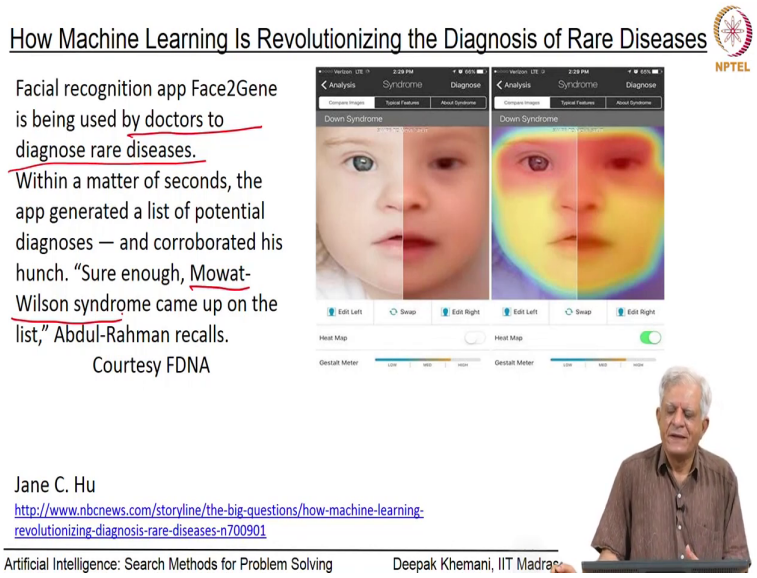

So, here is an example just one example amongst many where deep learning neural networks classification have been a tremendous amount of success essentially ok. So, this is a example of one such application which is developed for the mobile phone called Face2Gene and it is being used by doctors to diagnose real diseases rare diseases.

What is happens that, supposing you have a child who is suffering from let say the Mowat Wilson syndrome and, but you do not know of course, you know not every doctor is an expert in every specific rare diagnosis.

What machines can do is take an harness the information provided by thousands of doctors all over the world who are looking at images like this and saying at this is this ah disease or this is this syndrome and things like that and learning from that. So, this application called Face2Gene you take a picture of your child and upload it on to this app and immediately it will

give you a diagnosis about what the child is suffering from or not suffering from is the case may be.

Now you can see that this is a tremendous advantage for a humankind the ability to arrive at quick diagnosis and it has been one of the greatest successes of machine learning essentially. So, in the beginning of this year 2020 there was news from UK that machines have become better at identifying breast cancer than human experts essentially. Why is this possible? It is possible because these machines are making use of the data which has been extracted or curled out of the diagnosis given by thousands of doctors and machines can learn from that essentially.

So; obviously, it is a great advantage and in fact, I would go so far as to say that the diagnosis is probably the biggest pay of that machine learning is given to humans, but there are others as well.

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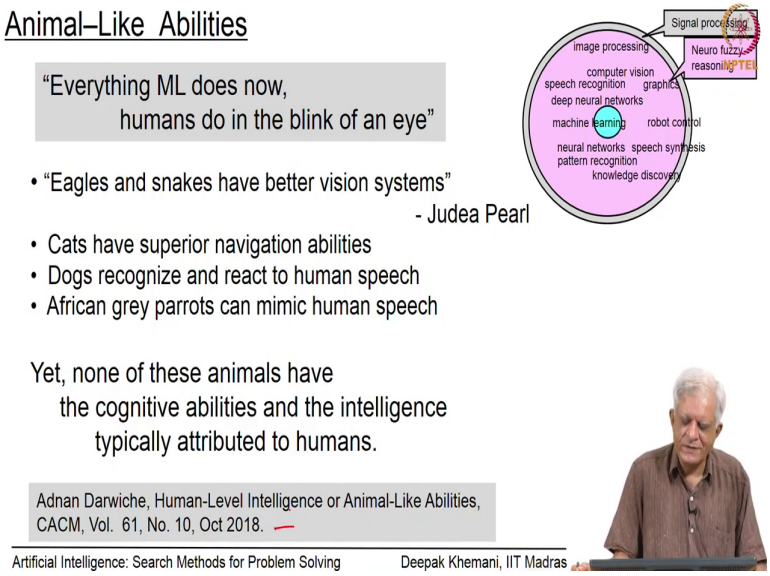

Now, since we want to kind of emphasize a fact that diagnosis or classification or data processing is not everything that is there to AI we are just looking at what may be missing from AI here.

So, many people have observed Stuart Russell for example, that where machine learning is powerful and you would do well to look at the diagram which I have reproduced here on the top right, which kind of says that the that machine learning or neuro fuzzy processing is the largest core of most current systems and of course, they can do things like diagnosis and image labeling and language processing as well for example, Alexa does it all the time.

But what they do and many people have observed this is that everything machine learning does now, humans do in a blink of an eye a doctor has to simply look at an image and be able to say that it is a case of cancer or not the doctor then take much time to do that of course, machines

also are becoming faster and faster, but they have to go through a process of training for every specific example we will see that essentially.

So, here is a nice article which I read on communications of ACM appeared in 2018 and it talks about the differences between human level intelligence and animal level abilities. So, I am giving you a few quotes these quotes are not necessarily from this author, but other people also. For example, Judea Pearl who has been well known he got the Turing award for his work on causality has also been talking about things like that and so, he has said for example, that eagles and snakes have better vision systems than human beings.

We are trying to contrast with what animals can do what machines are doing and what humans are considered to be intelligent for essentially. So, eagles and snakes are better vision systems we know that eagles can spot up wave from high up in the sky.

Cats have superior navigation ability you can leave a cat somewhere and it can find it is way home quite easily, dogs recognize and react to human speak as well as humans do, sometimes may be perhaps even more they are more sensitive to your emotions and I mean if you have a relationship with the dog if the dog is your pet and so on.

African grey parrots can mimic human speech. So, it is not just that humans can speak and of course, machines can speak for example, Alexa probably speaks to you if you have one at home ah, but parrots can also do that essentially.

Yet, none of these animals have the cognitive abilities and the intelligence that is typically attributed to humans. So, what we are trying to do is to kind of step back a little bit and say fine we are doing lot of machine learning and it has a great success and almost everyone wants to do machine learning, but there is more to intelligence then classification, there is more to intelligence and pattern recognition and things like that data processing.

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Now, Rodney Brooks who is also a well known person in AI he wrote this article called The Seven Deadly Sins of AI predictions in the MIT technology review he compares performances versus competences so, performance versus competence.

So, he says now suppose a person tells us that a particular photo shows people playing Frisbee in the park. So, when human talks human beings talks about people playing Frisbee in the park we create a much larger picture.

We naturally assume that the person can answer questions like, what is the shape of a Frisbee? So, those of you who have come into contact with the Frisbee or seen the Frisbee you would know that, roughly how far can a person throw a Frisbee? Can a person eat a Frisbee? Of

course, we cannot, but we can answer these questions essentially. I mean we cannot eat the Frisbee, but we can answer the question whether a person can eat a Frisbee or not.

Whereas computers can label images by saying putting a label that people playing Frisbee in a park, but then have no chance of answering the kind of questions that we have indicated here what is a shape of a Frisbee, how far can it typically throw a Frisbee. And the reason for that is the they have no idea about a person is they have no idea about parks are that, they are usually outside that people have ages there are young people and old people the weather and so on all kinds of things we know and we can reason in the context of that.

So, as I said creating a model of the world in which you are operating in is a goal that AI is working towards, but we are still some distance away from doing it at a general level also quoted by Rodney Brooks is Marvin Minsky.

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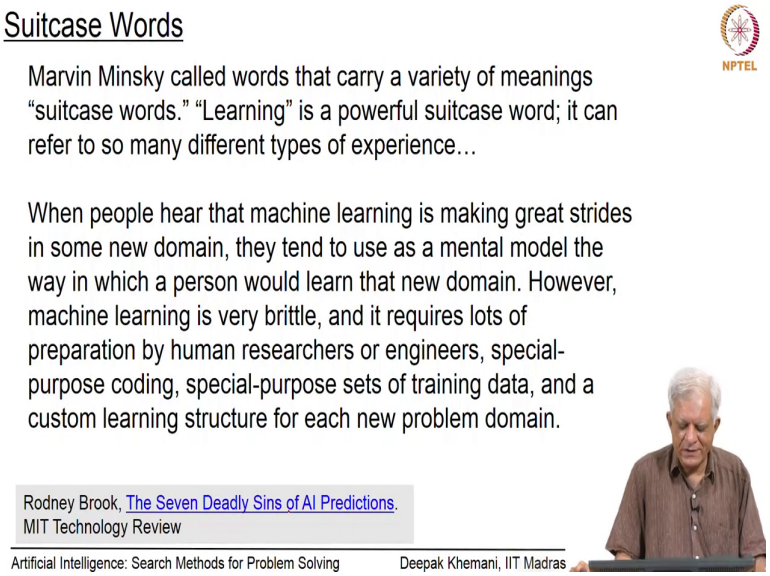

He said that there are certain words which he called as suitcase word essentially that they carry a variety of meanings. So, they are like suitcases you know in which you can pack many different meanings essentially. And he said learning which is of course; the big thing in the last 10 years in AI is a powerful suitcase word he says it can refer to so many different types of experience.

When people hear that machine learning is making great strides in some new domain, they tend to use as a mental model the way in which a person would learn in that new domain essentially. However machine learning is very brittle and Marvin Minsky is saying that and it requires a lot of preparation by human researchers or engineers, special purpose coding, special purpose sets of training data and a custom learning structure for each new problem domain essentially.

Whereas, what we are interested in is even when we interested in learning, we are interested in general learning when we are interested in AI we are called general interested in general AI essentially ok.

So, one has to kind of distinguish between what is useful and what is academically interesting essentially. So, many programs which can do classification may be very useful, but they may be using the same kind of network architecture. In fact, they may be using the software provided for example, by Google to train neural networks and doing a new task essentially.

So, that is a different kind of achievement it may be very useful, but does not necessarily make advancements into AI in the sense that we want to produce thinking machines essentially because that was a original goal of AI and as we will discussed as in the next 4 or 5 lecture when we talk about history of AI and the philosophical aspects of AI as well.

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Another great achievement in the last few years was in this game called Go. Now, those of you who have followed this and we will again look at the introduction in this we will see that computer games and specially games like chess and checkers and Go have always fascinated human beings because you know human beings are find this as a challenging task to play this game essentially and sometimes people used to say that if you can play good chess you must be intelligent and that kind of thing, but in 1997 when IBMs deep blue program beat Kasparov then people are saying oh it is just a program it is following the same old some you know predefined rules and things like that.

So, we start disassociating intelligence with games like chess, but Go was still considered to be a much harder game. So, as you can see from this diagram here the board is in the centre it is a brown colored board and at every intersection for example, here you could have place the

coin essentially and this dimension of this board is 25 by 25 which means that the number of choices available to any player is very large.

So, you can place a coin on any one of 25 into 25 available places and so, we thought that go is much harder to play and people is so associate the fact that it is popular in the eastern part of the world specially in Korea, in Japan and so on and perhaps that you know they have a different approach to thinking which is kind of tied up to Zen or Zen Buddhism and maybe they are doing a different kind of thinking based more on perception and less on reasoning and things like that.

So, we used to think that Go is a hard game and until of course, this company which was at that point in the UK company called Deep Mind with a team of 25 odd engineers they kind of worked hard over a few years. So, produce this program which finally, beats the world champion Lee Sedol whose picture is shown on the right in 2016 and it created great approval and a lot of publicity for AI.

In fact, deep mind went ahead and made a film on this topic and if you can get your hands on the film you can see that it is like a gripping feature film essentially not only that Alphago of course, learnt by studying the games of other experts human experts and so on.

But pretty soon they came up with an new algorithm called Alphago 0 in which all this experience that they were learning from was no longer required. And all you had to do was to give the rules of the game to the machine and the machine would play against itself repeatedly and you can you can imagine that machines are fast and they can play millions of games against itself and through a process which is called as reinforcement learning it could figure out what are the best strategies to play.

So, it turns out that in 2017 Alphago 0 comprehensively beat Alphago not only in go, but also in chess essentially. So, learning of course, has it is plus points provided that you are working in a well defined domain and chess and go are pretty well defined domains.

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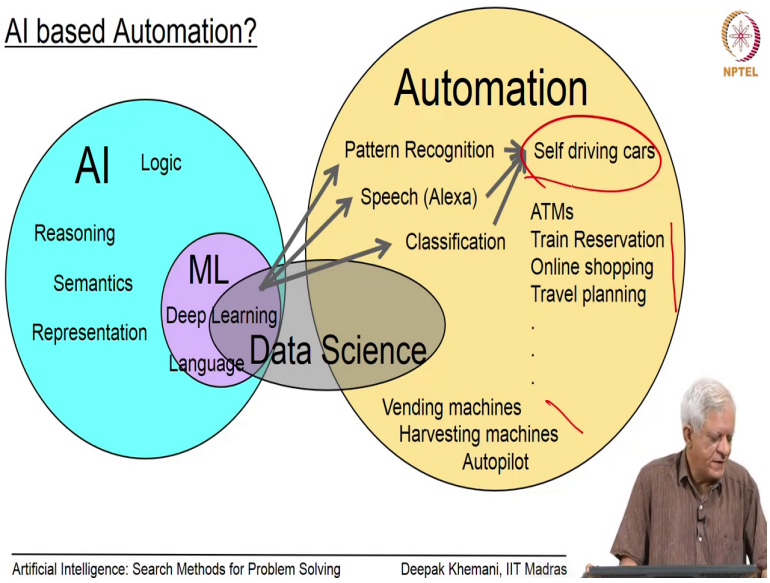

Now, we often confuse nowadays automation with AI and I would like to kind of emphasize here that they are quite different features you know, when we talk about AI, we want to talk about intelligent machines, we want to talk about logic and reasoning and semantics and representation and so on we also want to talk about machine learning, deep learning, language processing and so on. And we also want to talk about data processing because you know machine learning works on data. So, if you want to build an algorithm to learn a decision tree you have to learn from training examples.

So, data is the key there, but automation is a totally different cup of tea together essentially I mean you have things which have nothing to do with AI things like train reservation, online shopping, travel planning, travel planning may have a little bit of influence from AI vending machines, harvesting machines and so on and so forth.

But also that a lot of automation benefits from machine learning and data science, specially things like self driving cars because they have to learn to recognize images and you know do pass planning and thing like that. So, I just want to in this slide differentiate between these different terms which are so popular nowadays, machine learning AI, data science and automation essentially. Our focus is again on the left part of the screen which is AI or symbolic AI.

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Winograd Schema Challenge