**Modified**

Hi everyone and welcome back to Intelligent Systems. In this week's lecture, we are going to look into machine learning, an important subfield of AI. So you probably already know that the most recent achievements in AI have mainly been achieved through machine learning and there's a reason for that.

So before we go into those achievements and talk about how machine learning has elevated AI, let's start with an overview of what machine learning is. We will also discuss why it's important to study machine learning and when it's useful to apply it to specific problem domains. Additionally, we'll explore various applications of machine learning, including recent accomplishments. We'll also delve into different types of machine learning: supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning, discussing the key aspects of each type.

When considering machine learning, the question often arises: why is it important? Machine learning allows computers to process massive amounts of data and extract patterns or insights from it. As technology advances, large datasets become more available, making machine learning increasingly applicable. For instance, in domains like biomedicine, medical records and imaging data, such as X-rays, MRIs, CT scans, and ultrasounds, generate vast amounts of data that are impractical for humans to manually process. Automated techniques powered by machine learning become crucial.

Certain applications also demand machine learning. Tasks without fixed rules, like flying helicopters or recognizing facial expressions, require learning from experience rather than traditional programming. Additionally, when dealing with extensive customer bases, personalization becomes essential. Companies like Amazon and Netflix use machine learning to tailor recommendations to individual users, adapting to changing preferences.

Machine learning even provides a means to study human learning mechanisms. Now, let's explore why machine learning is pivotal and what it involves. Machine learning enables systems to enhance their performance through experience. Experience can be gained by interacting with the environment, and each instance of receiving input counts as an experience. Alternatively, pre-collected data relevant to a domain and task can serve as experiences to train a machine learning system. Arthur Samuel defined machine learning as the field that allows computers to learn without explicit programming.

Tom Mitchell's definition aligns with this concept, emphasizing performance improvement on a specific task through learning from experience. This model fits into the framework of intelligent agents, involving performance measures, the environment, actuators, and sensors. Traditional programming involves explicit instructions, while machine learning generates programs from learning.

However, not all tasks are suitable for machine learning. Situations requiring human expertise or well-defined rules may not benefit from machine learning. Calculating payroll, for instance, demands adherence to specific rules, making traditional programming more appropriate.

In summary, machine learning's importance is evident across various applications. Its ability to handle massive data, learn from experience, and adapt to changing situations makes it a critical tool in AI advancement. However, understanding its limitations is equally important. Machine learning isn't a universal replacement for traditional programming, but rather a powerful approach in the right contexts.

Thank you for tuning in to this week's lecture on machine learning. Stay curious and keep exploring the fascinating world of intelligent systems!

**Summarise**

In this week's lecture, we delve into machine learning, a crucial subset of AI that has driven recent advancements. Machine learning enables computers to process extensive data and discern patterns, making it increasingly vital due to the availability of large datasets. It's particularly useful in scenarios where vast amounts of data are involved, such as medical records, images from various sources, and business-related customer preferences.

Machine learning finds its purpose in areas that lack explicit programming solutions, like piloting aircraft or recognizing handwriting and facial expressions. It's also valuable for customizing recommendations in services like Netflix based on individual preferences and adapting to changing user tastes. Moreover, machine learning provides a means to understand how humans learn, aiding the study of human cognition.

Arthur Samuel defined machine learning as the field where computers learn without explicit programming, like his checker-playing program that learned by playing games. Tom Mitchell also defines it as improving system performance through experience. This fits into the model of intelligent agents, where agents learn from interactions with their environment to enhance performance.

Machine learning differs from traditional programming, as it doesn't involve explicitly programming for every problem instance. Instead, the computer learns and produces a program itself based on data, sometimes requiring human feedback as labels to guide the learning process. However, not all tasks are suitable for machine learning; tasks with well-defined rules, where human expertise exists, are often better solved with traditional programming.

Notable machine learning applications include recognizing patterns in handwritten characters, facial expressions, medical images, generating images and movies, anomaly detection in various domains, and predictive tasks like stock price forecasting. Learning paths are defined by tasks (t), performance measures (P), and experience (e), with examples ranging from playing checkers to recognizing email spam.

In essence, machine learning's ability to uncover insights from data and improve performance without explicit programming has led to its widespread use in solving complex problems and enhancing various aspects of AI.

***Important***

**MACHINE LEARNING**

In this week's lecture we are going to look into machine learning, an important subfuel of AI. The most recent achievements in AI has mainly been achieved through machine learning. We also look into when machine learning can be important and useful to apply into a particular problem domain.

**MACHINE LEARNING AND THE FUTURE OF AI**

Each individual requires some sort of personalized recommendations. This self customizing program requires some techniques like machine learning. Machine learning enable the system to improve its performance from experience. These are the area of applications where machine learning can become important.

**WHAT IS MACHINE LEARNING?**

Machine learning is able to recognize the patterns with facial identities, facial expression, handwritten or spoken words, medical images. All the very useful examples of machine learning include in recognizing anomalies. And of course, there's a lot of prediction tasks have been assigned to machine learning.

**Original**Hi everyone and welcome back to Intelligent Systems. In this week's lecture we are going to look into machine learning, an important subfuel of AI. So you probably already know that the most recent achievements in AI has mainly been achieved through machine learning and reason for that one. So before we go to those achievements and then talk about how machine learning has lifted the games in AI, let's have an overview about what machine learning is. And we also motivate the need to study machine learning and also looking into when machine learning can be important and useful to apply into a particular problem domain. Then we're looking at the important applications of machine learning, including the most recent achievements of machine learning. And then we have a quick look into different types of machine learning, including supervised learning, unsupervised learning, semi supervised learning and reinforcement learning and discuss the main aspect of these different types of learning. So when we look at machine learning, typically the question is why is it important? Now there are a number of reason and applications why you see that when you see that machine learning is become critical. The important thing to keep in mind about machine learning is that machine learning allow the computer to process huge amount of data and then extract some sort of pattern, some sort of insight from that huge amount of data. And because nowadays, with the advancement of technologies, the large amount of data become available and that makes machine learning become more and more applicable and important. So in particular, when we have big data, for instance, large data sets from the Web from different kind of applications could be in many biomedical domains, such as we have medical records from millions of patients or images from the patients using all these imaging technologies such as X ray, MRI, CT scans, ultrasounds and so on and so forth. So you can see that there are huge amount of data that need to be processed and no humans will be able to go through this huge amount of data manually. And so clearly we will need some automated techniques to deal with this huge amount of data and machine learning would be the main engine behind such automated techniques. Some other applications is also require the use of machine learning. So these are the applications when we cannot have a program written by a programmer knowing about the rules on how to deal with these problems applications. So for instance, we have no set of fixed rules to tell people on how to fly a helicopters or an airplane. So these can only be trained through a lot of practices and also through the experience that the pilot is able to deal with different situations in the cockpit of the helicopter or the aeroplane and knowing what sort of maneuver that they can perform in order to allow the helicopter or the aeroplane to stay in the air or safely landing, safely take off, and so on and so forth. So all of these cannot be expressed for instance using a C programs or a Python program. And machine learning will be a very useful tool to allow the machines to be actually picking up those maneuvers skills in order to control the helicopter and the aeroplane. Another kind of applications that we cannot program by hand, for instance, how to recognize handwriting, how to recognize the facial expression of a human and so on and so forth. All these require machine learning to actually learn from huge amount of data in order to actually find a way to deal with that image or that handwriting characters and so on and so forth. Also we talk about large data and this is also relevant to a particular applications data. You will see that a lot of business these days very concerned about. So companies like Amazon and Netflix and many other companies, they have billions of customers and with this huge amount of customers, wow, it's okay to actually offer their products in such a way that is generic and same for everyone. But then clearly this is not a good idea because if you actually provide the recommendations to a child who watch Netflix with some recommendation that you provide to an adult, then that may not be appropriate or even for adults. But then some adults, maybe they are going to be interested in comedies, some other adults interested in action movies and so on and so forth. And so clearly each individual requires some sort of personalized recommendations and this kind of personalized cannot be programmed individually because if you have to write such programs for every customer, then if there are 1 billion customers of Netflix, then they will need 1 billion different programs for each of these customer. And again this is not a good idea, not taking into account that the customers may actually change their preferences. And so today, this month maybe I'm really into action movies, but then after that I got sick of those and then I start choosing only comedies in order to watch. And so if the program stayed the same for me, then clearly Netflix is going to recommend action movie to me all the time and this certainly not what I prefer. And so again, this self customizing program requires some techniques like machine learning to actually allow the system to adapt into different users and also when they change their preferences then the system is able to automatically recognize that and then always make the right recommendations. Furthermore, if we really want to learn about how human actually learn, if we really want to study about what would be the mechanism behind human learning, then machine learning could also provide an avenue to allow us to explore that aspect of human mind as well. So these are the area of applications where machine learning can become really important and this motivates many researchers and practitioners to actually look into different techniques for machine learning. In general, the definitions of machine learning is that machine learning enable the system to improve its performance from experience. The terminology experience here is quite broad in the sense that the experience could be gained by the system interact with its environment and then every time it receives some input from the environment, then it immediately counts as an experience and then try to learn from those experiences in order to improve its performance. But the experience could be in the form that someone already tried to build a machine to learn about a particular domain and a particular task. Then the person may be deliberately collecting all the data relevant to that domain and that task. And so this sort of data set containing a lot of instances of data relevant to that domain and that task can be considered to be a set of experiences relevant to the learning to perform well on that task in that domain. And so it can be given to the machine learning system in a batch. So you don't learn from every experience and then update the system. You actually learn from, let's say that million of instances of the particular task in that particular domain in order to improve the system. And for instance, Arthur Samuel basically defined machine learning as the field study that enable the computer to learn without being explicitly programmed. And so we already mentioned about when the machine need to deal with huge amount of data. There are certain parts that we cannot explicitly program in order to tell the machines what would be the rules of flying a helicopter or an aeroplane, then this particular machine learning technique is the few that develop the technologies and the technique to allow the machines to learn without required explicitly programmed. And so, for instance, Arthur Samuel was the one was the researcher who actually allowed the machines to play many checker games and then learn from those games in order to discover the rules of the checker games and then incorporates those rules into its program and then through this process, improve its own ability to play the checker game. So this is one example of machine more formally one of the grandfather of machine learning, tom Mitchell defined the machine learning problem in the same line as what you have seen in the previous two definitions. Here the systems learn from experiences as well and then when it learns from experience it try to improve its performance on some specific path t. And if the machine learning system is able to learn, then with more and more experience passed through this learning system, then the system is able to improve its performance on the task. And so that means that if it gets the experience then at some point its performance on the task is actually improved and become better and better. If that's the case, then the system is safe to be able to learn. And this you can remember if you remember from our lecture in week one fit into the general model of intelligent agents because the general model of intelligent agents essentially is defined by three components, sorry, four components the performance measure P, the environment e the capabilities of the agents with actuators am sensor s, right? And so peas here with the performance measure p given, then the agent will be able to gain this experience by performing some action in the environment with its actuator and then observing the outcome of those actions with its sensor. That particular activities of performing action and observing the outcomes allow the agent to receive some sort of experience. And then with this experience now relating to the task at hand, the agent will try to update its program using the learning element in order to improve the performance element. And over the time with many experience being received and learned from, then the system is able to improve its performance and measure. Now, this is also another perspective to differentiate between machine learning and traditional programming. So in traditional programming, the programmers know how to deal with a particular application in order to solve the problems in that particular domain. Then they write this program so that whenever data for the relevant data for a particular instance of that problem will be received by the computer, then the computer will run that program data given to it by the programmer and then produce the correct output for that particular problem instance. Okay? So this is the traditional form of programming and we all have done this write a lot of programs and then the program will process the data and produce the output. On the other hand, machine learning remember that we don't explicitly program to process the data and the computer will have to learn and produce a program by itself. Okay? So that means that for machine learning the computer is actually able to output the program, the appropriate program to deal with different problem instances represented by the data, by the input into the computer. Now, in order to produce this program, sometimes the computer requires some sort of feedback and input from the humans or from the supervisors of this learning process. And so that feedback and input is also the output that designed for this particular program instance. And with this design output, we sometimes call this design output the label for those problem instance associated with this data input. Then the computer perform machine learning in order to produce this program. So that in the future the program can be used in order to process future problem instances with future data for those future problem instances. Now, so we have seen the reason why we want to study machine learning and develop machine learning systems. We also know what it is a machine learning system supposed to do. Now the question is so can we just use developed machine learning system for everything? Because then we no longer have to write program anymore. We just introduce machine learning systems and then the machine learning system is going to do everything because it's going to learn every program that we need and then it's going to run this program and then doing the thing that we want. And so we no longer need any programmers, any It worker anymore. The short answer is no. There will be some situations where machine learning is suitable and there are many situations when the machine learning system are not suitable. So if we are dealing with problems where human expertise doesn't exist, for instance, how to navigate on Mars, how to perform certain kind of actions on a planet that we have never been to and don't really know about the characteristics in the planets, then clearly the machines cannot really receive good enough instruction from the humans. If that's the case, then the machine will need to perform machine learning in order to learn from its experience when it operates within those environments where human expertise doesn't exist. We already talked about a case when a lot of problems human know how to do it, but then they can't explain how they do it. Okay, so for instance, the pilot knows how to fly the helicopter and the aeroplane, but they can't exactly tell you. And then based on what they tell you, then you will be able to simply fly the helicopter and the airplane. So not only that, you know about the principle of those control maneuver, but then you also need to perform a lot of practice. And this how to perform those practice is actually the domain for machine learning. So the machine learning can perform, for instance, speech recognition. And in this case we can't explain how to recognize a speech, knowing what people are saying, what words, what sentences they are speaking. But this can be achieved using machine learning or if there are huge number of customers or people that the system have to serve and then they serve them in a personalized basics, for instance, personalized medicine, then again machine learning will become useful in that case. And of course when we have huge amounts of data, for instance genomic data about our genes, then machine learnings have been used in those contexts. So these are the situations that we already mentioned when we motivate why we want to study and develop machine learning systems. But there are also situations where machine learning is not too useful. And so for instance, when we calculate the payroll for a company, then clearly there are very specific rules on how payroll can be calculated and processed to ensure that they correct because they comply with the law, they provide correct output based on those set of rules for payroll calculations. Then if this is the case, then it's much better to follow those rules in order to encode those rules in a program, for instance in Python or in Java, in order to implement this payroll calculation rather than use a machine learning that possibly output a wrong payroll program. And then if that's the case, then the outcome would be a disaster. So you spend a lot of money and a lot of time to help the machine to learn that payroll calculations, but then in the end it probably produce a very big and heavy models for payroll calculations that may not always produce correct output for payroll calculation. So in those situations then learning is eligible. So some classical example of tasks that may require machine learning to perform. So if you look into this one then it's very difficult to actually talk about what would be the rule to recognize these digits, right? And then you can see that if we just use some sort of hard rules in order to recognize them, it's very easy to wrongly recognize some of these digits as well. So if you look into this number for instance, so is it going to be a number one or number seven, right? And so sometimes even us humans unable to explain how we actually determine a particular characters as being a number seven or number two or number three and so on and so forth. And so another example is with numbers like number two and number three. So you can see that quite a few number three like this instance and then this instance may look quite similar to number two. Now this when machine learning can become very useful to recognize these characters. In this case, the machine learning system is able to correctly classify these characters in this green box as number two and incorrectly classify this one as not a number two and incorrectly classify these characters and this character and these two characters as being number two as well. But as you can see that there is a very good reason why these are misclassified by the machine learning system. So in this case, even though without any explicit programming, the machine learning system managed to actually perform a decent job in recognizing handwritten characters. So there are several examples of machine learning. For instance is able to recognize the patterns with facial identities, facial expression, handwritten or spoken words, medical images. Not only that, it can recognize those patterns based on huge amount of data that is received to learn about how to recognize them, but thanks to those huge amount of data that it learn about those patterns now it can actually also generate the pattern as well. And so machine learning has been used to generate images or a movie. And very well known recent example of this one is that machine learning was able to generate AI generations of a photograph. And then the researchers of that photograph generated by machine learnings submitted that to a photography competition and then that particular photograph actually received the award from the competitions organizer. All the very useful examples of machine learning include in recognizing anomalies which have been used in order to identify credit card fraudulent transactions or for instance is able to run automatically to identify any anomalies in a nuclear power plant in order to provide early warning about some potential issues that can happen to the nuclear power plant. And of course, there's a lot of prediction tasks have been assigned to machine learning. For instance, predicting the future stock price or currency exchange rates. So an example of how a particular learning path can be defined for the machine in order to learn according to the formal definitions from Tom Mitchell. So remember that our machine learning systems try to improve its performance on task t based on the performance measure P. Okay? Now by learning from the experience e okay, so there are many examples of such a learning problems. For instance when you play checkers, then the task is to play checkers and so there is this eight by eight board and then checker pieces. Then the performance measure is try to improve the percentage of games won against an arbitrary opponent. So the more wind the better. And then the experience is that the system will be trying to play practice games against itself and so for each of such practice games and then the machine is able to learn more and more strategies in order to play really well in the checker games. And so there are quite a few other examples of machine learning tasks in the different applications. For instance handwritten recognition, or recognizing the lens on highway using vision sensors or classify email messages into either spam or legitimate emails.