**Modified**

Hi and welcome back to Intelligent Systems. In this lecture, we are going to cover the topic of multi-agent systems. So the outline of the lecture is I'm going to introduce you to the concept and ideas behind multi-agent systems, including answering the questions why do we need motor agent systems, what are they? And how are we going to develop these systems? For motor agent systems to work, then there will be the need for the agent to communicate.

So we are going to learn about agent communication. They also need to interact. So we are going to learn about a number of interaction protocols to allow the agent to interact. And one important aspect of multi-agent systems is that they can actually negotiate with each other in order to reach a common consensus. So automatic negotiation is also an important topic. And remember, automatic negotiation is one of the assignment topics in this unit. So some of you who choose this topic, we want to look into the material in this lecture.

So let's start with why do we need multi-agent systems. So this is the current technologies that almost enable this situation, except from some futuristic situations in this picture. So just imagine that I have an Amazon Echo system at home and I choose to call Charles, our tutor in this unit, using this device. So I say to Echo Alexa, call Charles Harold. Now, this is the current technology that currently is already available for us to use.

So you know that Amazon already making echo devices, allow Echo to listen to me speak in English and some other languages as well, and can actually do some tasks. For instance, calling a person by accessing my address book that store somewhere in the cloud. And then knowing about who Charles Haro's contact number is, Amazon Alexa then makes the connection via my phone. So there will be mobile phone, which is another device. And then there will be some communications between Alexa and my phone.

My phone will make the call to Charles' phone. So this is Charles' phone. Now this is a bit of futuristic situation here because Charles, he's actually having an intelligence agent situated in his phone, being the personal assistant for Charles. So this smart intelligence agent is able to actually check in whether Charles is available and then using some advanced technology sitting in the cloud as well.

So these systems can run on some AI and Lap and natural language processing servers in the cloud in order to know about Charles' whereabouts. So he is currently in a meeting. And so this intelligence agent, knowing that Bao is someone who is calling Charles, and so this intelligent agent answering this phone call, telling me to my mobile phone that, "Sorry Bao, Charles is in a meeting right now. How can I help you?" So this intelligent agent is actually having a conversation with me and within his own intelligence is able to have a conversation with me.

For instance, if Bao is only asking Charles about his availability for a meeting on Thursday at 02:00 PM, then these intelligent agents may be able to check Charles' calendar and then knowing that Charles is available during that time and then schedule a meeting with Bao on Thursday at 02:00 PM. So you can see that this situation is an example of multi-agent systems. In this case, the person Bao is an agent talking to some devices like Amazon Echo plus like the mobile phone from Bao and then talking to some agents somewhere on the internet in the internet like Charles' intelligent agent who's also talking to some other AI systems sitting somewhere in the cloud and so on and so forth.

And so this is an example of multi-agent systems and then you can see that this example becomes the reality now and in the very near future. So that is the reason why motor agent system is an important technologies that we will see, we are seeing now and then we will see in the near, very near future. And the reason is clear because these days computer systems and devices are no longer a standalone device, they are networked into large distributed systems.

And with the many devices connected now we are actually having not just the internet, but we actually having the internet of things where a smart TV, a CCTV camera, a sensor somewhere in your house, in the CBD connected together and with many other computers around the world. And they actually become smarter as well. They have the ability to process information and then they can actually act on the information.

They can communicate with all the devices. They can interact with all the intelligent agents. They can coordinate the activities. They can also work together cooperatively. They can actually compete with each other as well. Because one intelligent agent may be working for a company, for instance, the Commonwealth Bank of Australia, and another intelligent agent actually working for the competitor, for instance, the ANZ Bank.

Okay. And then these two agents both trying to win customers for their owners and so they may be competing. So the CBA agents knowing about the strategies that the ANZ agents may be doing and so they may be offering some more attractive offers to the customer, they will offer the lower interest rates to the customer who wants to borrow money from CBA. They're showing that they provide better customer services to the customer in order to win customers from ANZ for instance.

So this is the reality at the moment and will be the reality in the very near future when there are more and more such intelligent agents operating in the real world. All right, so now that motivates us to look into studying multi-agent system and also to view multi-agent systems. So now let's define them.

So the general definition for motor agent system is they are just computer systems that consist of a number of agents rather than just one agent. And these agents interact with each other. In the general cases, the agents will be acting on behalf of users. And these users may have different goals and motivations. The example that I gave you previously is that some agents working for Commonwealth Bank, other agents working for ANZ bank, and they may have conflicting goals.

Because if Commonwealth Bank agents win customers, then ANZ agents lose customers. They can also be agents who work together as well. So within the Commonwealth Bank, you may have many intelligent agents, some of them working as customer service agents, some of them working as payroll agents, some of them working as IT agents. And they may be working together to achieve the common goals of Commonwealth Bank.

So because of those reasons, to successfully interact, they will require the ability to cooperate. For instance, intelligent agents within the Commonwealth Bank will try to cooperate in order to achieve the common goals. They need to coordinate. So the agents working even for different users. So for instance, the agents working for Commonwealth Bank may need to coordinate with the agents working for the customers of Commonwealth Bank in order to allow these agents to work together and then achieving their own objectives.

And they may need to negotiate. And so an agent working for Commonwealth Bank may need to negotiate with an agent working for the customer of Commonwealth Bank in order to agree on the interest rate for the loan that the customer wants to borrow the money from the Commonwealth Bank. And so they actually operate based on these activities, using these capabilities in the same way as people will do those things.

Now, in order to build multi-agent systems, there are two key problems we need to overcome. The first problem is to design the agents. So each agent needs to be designed so that they can actually operate independently and perform autonomous actions and they can successfully carry out the tasks that we delegate to them. So how to build those is the question for agent design.

On the other hand, there is also the question on building the systems of agents who are capable of interacting with other agents as well. And so if we have multiple agents, how do they cooperate with each other, how do they coordinate the activities with each other, how do they negotiate each other to reach a common consensus in order to successfully carry out the task that their owner, their users, delegate to them.

And so the questions of how to build such systems that consist of many agents and they can interact with each other successfully is the question for society design. So you design a society of intelligent agents and they can work in order to successfully carry out the delegated task. And these typically look into the situations when agents share the same objectives and goals.

For instance, agents belong to the same organization and they have the same goals that the organization has and also more difficulty when the agents cannot be assumed to share the same interests and goals. So this is the reality in most situations when agents can belong to different owners, they may have different objectives. As I already mentioned in my previous example, some agents working for Commonwealth Bank, some other agents working for ANZ, and they may not have the same interest.

So when looking at those high-level questions to design the agents and to design the society of agents, then more specific questions that need to be considered, including how can cooperation emerge in societies of self-interested agents? So if you have a group of self-interested agents, can cooperation emerge from those agents?

Now the next question is what kind of languages can the agent use to communicate? So if we have all these intelligent agents and they try to coordinate, they try to cooperate and so on and so forth. Now the question is what languages these agents can use in order to communicate with each other, in order to understand each other and then knowing about what they would like to do, their request or whether they informing me of some information and so on and so forth.

So the language is something important for these agents to communicate. And also, other kinds of questions, including how can self-interest agents recognize the conflict and then they try to resolve this conflict in order to reach an agreement. How can they coordinate the activities so that they can cooperatively achieve the goals?

So cooperation, communications, coordination, negotiations are some of more specific questions to consider when building multi-agent systems. So these are not the only questions, specific questions to be considered, but these are the very typical questions. And these are the questions that we are going to cover in this lecture.

So today's lecture, we are going to look into these specific questions. So just to give you a few examples of multi-agent communication and coordination. So these are one of the examples for competitive behavior. So in this example, you have people trying to win an auction for an item that they all want.

And so to win this item, they compete in these auctions by bidding for the item. And so clearly no one wants to pay a very high price, but in order to win the item, so they have to drive the price, the bid that they bid for the item and therefore they're competing, which will win the one with the higher bid. Or in another example for coordination.

So you can see that in order to change the library, then these minions, each individual minion, so you probably remember the minions in the movie Despicable Me. So each individual minion wouldn't be able to replace the library, but by working together. And so one carried the new library, the other one tried to remove the old library by stacking on each other. So they coordinate in order to reach this height and after reaching the height, they will be able to remove the one and then this one passing the libol to this one in order to pass the libol to the one on the top in order to replace the new one.

Or more seriously, we have mobile robot networks where they can actually communicate and then share the information and then pass the object from one another in order to allow the object to be carried to a particular location. In this example of mobile robot networks. So in other examples, you can see that even animals actually also display this kind of communication and coordination as well.

A flock of birds allows each other to move to a direction together. For instance, in migrations, or when they actually try to find the stick food, then different birds with their senses may identify the food and then go to that place and then the other bird, the whole flock actually follows that bird who could identify food.

Or when they try to evade the predators. And then this flock of birds can work together as well. All the examples in Human for coordination, including group buying, which is the behavior when a group of individuals, they don't know each other, but because they want to buy the common design item at the lower price, they will form collisions in order for them to actually have the buying power that can purchase the item purchase the item at the lower price in this group buy in behavior.

So these are some of the examples of multi-agent coordination.

**Summarise**

In this lecture on multi-agent systems, the focus is on introducing the concept and significance of these systems. The lecture begins by illustrating how modern technology, like Amazon Echo, exemplifies multi-agent systems through interactions among devices, intelligent agents, and cloud-based servers. The rationale for studying multi-agent systems lies in the interconnected nature of devices and the growing presence of intelligent agents with varying objectives.

Multi-agent systems consist of multiple agents, each acting on behalf of users with distinct goals. These agents need to communicate, cooperate, coordinate, and negotiate to achieve their objectives. Designing agents and societies of agents that can interact effectively and resolve conflicts presents challenges. The lecture emphasizes questions like how cooperation arises in self-interested agent societies, what communication languages agents should use, and how agents coordinate activities and negotiate agreements.

Several real-world examples showcase multi-agent communication and coordination. These range from competitive behaviors, like auction bidding, to collaborative efforts, such as minions stacking to replace a lightbulb. Animals like birds also demonstrate coordinated behaviors, and even human activities like group buying illustrate multi-agent coordination.

In summary, the lecture underscores the significance of multi-agent systems in our networked world and introduces key questions and examples related to agent interaction and coordination.

***Important***

**INTELLIGENT SYSTEMS: MULTI-AGENT SYSTEMS**

In this lecture, we are going to cover the topic of multi agent systems. For motor agent systems to work, then there will be the need for the agent to communicate. And one important aspect of multi agent systems is that they can actually negotiate with each other.

**INTELLIGENT AGENTS**

Multi agent systems are an important technology that we will see in the near future. Computer systems and devices are no longer a standalone device, they are networked into large distributed systems. More and more intelligent agents will be operating in the real world.

**MULTI-AGENT SYSTEMS**

A motor agent system is a computer system that consists of a number of agents. These agents interact with each other. To successfully interact, they will require the ability to cooperate. How to design the agents is the questions for agent design. Can corporations emerge from a society of self interested agents?

**MULTI-AGENT COMMUNICATION AND COORDINATION**

So just to give you a few example of multi agent communication and coordination. These are one of the example for competitive behavior. Or in another example for coordination. A flock of birds allow each other to move to a direction together. All the example in Human for coordinations.

**Original**

Hi and welcome back to Intelligent Systems. In this lecture, we are going to cover the topic of multi agent systems. So the outline of the lecture is I'm going to introduce you to the concept and ideas behind multi agent systems, including answering the questions why do we need motor agent systems, what are they? And how are we going to develop these systems? For motor agent systems to work, then there will be the need for the agent to communicate. So we are going to learn about agent communication. They also need to interact. So we are going to learn about a number of interaction protocols to allow the agent to interact. And one important aspect of multi agent systems is that they can actually negotiate with each other in order to reach a common consensus. So automatic negotiation is also an important topic. And remember, automatic negotiation is one of the assignment topic in this unit. So some of you who choose this topic, we want to look into the material in this lecture. So let's start with why do we need multi agent systems. So this is the current technologies that almost enable this situation, except from some futuristic situations in this picture. So just imagine that I have an Amazon Echo system at home and I choose to call Charles, our tutor in this unit, using this device. So I say to Echo Alexa, call Charles Harold. Now, this is the current technology that currently is already available for us to use. So you know that Amazon already making echo devices, allow Echo to listen to me speak in English and some other languages as well, and can actually do some tasks. For instance, calling a person by accessing to my address book that store somewhere in the cloud. And then knowing about who Charles Haro's contact number is, amazon Alexa, then make the connections via my phone. So there will be mobile phone, which is another device. And then there will be some communications between Alexa and my phone. My phone will make the call to Charles phone. So this is Charles'phone. Now this is a bit of futuristic situation here because Charles, he's actually having an intelligence agent situated in his phone, being the personal assistant for Charles. So this smart intelligence agent is able to actually check in whether child is available and then using some advanced technology sitting in the cloud as well. So these systems can run on some AI and Lap and natural language processing servers in the cloud in order to know about Charles whereabout. So he is currently in a meeting. And so this intelligence agent, knowing that Bao is someone who is calling to Charles. And so this intelligent agent answering this phone call, telling me to my mobile phone that, sorry Bao, Charles is in a meeting right now. How can I help you? So this intelligent agent is actually having a conversation with me and within his own intelligence is able to have a conversation with me. For instance, if Bao is only asking Charles about his availability for a meeting on Thursday at 02:00 P.m., then these intelligent agents may be able to check Charles calendar and then knowing that Charles is available during that time and then schedule a meeting with Bow on Thursday at 02:00 P.m.. So you can see that this situation is an example of multi agent systems. In this case the person Bao is an agent talking to some devices like Amazon Echo plus like the mobile phone from Bao and then talking to some agents somewhere on the internet in the internet like Charles intelligent agent who's also talking to some other AI systems sitting somewhere in the cloud and so on and so forth. And so this is an example of multi agent systems and then you can see that this example becomes the reality now and in the very near future. So that is the reason why motor agent system is an important technologies that we will see, we are seeing now and then we will see in the near, very near future. And the reason is clear because these days computer systems and devices are no longer a standalone device, they are networked into large distributed systems. And with the many devices connected now we are actually having not just the internet, but we actually having the internet of things where a smart TV, a CCTV camera, a sensor somewhere in your house, in the CBD connected together and with many other computers around the world. And they actually become smarter as well. They have the ability to process information and then they can actually act on the information. They can communicate with all the devices. They can interact with all the intelligent agents. They can coordinate the activities. They can also work together cooperatively. They can actually compete with each other as well. Because one intelligent agents may be working for a company, for instance, the Commonwealth Bank of Australia, and another intelligent agent actually working for the competitor, for instance, the ANZ Bank. Okay. And then these two agents both trying to win customer for their owners and so they may be competing. So the CBA agents knowing about the strategies that the ANZ agents may be doing and so they may be offering some more attractive offers to the customer, they will offer the lower interest rates to the customer who want to borrow money from CBA. They showing that they provide better customer services to the customer in order to win customer from ANZ for instance. So this is the reality at the moment and will be the reality in the very near future when there are more and more such intelligent agents operating in the real world. All right, so now that motivates us to look into studying multi agent system and also to view multi agent systems. So now let's define them. So the general definition for motor agent system is they are just computer system that consists of a number of agents rather than just one agents. And these agents interact with each other. In the general cases, the agents will be acting on behalf of users. And these users may have different goals and motivations. The example that I gave you previously is that some agents working for Commonwealth Bank, other agents working for ANZ bank, and they may have conflicting goals. Because if Commonwealth Bank agents win in customer, then ANZ agents lose in customer. They can also be agents who work together as well. So within the Commonwealth Bank, you may have many intelligent agents, some of them working as customer service agents, some of them working as payroll agents, some of them working as It agents. And they may be working together to achieve the common goals of Commonwealth Bank. So because of those reasons, to successfully interact, they will require the ability to cooperate. For instance, intelligent agents within the Commonwealth Bank will try to cooperate in order to achieve the common goals they need to coordinate. So the agents working even for different users. So for instance, the agents working for common web banks may need to coordinate with the agents working for the customers of Commonwealth Banks in order to allow these agents to work together and then achieving their own objectives. And they may need to negotiate. And so an agent working for Commonwealth Bank may need to negotiate with an agent working for the customer of Commonwealth Bank in order to agree on the interest rate for the loan that the customer want to borrow the money from the Commonwealth Bank. And so they actually operate based on these activities, using these capabilities in the same way as people will do those things. Now, in order to build multi agent systems, there are two key problems we need to overcome. The first problem is to design the agents. So each agents need to be designed so that they can actually operate independently and perform autonomous actions and they can successfully carry out the tasks that we delegate to them. So how to build those is the questions for agent design. On the other hand, there is also the questions on building the systems of agents who are capable of interacting with other agents as well. And so if we have multiple agents, how do they cooperate with each other, how do they coordinate the activities with each other, how do they negotiate each other to reach a common consensus in order to successfully carry out the task that their owner, their users, delegate to them. And so the questions of how to build such systems that consists of many agents and they can interact with each other successfully is the questions for society design. So you design a society of intelligent agents and they can work in order to successfully carry out the delegated task. And these typically look into the situations when agents share the same objectives and goals. For instance, agents belong to the same organization and they have the same goals that the organization has and also more difficultly when the agents cannot be assumed to share the same interests and goals. So this is the reality in most situations when agents can belong to different owners, they may have different objectives. As I already mentioned in my previous example, some agents working for Commonwealth Bank, some other agents working for ANZ, and they may not have the same interest. So when looking at those high level questions to design the agents and to design the society of agents, then more specific questions that need to be considered, including how can corporation emerge in societies of self interested agents? So if you have a group of self interested agents, can corporations emerge from those agents? Now the next question is what kind of languages can the agent use to communicate? So if we have all these intelligent agents and they try to coordinate, they try to cooperate and so on and so forth. Now the question is what languages these agents can use in order to communicate with each other, in order to understand each other and then knowing about what they would like to do, their request or whether they informing me of some information and so on and so forth. So the language is something important for this agent to communicate. And also all the kind of questions including how can sell interest, agents recognize the conflict and then they try to resolve this conflict in order to reach an agreement. How can they coordinate the activities so that they can cooperatively achieve the goals? So cooperations, communications, coordinations, negotiations are some of more specific questions to consider when building multi agent systems. So these are not the only questions, specific questions to be considered, but these are the very typical questions. And these are the questions that we are going to cover in this lecture. So today lecture we are going to look into these specific questions. So just to give you a few example of multi agent communication and coordination. So these are one of the example for competitive behavior. So in this example, you have people trying to win an auction for an item that they all want. And so to win this item, so they compete in these auctions by bidding for the item. And so clearly no one want to pay a very high price, but in order to win the item, so they have to drive the price, the bid that they bid for the item and therefore they're competing, which are until the one with the higher bid we win the item. Or in another example for coordination. So you can see that in order to change the library, then these minions, each individual minion, so you probably remember the minions in the movie Despicable Me. So each individual minion wouldn't be able to replace the library, but by working together. And so one carried the new library, the other one tried to remove the old library by Stacking On Each Other. So they coordinate in order to reach this height and after reaching the height, they will be able to remove the one and then this one passing the libol to this one in order to pass the libol to the one on the top in order to replace the new one. Or more seriously, we have mobile robot networks where they can actually communicate and then sharing the information and then passing the object from one another in order to allow the object to be carried to a particular location. In this example of mobile robot networks. So in other example, you can see that even animals actually also display this kind of communication and coordination as well. A flock of birds allow each other to move to a direction together. For instance, in migrations, or when they actually try to find the stick food, then different birds with their senses may identify the food and then go to that place and then the other bird, the whole flocks actually follow that bird who could identify food. Or when they try to evade the predators. And then this flock of birds can work together as well. All the example in Human for coordinations, including group buying, which is the behavior when a group of individual, they don't know each other, but because they want to buy the common design item at the lower price, they will. Form collisions in order for them to actually have the buying power that can purchase the item purchase the item at the lower price in this group buy in behavior. So these are some of the example of multi agent coordination.