**Modified**

All right, now we can start with the first specific question of how to develop agent communication to allow agents to communicate, to share information or to request another agent to do something. So the agent communication aspect of intelligent agent technology is related to the macro aspect. That means that they have developed the agent society rather than to deal with developing the intelligence within an individual agent. The communication is needed to allow the agent to communicate, to share information, to request cooperation and also enable cooperation. So that means data is allow the agents to work together to achieve some common goal.

So the question we are concerned with is how do agents communicate? The agent communication theory is based on speech act theory. So these are the pragmatic theories of languages. So that means they are dealing with a question of how language is used by people every day to achieve their goals and intentions. And for detailed information about speech of theories, you can refer to Austin book published in 1962, how to do things with words.

All right, so the idea behind pitch up theory is that Austin, the author of the book, noticed that some utterances are rather like physical actions that appear to change the state of the word. So that means that when an agent, when a person makes some utterance, then what? The intention behind making the utterance is to change the state of the word. Some examples would be a statement declaring war or statements when christening a person or a marriage celebrant stating that I now pronounce you men and wife. So these statements will change the state of the word and so they have similar effects as an action. But more generally, everything that we utter is utter with the intention of satisfying some goal or intention. So in general, we don't say something without any purpose. Whenever we say something it is because there's some goal that we want to achieve or we have the intention to achieve something. And then this purpose is essentially the semantics, the meaning behind the utterances that we make. The theory of how utterances are used to achieve intentions is a speech act theory. So another author sol in a book published in 1969 identify various different aspects, different times of speak up. So the five main times that sol identify are representative. So these are the statements informing the hero of some state of the world such as it is raining. So representatives means to inform the hearer.

Another time of speech act is directive this attempt to get the hearer to do something, asking the hero for performing a particular action. For instance, the statement the utterance say please make the tea. So the person who make this utterance mean to ask the hearer to perform that action.

Another time of speech is committed. So this commit the speaker. So the speaker when making this commissive speech act, commit himself or herself to do something for instance, when the speaker say I promise to, then the speaker essentially commit himself or herself to that particular statement that they make after I promise to, another type of speech is expressive. So when the speaker express a mentor state, for instance in thank you or I'm sorry, these are expressive speech acts. And another type of speech act is declarations such as declaring world or Christian. So these are the general theory behind speech acts which are developed by linguists who try to identify the use of speech and utterances in human communication.

Now, to translate this speech theory from human communication, human languages to languages used by agents for communication, then the idea is to identify the two components within an utterance, within an utterance. So the first is the performative verb and the second is a propositional content. The performative verb will indicate whether the speech act is a request or an inform or a promise or a declaration. And then after the performative verb indicating the speaker intention of requesting something or informing something or promising something or declaring something, then there is the proposition of context where the state of the word related to that request or that inform or that promise will be stated. So the propositional content such as the statement assert that the door is closed.

Now, depending on the performative verb, this particular speech act can be the speaker request the hearer to close the door or the speaker inform the hearer that the door is being closed or the speaker promised to the hearer that the door will be closed. So making the commitment to close the door. So with this particular way of defining the speech act by looking at these two components, then all the speech acts that we mentioned early can be earlier, can be covered by these two components.

So for instance, if the performative is request the content is the door is closed, then the speech act look like please close the door. If the performative is to inform and the content is the door is closed, then the speech act is the speaker saying that the door is closed. So informing the hearer that the door is closed. And if the performative is inquired, the content being the door is closed, then the speech act will look like is the door closed? So essentially, when making this speech act, the speaker indicated that they don't know about whether the door is closed and they want the hearer to inform them whether the door is closed. So these are the basic theory behind speech act that computer scientists and Asian researchers look into and then identify these two essential components of the performative verb and the propositional content.

And after they've done that, they define the language used for agent communication called Agent Communication Languages or ACLs they contain in the standard format of the exchange of messages. So there are several well known ACLs. Perhaps the best known ACL is Kqml, developed by APA for knowledge sharing. So APA is the Department of Defense of the US. For research and development, and they develop many different technologies in military, in artificial intelligence, in biology, in many different areas that can be used for the purpose of defense. For instance, to be weapons, to do cyber defense, and so on and so forth. And one of these initiatives is the Knowledge Sharing initiative and APA developed the kqml for this initiative. The language kqml consists of two parts the Knowledge query and manipulation language kqml and the second part is the Knowledge interchange format KIS. Even though kqml contains both kqml and KIS, but the whole language is referred to as kqml only. And if you look back to the previous slide I mentioned about speech act typically contain two components the performative verb and the propositional content. Then kqml is the part of the language to deal with performative verb. Okay? So this is for performative verb.

On the other hand, KAF is the part of the language to allow you to capture the content, the propositional content of the speech app. Okay? And kqml part of the language is an outer language to define some communicative verbs or performatives. So some example performatives are ask if. So this is to inquire perform, this is to request tell. This is to inform reply. This is also a kind of informed performative, but with the purpose of replying to some previous speech act. Because if the previous speech act is an ask if, then the expectation is that the hearer would come back with a reply speech act. There are many, but these are some of the more popular one more popular performatives in kqml.

So, as I already mentioned, so the kqml part of the language is to capture the performatives. On the other hand, the content, the propositional content of the speeches is captured by KAF, the Knowledge interchange format part of the language. So these are some of the example of the contents captured within KAF. So the KAF can be used to state the properties of things in a domain. For instance, one object in the domain that the agents may want to reason about is Bao. And the agents may inform another agent that Bow is a lecturer, saying that the object bow had the property that be in a lecture.

Or for instance, this content can be used to state the relationships between things in a domain. So between two objects, Charles and the unit COF three, then the relationship is Charles is enrolled in three, and then KAF can be used to state this gap relationship as well. Or KF can be used to state general properties of a domain. So all students are enrolled in at least one course. So this particular statement express the properties for all the students. So all the objects that satisfy being students then satisfy this property must satisfy this property. So these are some of the formats used by KAF to express the propositional content.

So if you want to assert the propositional content the temperature of hot on is 17 Celsius, then KAF allow you to write something like temperature hot on to indicate that this path between these two parentheses is to capture the temperature of hot on. And then this indicates this is a value of 17 Celsius degree. And this equality allow you to state that the temperature of photon is equal to 17 Celsius degree. Another statement that can be stated is a definition definition of an object being a bachelor. An object is a bachelor if the object is a man and the object is not married. And so in this case KAF allow you to give this definition using the keyword deaf relation. Deaf relation is a keyword used defined within KAF to allow you to define something. And after using this keyword, now you can define, for instance, an object x being a bachelor, then that is defined. So this is the symbol for definition. So this is a symbol for definition. And the way that we define this object being a bachelor is that the object has to be both a man and the object is not married. And so both of these has to be satisfied for the object x to be a bachelor.

Or for instance another definitions for the property of a person is that if you want to state that any individual with the property of being a person then also has the property of being a mammal so any x who is a person then x also has to be a mammal as well. So again we use def relation in order to state in these definitions of the property of an object and then we give this particular way in order to infer that an individual with this property person implies that the object have this property of being a mammal. So, as you can see, Kaif defines all these particular symbols like definitions. Like these definitions. Column equal. And then these implications column equal. Arrow to allow you to express the propositional content of the sentences that we human make in natural language such as English or French or German, and write them in a syntax that a computer can understand. So these strings like this one, like this one, like this one are the kind of strings that the computer can pass and then can understand and can process such strings.

So put together Kqml and KF. Then now we have the language that can be used by the computer and the computer can put these strings into the form that when it is sent from one computer or from one system to another system, then the second system can interpret. What the first system? The message that the first system sends through. And because they share the common understanding so essentially they communicate. And because they need to have that shared understanding. Therefore the agents must agree on a common set of terms and that common set of terms is called an ontologies. So if they have the same common set of terms or they share the same ontology, then they will see the same message in the same way, otherwise with the same message.

But Agent 1 may interpret it as a cow and Agent 2 may interpret it as a chicken. Then that's clearly not good, because they fail in communicating. So the nerve sharing effort associated with the effort to define the common ontology because this is actually one of the hardest thing when defining the agent communication language. And in order to define that common ontologies then some software tools like On SolidWork can be used for this purpose. So this is an example of a Kqml KF dialogue. So from agent A to agent B the following message is sent. So the performative is ask if. And then the proportional content is the PSI of chip one greater than the PSI of chip two. So essentially here agent A ask agent B whether the size of chip one is greater than the size of chip two.

And according to the interaction protocol between the two agents, agent B send back the speech act to agent A by the performative reply. And then with this reply, both agents know that the reply is for the ask if speech act and the propositional content of this reply is true. Meaning that H and B stated that yes, it's true that the size of chip one is indeed greater than the size of chief two. And then H and B can subsequently continue the conversation by inform. So the performative now is become informed be informed to A that the size of jeep one is equal to 20 and then B also inform continue to inform A that the size of jeep two is 18. So this conversation, this dialogue allow H and A to ask H and B about whether the size chip one is greater than the size chip two. Not only that, B confirm to A that is true that the size of chip one is greater than the size of chip two. But because B knows that A doesn't know the size of one of the chips, at least one of the chip could be chip one or could be chip two.

Otherwise if A already knows the size of both chips then he wouldn't have to ask this question. So B proceeded to inform A of the size of both chips. So the size of chip one being 20 and the size of chip two being 18. So you can see that this signified the use of agent communication language to allow the agent to express something to another agent and then the other agents understand the intention, the goal of the first agent and then accordingly will send back the appropriate messages. So that is Kqml A very famous and well established agent communication language. But after Kqml, there are many other efforts to define the agent communication languages as well.

And then if there are many different research groups, many different companies developing different agent communication language, then that may not be a good idea. So the foundation for intelligent physical agents, FIFA, introduced the Agent Communication standard and among these standards they introduced the Agent Communication Language ACL. So ACL is one of the standard defined by HIPAA and this standard is defined in order to introduce an agent communication language. So the basic structure of ACL is very similar to Kqml. So it contains performative and also the content. So these are the two most important things within an agent communication language. But it also have the housekeeping path within a message as well.

So it will be able to tell you whether the assurance is from which sender and then intended for which receiver and so on and so forth. And so the housekeeping allow you to identify the sender of the message, the receiver of the message and some other housekeeping details. Well, so example of ACL feedback ACL is the Speech Act contain an informative inform. The sender is agent one. The receiver is agent five. The language that is used for the content is SL and the ontologies. Remember, the ontology is used in order to allow the agents to have the common understanding of the content. The ontology used here is HPL Auction. And so with these HPL Auctions, some of the terminologies about the auction such as price, such as good, such as greater than, such as winning bid will be defined.

So based on these ontologies now such content such as price of good, 200, 150, now become a propositional content that one sender sent to another receiver. So here after this message has been sent, then we can interpret this message knowing that the utterance is an inform sender, agent One, inform receiver, agent five, that they want to put the price for good 200 at 150. And the language is defined by SL language and the ontologies that they use is HPL Auction.

So this table gives you a summary of the performative that's defined by FIFA ACL. So you can see that there are many performatives like inform, inform, if, inform, ref and so on and so forth. And then request and then refuel, reject and so on and so forth. But as you will see, most of these performatives can be actually defined based on inform and request. So these are the two basic performatives and the rest could be defy based on informant request.

**Summarise**

The agent communication aspect of intelligent agent technology focuses on how agents can communicate, share information, and cooperate within an agent society. This communication enables agents to work together toward common goals. Agent communication theory is rooted in speech act theory, a pragmatic approach to understanding language use for achieving goals and intentions. Speech act theory identifies different types of speech acts, such as informative, directive, commissive, expressive, and declarative.

In agent communication, the theory is translated from human languages to languages used by agents. This involves identifying two components in an utterance: the performative verb indicating the type of speech act (request, inform, promise, etc.), and the propositional content that conveys the intended message. This approach forms the basis for Agent Communication Languages (ACLs), which provide a standard format for exchanging messages between agents.

One well-known ACL is Kqml, which includes performatives like "ask if," "tell," "inform," and more. The Knowledge interchange format (KAF) within Kqml captures the propositional content, allowing agents to express properties, relationships, and general concepts. KAF uses defined symbols and syntax to convey meaning, making it understandable for computers.

FIPA introduced the Agent Communication Language (ACL) standard, which is structured similarly to Kqml. It contains performatives and content, along with housekeeping information like sender and receiver details. ACL enables agents to share a common understanding of messages by using ontologies, defining shared terms and concepts. ACL provides a framework for various speech act types and facilitates effective agent-to-agent communication.

ACL performative types cover a range of interactions, but many can be defined based on the core performatives of "inform" and "request." This standardization enhances communication and cooperation among intelligent agents in complex systems.

***Important***

**AGENT COMMUNICATION 4,**

The agent communication aspect of intelligent agent technology is related to the macro aspect. The theory of how utterances are used to achieve intentions is a speech act theory. Everything that we utter is utter with the intention of satisfying some goal or intention.

**KAF**

Kqml part of the language is an outer language to define some communicative verbs or performatives. The content, the propositional content of the speeches is captured by KAF, the Knowledge interchange format. This content can be used to state the properties of things in a domain.

**Original**

All right, now we can start with the first specific question of how to develop agent communication to allow agents to communicate, to share information or to request another agent to do something. So the agent communication aspect of intelligent agent technology is related to the macro aspect. That means that they have developed the agent society rather than to deal with developing the intelligence within an individual agent. The communication is needed to allow the agent to communicate, to share information, to request cooperation and also enable cooperation. So that means data is allow the agents to work together to achieve some common goal. So the question we are concerned with is how do agents communicate? So the agent communication theory is based on speech act theory. So these are the pragmatic theories of languages. So that means they are dealing with a question of how language is used by people every day to achieve their goals and intentions. And for detailed information about speech of theories, you can refer to Austin book published in 1962, how to do things with words. All right, so the idea behind pitch up theory is that Austin, the author of the book, noticed that some utterances are rather like physical actions that appear to change the state of the word. So that means that when an agent, when a person makes some utterance, then what? The intention behind making the utterance is to change the state of the word. Some examples would be a statement declaring war or statements when christening a person or a marriage celebrant stating that I now pronounce you men and wife. So these statements will change the state of the word and so they have similar effects as an action. But more generally, everything that we utter is utter with the intention of satisfying some goal or intention. So in general we don't say something without any purpose. Whenever we say something it is because there's some goal that we want to achieve or we have the intention to achieve something. And then this purpose is essentially the semantics, the meaning behind the utterances that we make. The theory of how utterances are used to achieve intentions is a speech act theory. So another author sol in a book published in 1969 identify various different aspects, different times of speak up. So the five main times that so identify are representative. So these are the statements informing the hero of some state of the world such as it is raining. So representatives means to inform the hearer. Another time of speech act is directive this attempt to get the hearer to do something, asking the hero for performing a particular action. For instance, the statement the utterance say please make the tea. So the person who make this utterance mean to ask the hearer to perform that action. Another time of speech is committed. So this commit the speaker. So the speaker when making this commissive speech act, commit himself or herself to do something for instance, when the speaker say I promise to, then the speaker essentially commit himself or herself to that particular statement that they make after I promise to, another type of speech is expressive. So when the speaker express a mentor state, for instance in thank you or I'm sorry, these are expressive speech acts. And another type of speech act is declarations such as declaring world or Christian. So these are the general theory behind speech acts which are developed by linguists who try to identify the use of speech and utterances in human communication. Now, to translate this speech theory from human communication, human languages to languages used by agents for communication, then the idea is to identify the two components within an utterance, within an utterance. So the first is the performative verb and the second is a propositional content. The performative verb will indicate whether the speech act is a request or an inform or a promise or a declaration. And then after the performative verb indicating the speaker intention of requesting something or informing something or promising something or declaring something, then there is the proposition of context where the state of the word related to that request or that inform or that promise will be stated. So the propositional content such as the statement assert that the door is closed. Now, depending on the performative verb, this particular speech act can be the speaker request the hearer to close the door or the speaker inform the hearer that the door is being closed or the speaker promised to the hearer that the door will be closed. So making the commitment to close the door. So with this particular way of defining the speech act by looking at these two components, then all the speech acts that we mentioned early can be earlier, can be covered by these two components. So for instance, if the performative is request the content is the door is closed, then the speech act look like please close the door. If the performative is to inform and the content is the door is closed, then the speech act is the speaker saying that the door is closed. So informing the hearer that the door is closed. And if the performative is inquired, the content being the door is closed, then the speech act will look like is the door closed? So essentially, when making this speech act, the speaker indicated that they don't know about whether the door is closed and they want the hearer to inform them whether the door is closed. So these are the basic theory behind speech act that computer scientists and Asian researchers look into and then identify these two essential components of the performative verb and the propositional content. And after they've done that, they define the language used for agent communication called Agent Communication Languages or ACLs they contain in the standard format of the exchange of messages. So there are several well known ACLs. Perhaps the best known ACL is Kqml, developed by APA for knowledge sharing. So APA is the Department of Defense of the US. For research and development, and they develop many different technologies in military, in artificial intelligence, in biology, in many different areas that can be used for the purpose of defense. For instance, to be weapons, to do cyber defense, and so on and so forth. And one of these initiatives is the Knowledge Sharing initiative and APA developed the kqml for this initiative. The language kqml consists of two parts the Knowledge query and manipulation language kqml and the second part is the Knowledge interchange format KIS. Even though kqml contains both kqml and KIS, but the whole language is referred to as kqml only. And if you look back to the previous slide I mentioned about speech act typically contain two components the performative verb and the propositional content. Then kqml is the part of the language to deal with performative verb. Okay? So this is for performative verb. On the other hand, KAF is the part of the language to allow you to capture the content, the propositional content of the speech app. Okay? And kqml as a language contain both parts, both the kqml part and the KAF part. All right? So kqml part of the language is an outer language to define some communicative verbs or performatives. So some example performatives are ask if. So this is to inquire perform, this is to request tell. This is to inform reply. This is also a kind of informed performative, but with the purpose of replying to some previous speech act. Because if the previous speech act is an ask if, then the expectation is that the hearer would come back with a reply speech act. There are many, but these are some of the more popular one more popular performatives in kqml. So, as I already mentioned, so the kqml part of the language is to capture the performatives. On the other hand, the content, the propositional content of the speeches is captured by KAF, the Knowledge interchange format part of the language. So these are some of the example of the contents captured within KAF. So the KAF can be used to state the properties of things in a domain. For instance, one object in the domain that the agents may want to reason about is Bao. And the agents may inform another agent that Bow is a lecturer, saying that the object bow had the property that be in a lecture. Or for instance, this content can be used to state the relationships between things in a domain. So between two objects, Charles and the unit COF three, then the relationship is Charles is enrolled in three, and then KAF can be used to state this gap relationship as well. Or KF can be used to state general properties of a domain. So all students are enrolled in at least one course. So this particular statement express the properties for all the students. So all the objects that satisfy being students then satisfy this property must satisfy this property. So these are some of the formats used by KAF to express the propositional content. So if you want to assert the propositional content the temperature of hot on is 17 Celsius, then KAF allow you to write something like temperature hot on to indicate that this path between these two parentheses is to capture the temperature of hot on. And then this indicates this is a value of 17 Celsius degree. And this equality allow you to state that the temperature of photon is equal to 17 Celsius degree. Another statement that can be stated is a definition definition of an object being a bachelor. An object is a bachelor if the object is a man and the object is not married. And so in this case KAF allow you to give this definition using the keyword deaf relation. Deaf relation is a keyword used defined within KAF to allow you to define something. And after using this keyword, now you can define, for instance, an object x being a bachelor, then that is defined. So this is the symbol for definition. So this is a symbol for definition. And the way that we define this object being a bachelor is that the object has to be both a man and the object is not married. And so both of these has to be satisfied for the object x to be a bachelor. Or for instance another definitions for the property of a person is that if you want to state that any individual with the property of being a person then also has the property of being a mammal so any x who is a person then x also has to be a mammal as well. So again we use def relation in order to state in these definitions of the property of an object and then we give this particular way in order to infer that an individual with this property person implies that the object have this property of being a mammal. So, as you can see, Kaif defines all these particular symbols like definitions. Like these definitions. Column equal. And then these implications column equal. Arrow to allow you to express the propositional content of the sentences that we human make in natural language such as English or French or German, and write them in a syntax that a computer can understand. So these strings like this one, like this one, like this one are the kind of strings that the computer can pass and then can understand and can process such strings. So put together Kqml and KF. Then now we have the language that can be used by the computer and the computer can put these strings into the form that when it is sent from one computer or from one system to another system, then the second system can interpret. What the first system? The message that the first system sends through. And because they share the common understanding so essentially they communicate. And because they need to have that shared understanding. Therefore the agents must agree on a common set of terms and that common set of terms is called an ontologies. So if they have the same common set of terms or they share the same ontology, then they will see the same message in the same way, otherwise with the same message. But Agent 1 may interpret it as a cow and Agent 2 may interpret it as a chicken. Then that's clearly not good, because they fail in communicating. So the nerve sharing effort associated with the effort to define the common ontology because this is actually one of the hardest thing when defining the agent communication language. And in order to define that common ontologies then some software tools like On SolidWork can be used for this purpose. So this is an example of a Kqml KF dialogue. So from agent A to agent B the following message is sent. So the performative is ask if. And then the proportional content is the PSI of chip one greater than the PSI of chip two. So essentially here agent A ask agent B whether the size of chip one is greater than the size of chip two. And according to the interaction protocol between the two agents, agent B send back the speech act to agent A by the performative reply. And then with this reply, both agents know that the reply is for the ask if speechat and the propositional content of this reply is true. Meaning that H and B stated that yes, it's true that the size of chip one is indeed greater than the size of chief two. And then H and B can subsequently continue the conversation by inform. So the performative now is become informed be informed to A that the size of jeep one is equal to 20 and then B also inform continue to inform A that the size of jeep two is 18. So this conversation, this dialogue allow H and A to ask H and B about whether the size chip one is greater than the size chip two. Not only that, B confirm to A that is true that the size of chip one is greater than the size of chip two. But because B knows that A doesn't know the size of one of the chips, at least one of the chip could be chip one or could be chip two. Otherwise if A already knows the size of both chips then he wouldn't have to ask this question. So B proceeded to inform A of the size of both chips. So the size of chip one being 20 and the size of chip two being 18. So you can see that this signified the use of agent communication language to allow the agent to express something to another agent and then the other agents understand the intention, the goal of the first agent and then accordingly will send back the appropriate messages. So that is Kqml A very famous and well established agent communication language. But after Kqml, there are many other efforts to define the agent communication languages as well. And then if there are many different research groups, many different companies developing different agent communication language, then that may not be a good idea. So the foundation for intelligent physical agents, FIFA, introduced the Agent Communication standard and among these standards they introduced the Agent Communication Language ACL. So ACL is one of the standard defined by HIPAA and this standard is defined in order to introduce an agent communication language. So the basic structure of ACL is very similar to Kqml. So it contains performative and also the content. So these are the two most important things within an agent communication language. But it also have the housekeeping path within a message as well. So it will be able to tell you whether the assurance is from which sender and then intended for which receiver and so on and so forth. And so the housekeeping allow you to identify the sender of the message, the receiver of the message and some other housekeeping details. Well, so example of ACL feedback ACL is the Speech Act contain an informative inform. The sender is agent one. The receiver is agent five. The language that is used for the content is SL and the ontologies. Remember, the ontology is used in order to allow the agents to have the common understanding of the content. The ontology used here is HPL Auction. And so with these HPL Auctions, some of the terminologies about the auction such as price, such as good, such as greater than, such as winning bid will be defined. So based on these ontologies now such content such as price of good, 200, 150, now become a propositional content that one sender sent to another receiver. So here after this message has been sent, then we can interpret this message knowing that the utterance is an inform sender, agent One, inform receiver, agent five, that they want to put the price for good 200 at 150. And the language is defined by SL language and the ontologies that they use is HPL Auction. So this table gives you a summary of the performative that's defined by FIFA ACL. So you can see that there are many performatives like inform, inform, if, inform, ref and so on and so forth. And then request and then refuel, reject and so on and so forth. But as you will see, most of these performatives can be actually defined based on inform and request. So these are the two basic performatives and the rest could be defy based on informant request.