Multi-Agent Systems

Lecture IV

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- Central to the development of any satisfactory Multi-Agent System. Effective communication is a prerequisite for achieving system coordination and system **coherence** (involves ensuring that the overall system performance is satisfactory)
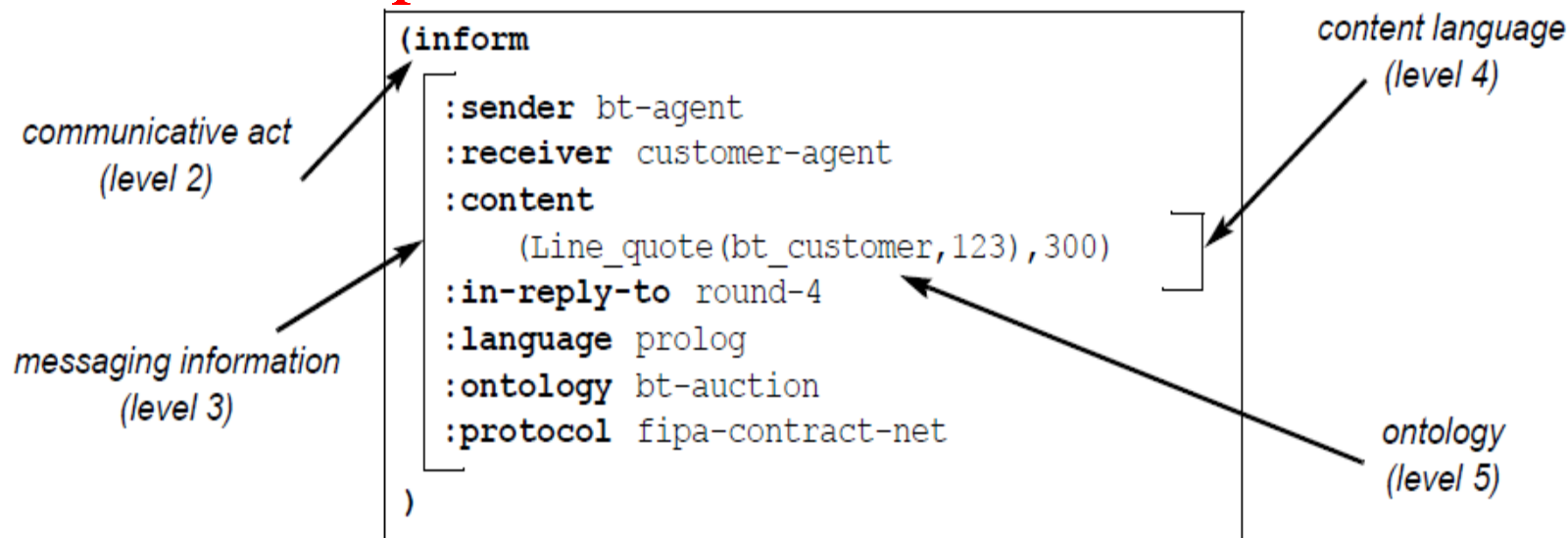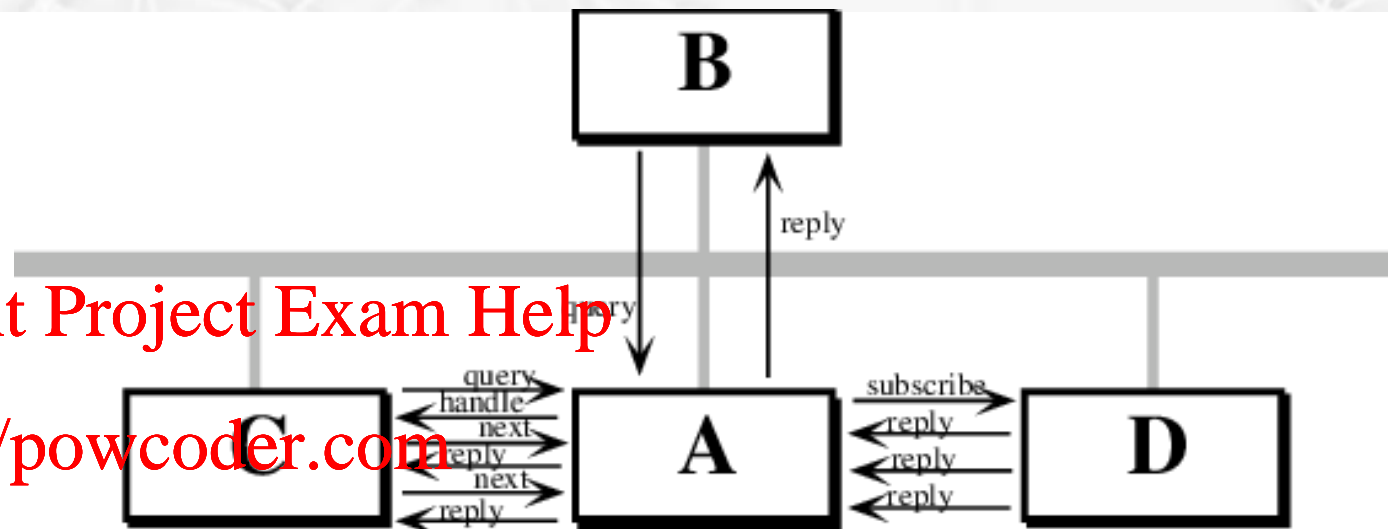
Agent Communication Languages

- To preserve an agent's ability to co-operate the need of a language is evident.

- Must be powerful enough to express an agent's Beliefs and Desires.

- Two of the most common Languages are:
  - FIPA ACL
  - Knowledge Querying and Manipulation Language (KQML)

```
(inform
    :sender bt-agent
    :receiver customer-agent
    :content
        (Line_quote(bt_customer,123),300)
    :in-reply-to round-4
    :language prolog
    :ontology bt-auction
    :protocol fipa-contract-net
)
```

communicative act (level 2)

messaging information (level 3)

content language (level 4)

ontology (level 5)

Classes of Agent Communication

- Werner identified several discrete classes of communication that occurs within Multi-Agent Systems.

1. **Complete absence of communication;**

2. **Inter-Agent Signalling;**

3. **Message Passing;**

4. **Plan Passing;**

5. **Speech Acts;**

Absence of Communication

- Sometimes communities of agents can achieve coherent behaviour without explicit communication.

- Geneserth Ginsberg & Rosenchein considered this very issue in a seminal paper entitled ***Cooperation without Communication.***

- Agents might have a prearranged regime for achieving their goals and this is established *a priori* thus avoiding any need for dynamic communication.

- Alternatively they may infer each others plans based on observations to date. This results in a prediction of agents' behaviour.

InterAgent Signalling

- Inter-Agent activity can be synchronised through the use of *semaphore based* technologies.

- Semaphores offer a relatively simplistic communication technique.

- They utilise the standard, primitives of wait and signal and are directly analogous to those techniques used within the design of real-time languages and systems

Message Passing

- Very common means of inter-agent communication is that of message passing.

- Early work by Hewitt & Agha formulated a computational paradigm based upon actor-based computation. Central to this was the notion of message passing.

- Message passing generally manifests itself in many DAI systems.

Plan Passing

- This approach involves agents exchanging plans to one another. By so doing agents can anticipate the future directed actions of other agents.

- One particular approach involves the exchange of Partial Plans. This approach called **Partial Global Planning (PGP)** was expounded by Durfee and Lesser. Within PGP agents build partial and incomplete plans which they subsequently share to colleagues in order to identify potential improvements.

Plan Passing

- Unlike multi-agent planning, allows agents to interleave planning and actions.

- Based upon future plans received agents can revise their plans and subsequently perform actions based upon this.

- PGP was employed with great effect in the DVMT system.

Essence of Speech Acts

- Spoken human communication is used as the model for communication among *computational* agents

- The origins of **Speech Act Theory** can be traced to the work of Austin.

- Two central characteristics associated with the basic theory of Speech Acts are:

   1. That human utterances are viewed as actions in manner similar to physical operations that result in the movement of a book for example. They too result in a change in the state of the world.

   2. That communication can be homogenised into a finite set of *Speech Verbs* that can be used to as an effective medium within which to communicate.

Speech Acts and State Change

- It is not immediately obvious how Speech Acts result in a change to the environment.

- All utterances are viewed as being situated within a particular context and each results in a revision to that very context.

- The context is often viewed as the aggregation of the mental states of the participants namely the speaker and the hearer.

- Such a mental state includes their Beliefs, Desires and Intentions.

- We can thus view a pragmatic theory of speech as a function which takes a set of all utterances of a given language let's say *L* and an associated set of Contexts within which these can be expressed let's say *C* and derives the new context.

Thus:

Speech_Function : L x C -> C

- Certain utterances involved not merely the ascertain of facts but rather the performance of associated action(s). These utterances are termed performatives and noted that these like physical actions are ***prone to failure***.

- The conditions that must exist for successful completion were called **felicity conditions**. Three key conditions are:

1. There must be an accepted procedure for the performative and the circumstances and individuals must be specified for this procedure.
2. This procedure must be executed correctly and completely.
3. The act must be performed in a sincere manner and any associated or implied behaviour honoured.

Speech Act Actions

- Austin also identified three discrete classes of action associated with any given utterance:

1. **Locutionary Acts:** which is performed by simply uttering syntactically correct phrase

2. **Illocutionary Acts:** which is performed via a performative verb examples include tell, inform, ask, instruct, demand. Each verb has an associated illocutionary force. ~1,000 such verbs in English.

3. **Perlocutionary Acts:** is the bringing about of an effect on hearer of the utterance.

- Communications are seen not just as transmitting information but as actions which change the state of the world

Greeting: "Hi, Peter. How are things going?"

Request: "Could you pass me the pie, please?"

Complaint: "I've already been waiting three weeks for the laptop, and I was told it would be delivered within a week."

Invitation: "We're having some people over Monday evening and wanted to know if you'd like to join us.'

Compliment: "Hey, I really like your shoes!"

Refusal: "Oh, I'd love to see that movie with you but tomorrow just isn't going to work."

"I couldn't agree with you more."

"how are you?"

Lecture IV Learning Objectives

❑ **Review the difference between reactive and deliberative agent architectures**

❑**To understand the Belief-Desire-Intention Architecture**

❑**To understand the different classes of Agent Communication.**

❑**To understand the different classes of Commitment Strategies.**

❑**To understand the principles and importance of Speech Acts**

Things to Do!

Agent Architectures

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- Brooks, R. (1986). A robust layered control system for a mobile robot. IEEE journal on robotics and automation, 2(1), 14-23.

Things to Do!

Agent Communication Languages

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Speech Act Theory

- Kibble, R. (2006). Speech acts, commitment and multi-agent communication. *Computational & mathematical organization theory, 12*(2-3), 127-145.`