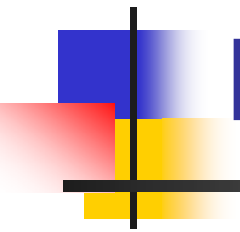
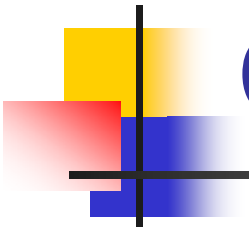


Multiagent Systems

ENSC 891 – Spring 2003

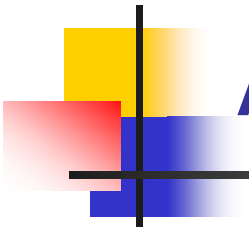
Prof: William Gruver

Student: Eman Elghoneimy



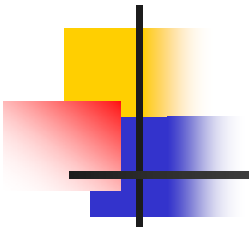
Outline

- Agent definition
- Agent architectures
- Programming languages
- DAI
- Agent communication and interaction
- Research areas



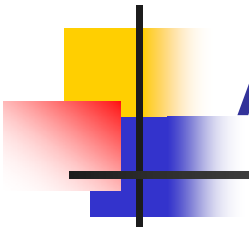
Agents

- Systems that can decide for themselves what they need to do in order to satisfy their design objectives.
  - Situated in some environment
  - Have partial control on the environment
  - Capable of autonomous action
- Examples:
  - Control systems
  - Software daemons



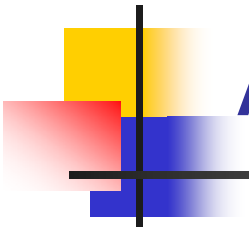
Intelligent Agents

- Agents that operate in a rapidly changing, unpredictable or open environments - where there is a high possibility that actions can fail.
- Agents that are capable of “flexible” autonomous actions
  - Reactivity
  - Pro-activeness
  - Social ability



Agents and objects

- Objects are computational entities that encapsulate some state, are able to perform some actions (methods) on this state, and communicate by message passing.
- Differences between agents and objects:
  1. Agents do not invoke methods upon one another, but rather request actions to be performed.
  2. Objects do not have flexible autonomous behaviour.
  3. Each agent have its own thread of control.
- OOP could be used for implementing agents, with some modifications

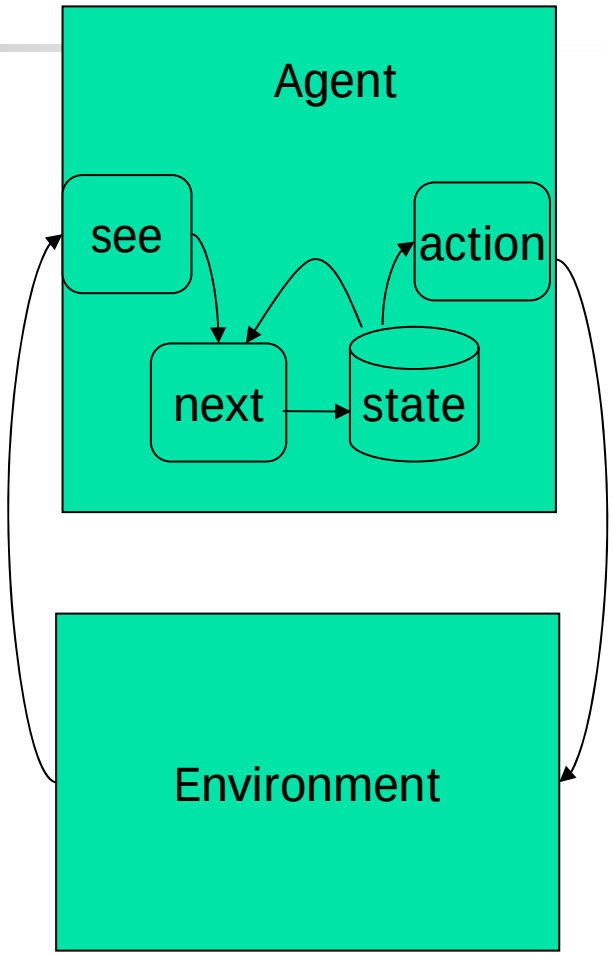


Agents and Expert systems

- An expert system is one that is capable of solving problems or giving advice in some knowledge-rich domain.
- Example: MYCIN medical diagnosis ES.
- Differences between agents and ES:
  - ES do not act directly with any environment
  - No cooperation with other agents
- Some ES with real-time control tasks are very close to agents, for example ARCHON.

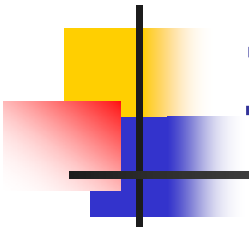
Abstract architectures for intelligent agents

1. Reactive agents
   action : S -> A
2. Perception and action
   see : S -> P
   action : P* -> A
3. Agents with state
   see : S -> P
   action : I -> A
   next : I X P -> I



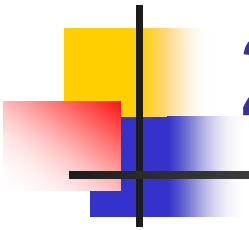
Concrete architectures for intelligent agents

- Internal structure and operation of agents
- Four classes of agents:
  1. Logic based agents
  2. Reactive agents
  3. Belief-desire-intention agents
  4. Layered architectures



1. Logic-based architectures

- Based on traditional symbolic AI where environment is represented as logical formulae and syntactic manipulation corresponds to logical deduction or theorem proving.
- Agent decision making is encoded as a logic theory, and selecting an action is reduced to a problem of proof, which could be time-consuming.
- Environment might change while agent is deciding on optimal action.
- Implementing procedural and temporal knowledge in traditional logic can be unintuitive

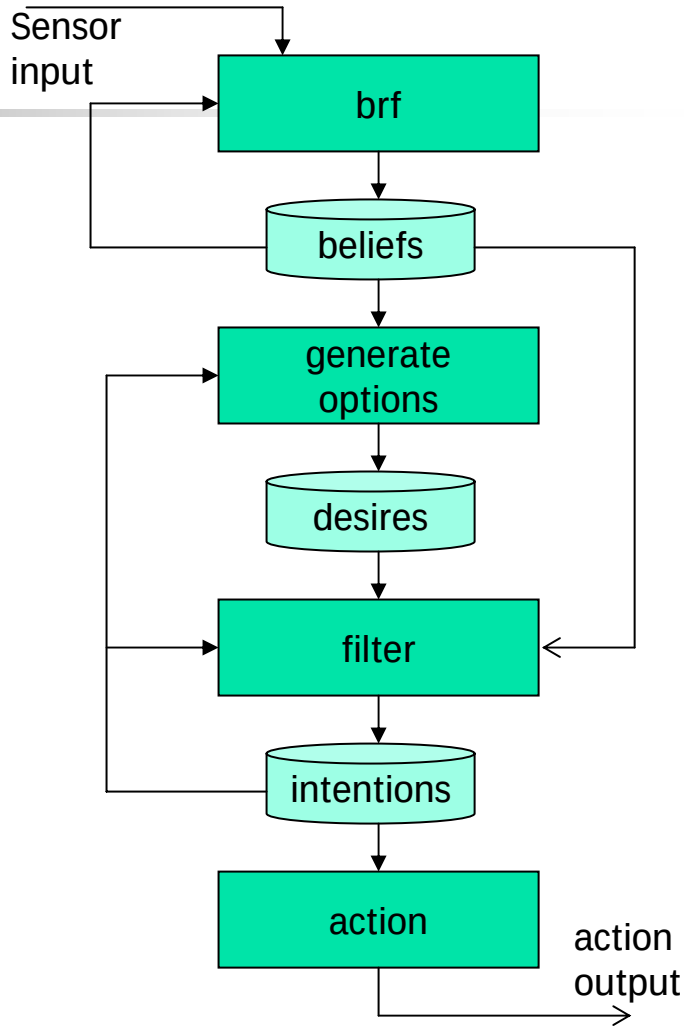


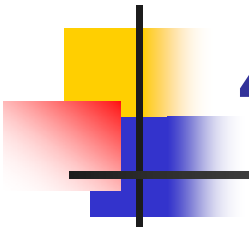
2. Reactive architectures

- situation -> action
- Many behaviours can fire simultaneously, form a hierarchy (layers)
- Based on local information (current state)
- Do not learn from experience
- No principled methodology for building such agents.

3. Belief-desire-intention architecture

- Beliefs represent information on current environment
- Desires or options represent possible courses of actions available
- Intentions represents the agent's current focus
- Brf (belief review function)
- Filter function represents agents deliberation process
- Action selection function (execute) determines an action to perform





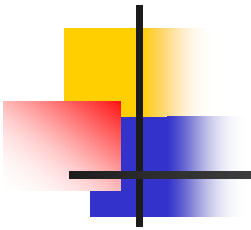
4. Layered architectures

- Horizontal layering
  - software layers are each directly connected to sensory input and action output. Each layer itself acts like an agent
  - need central control to decide which action to take.
  - Touring machines have reactive, planning and modeling layers
- Vertical layering
  - sensory input and action output are each dealt with by at most one layer each
  - control pass between each different layer, not fault tolerant
  - Example: INTERRAP has behaviour, plan and cooperation layers

Agent programming languages

- Agent-oriented programming Agent0 (BDI agent)
- Concurrent METATEM (logic-based agent)

Distributed Artificial Intelligence – Definition



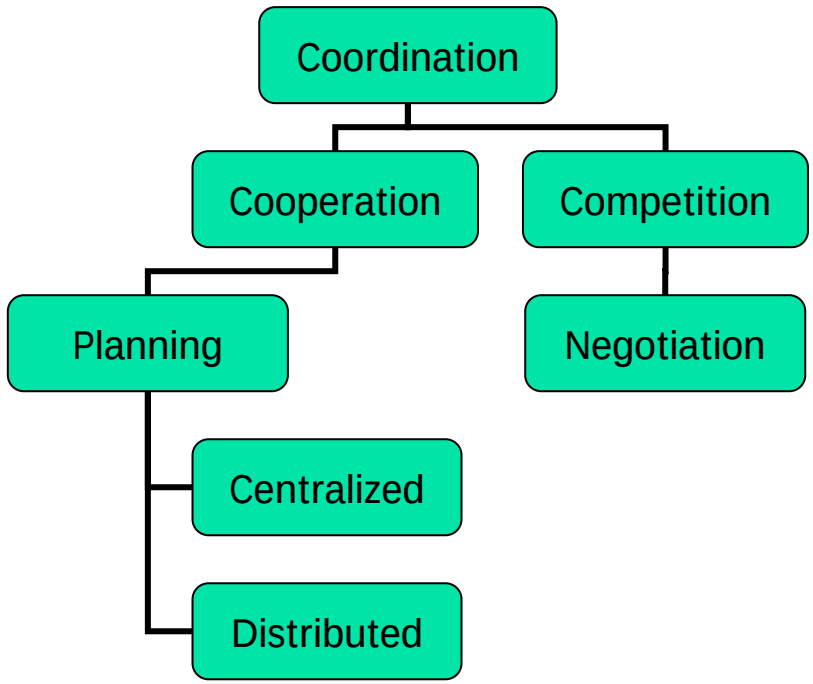
- A multiagent system (MAS) is a system in which several interacting, intelligent agents pursue some set of goals or tasks that are beyond their individual capabilities.
- Distributed problem solving considers how the task of solving a particular problem can be divided among a number of agents that cooperate in dividing and sharing knowledge about the problem and about its evolving solutions
- DAI is the study, construction and application of MAS.

Agent communication and interaction

- Communication protocols enable agents to exchange and understand messages
  - Propose, accept, reject, retract, disagree or counterpropse a course of action
- Interaction protocols enable agents to have conversations
  - Agent1 proposes an action to Agent2
  - Agent2 evaluates the proposal and sends to Agent1: acceptance, counterproposal, disagreement or rejection

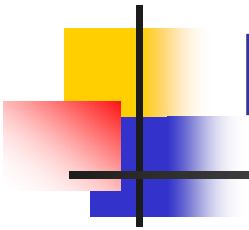
Agent communications - coordination

- Agents communicate in order to achieve better the goals of themselves or of the society in which they exist.
- MAS to maintain global coherence (behaving as a unit) without explicit global control.
- Agents determine common goals and common tasks, avoid conflicts and pool knowledge and evidence.



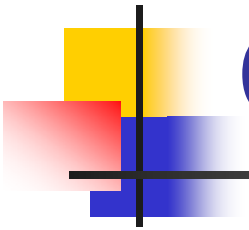
Communications - meaning

- Three aspects to the formal study of communication:
  1. Syntax: how the symbols of communication are structured
  2. Semantics: what the symbols denote
  3. Pragmatics: how the symbols are interpreted
  - Meaning is a combination of semantics and pragmatics.



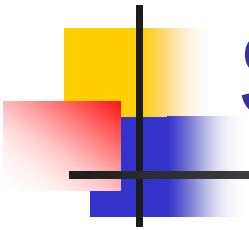
Message types

- Communication could be active, passive or both (agent is master, slave or peer)
- Two message types: assertions and queries.
- All agents accept information by means of assertions.
- Passive agent: accepts queries, sends replies
- Active agent: issue queries, make assertions
- Peer agent: all of the above.



Communication levels

- Communication protocols are typically specified at several levels:
  - Method of interconnection
  - Syntax
  - Meaning (semantics)
- Binary, multicast, broadcast.
- Data structure of a protocol:
  - Sender, receiver(s), language, encoding and decoding functions, actions to be taken by the receiver



Speech acts

- Speech act theory used for analyzing human communication
- Aspects of speech act theory:
  - Locution: physical utterance by the speaker
  - Illocution: intended meaning
  - Perlocution: action that result from the loction
- Message contained within the protocol maybe ambiguous or require decomposition, however, the communication protocol itself should clearly identify the type of message.

Knowledge Query and Manipulation Language (KQML)

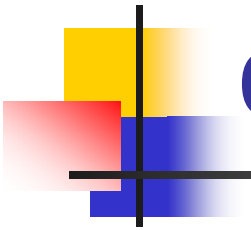
- KQML is a protocol for exchanging information and knowledge.
- The semantics of the communications protocol must be domain independent, while the semantics of the enclosed message may depend on the domain.
- KQML performatives: evaluate, ask-one, ask-all, reply, sorry, cancel, ready, advertise, broadcast, etc.

- Example:

```
(tell
:sender Agent1
:receiver Agent2
:language KIF
:ontology Blocks-World
:content (AND (BLOCK A) (BLOCK
    B) (On A B))
```

- Languages: KIF (Knowledge Interchange Format), Prolog, Lisp, etc.
- An ontology is a specification of objects, concepts and relationships in an area of interest.

Interaction protocols - coordination



- DAI involves distributed control and distributed data.
- Agents have a degree of autonomy in generating new actions and deciding which goal to pursue next.
- Knowledge of the system's overall state is dispersed throughout the system.
- Coordination activities include:
  - defining goal graph,
  - assigning regions of the graph to appropriate agents
  - decisions about which areas of the graph to explore
  - traversing the graph
  - ensuring that successful traversal is reported.

Coordination protocols

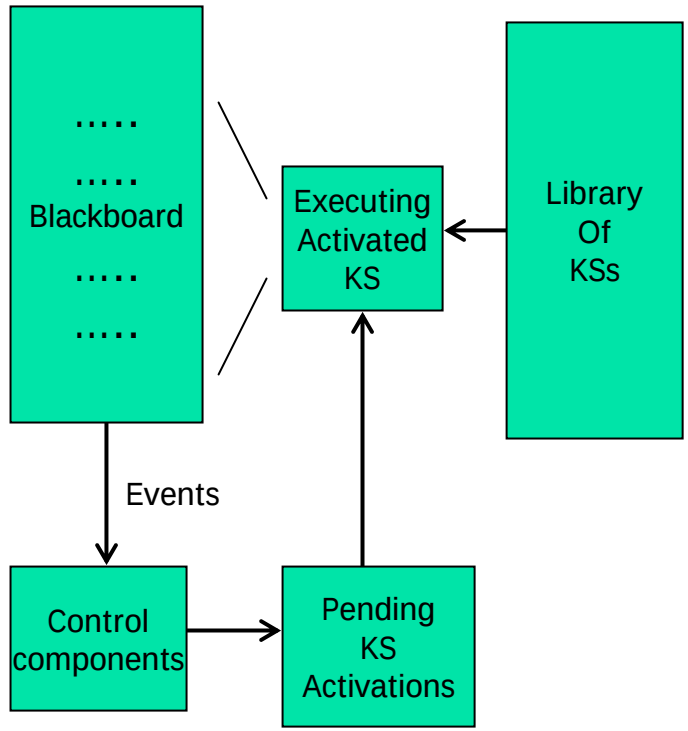
- Commitments
  - They are pledges to undertake a specified course of action
  - Provide a degree of predictability
  - Agents evaluate validity of existing commitments
- Conventions
  - They provide a means of managing commitments in changing circumstances
  - Restrain the conditions under which commitments should be reassessed and specify the associated actions: retain, rectify or abandon the commitments
- Agent's commitments should be internally consistent, as well as consistent with the agent's beliefs
- Social conventions: For dependant goals, relevant agents should be informed of changes that affect them

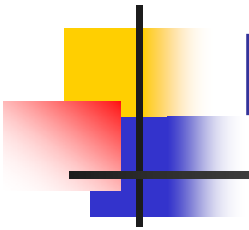
Cooperation protocols

- Basic strategy is to decompose and then distribute tasks
- Decomposition done by system designer or by agents
- Distribution criteria:
  - Avoid overloading critical resources
  - Assign tasks to agents with matching capabilities
  - Make an agent with a wide view assign tasks to other agents
  - Reassign tasks if necessary for completing urgent tasks ...
- Distribution mechanisms:
  - Market mechanism: generalized agreements or mutual selection
  - Contract net: announce, bid and award cycles
  - Multiagent planning: planning agents perform task assignment
  - Organizational structure: agents have fixed responsibilities

Blackboard systems

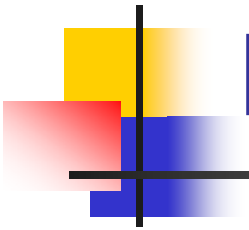
- Independence of expertise (knowledge sources)
- Diversity in problem solving techniques
- Flexible representation of information
- Common interaction language
- Event-based activation
- Need for control
- Incremental solution generation





Negotiation

- Occurs among agents with different goals to reach a joint decision
- Negotiation mechanism ideally:
  - Efficiency
  - Stability
  - Simplicity
  - Distribution
  - Symmetry

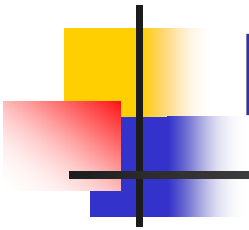


Multiagent belief maintenance

- Truth maintenance system (TMS) ensure the integrity of an agent's knowledge, which should be stable, well-founded and logically consistent
- Multiagent TMS assess and maintain the integrity of communicated information as well as of their own knowledge

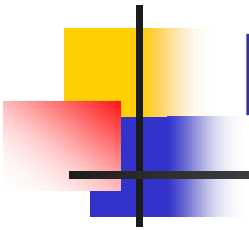
Market mechanism protocols

- Previous protocols require direct communications between agents, appropriate for small number of agents
- Computational economies are used for a large or unknown number of agents.
- Solve specific problems of distributed resource allocation based on “current prices”.
- Agents are either consumers (trading goods) or producers (transform goods into others)



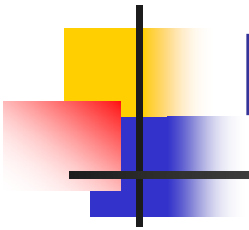
DAI- A multidisciplinary field

- AI, computer science
- Sociology
- Economics
- Organization and management science
- Philosophy



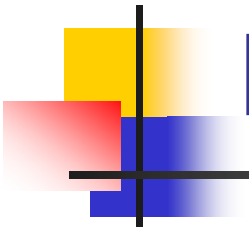
DAI research areas

1. Agent prespective
2. Group prespective
3. Specific approaches
4. Designer prespective



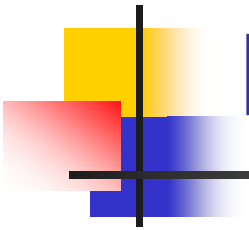
DAI - Agent perspective

- Agent categories
- Knowledge structure/maintenance
- Reasoning abilities
- Adaptation and learning abilities
- Agent architectures



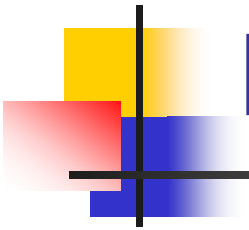
DAI - Group perspective:

- Organization, societies of agents
- Coordination and cooperation
- Negotiation
- Coherent behaviour
- Planning
- Communications (message passing, blackboards, human/machine interaction)



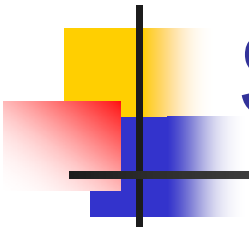
DAI- Specific approaches

- Open-systems science
- Eco-systems
- Autonomous/reactive agents
- Intelligent and cooperative information systems



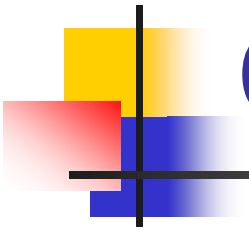
DAI- Designer's perspective

- Agent implementation techniques
- Testbeds
- Design tools
- Applications



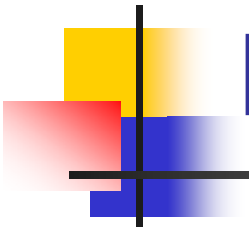
Summary

- Definitions of agents and DAI
- Agent architecture
- Communication
- Coordination
- Research directions for DAI



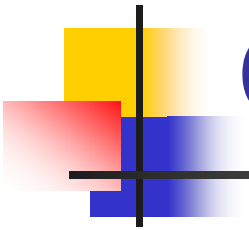
Conclusions

- Intelligent agents are autonomous systems that exist in a flexible environment that can be influenced by the agent
- There are several architectures for agents, including BDI and layered architectures
- Agents usually exist in a society of MAS
- Communication protocols enable agents to exchange and understand messages
- Interaction protocols enable agents to have conversations
- DAI is the study, construction and application of MAS
- DAI is a multidisciplinary field



References

- “Multiagent systems, a modern approach to distributed AI”, Gerhard Weiss, 2001.
- “Foundations of distributed artificial intelligence”, G.M.P. O’Hare, N.R. Jennigns, 1996.



Questions ?