

Seminar in Computer Science

Agent-based Applications

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Contents

- Agent-based Computing
- Agent-based Software Engineering
- Agent-based Programming Languages
- Agent-based Applications

Agents

- An agent is a computational entity which [IAG 2003]
 - Acts on behalf of other entities in an autonomous fashion
 - Performs its actions with some level of proactivity and/or reactivity
 - Exhibits some level of the key attributes of learning, cooperation and mobility.

Agents

- Act on behalf of others
- Autonomy
- Proactivity
- Reactivity
- Learning
- Cooperation
- Mobility

Agents

- We need software agents because
 - More and more everyday tasks are computer-based
 - The world is in a midst of an information revolution, resulting in vast amounts of dynamic and unstructured information
 - Increasingly more users are untrained
 - Therefore users require agents to assist them in order to understand the technically complex world we are in the process of creating.

Intelligent Agents Group

- Trinity College Dublin and Broadcom Ireland [IAG 2003]
- 3 research areas
 - Intelligent User Interfaces
 - Distributed Agent Technology
 - Mobile Agent Technology
- 3 main agent attributes
 - Learning, cooperation and mobility

Intelligent User Interfaces

- By adaptive IUI attempt to modify their behavior to maximize the productivity of the current user's interaction with the system.
 - Such adaptation must be based on information gathered concerning the current users behavior.

Intelligent User Interfaces

- Interesting questions
 - What aspects of the user's behavior are useful to capture?
 - What information such behavior gives us on the actual intentions and preferences of the user?
 - What use can be made of any such information captured?

Intelligent User Interfaces

- Intelligent (User) Interface Agents
 - The major factors that distinguish Interface Agents from any other IUI
 - Agents are proactive and enjoy a degree of autonomy.
 - Examples: information filtering

Distributed Agent Technology

- Distributed AI (DAI) is a sub-field of AI which is concerned with a society of problem solvers or agents interacting in order to solve a common problem: computers and persons, sensors, aircraft, robots, etc.
- Multi-Agent System (MAS)
 - A NW of problem solvers that work together to solve problems that are beyond their individual capabilities.

Distributed Agent Technology

- Multi-Agent System (MAS)
 - Solve problems that may be too large for a centralized single agent
 - Provide enhanced speed and reliability
 - Tolerate uncertain data and knowledge
- Distributed problem solving by agents in a MAS involves
 - Coordination
 - Negotiation
 - Communication

Distributed Agent Technology

- In a MAS, agents must
 - Communicate among agents
 - Coordinate their activities
 - Negotiate once they find themselves in conflict

Distributed Agent Technology

- In a MAS, among agents
 - **Conflicts** can result from simple limited resource contention to more complex issue-based computation where the agents disagree because of discrepancies between their domains of expertise.
 - **Coordination** is required to determine organizational structure among a group of agents and for task and resource allocation.
 - **Negotiation** is required for the detection and resolution of conflicts.

Mobile Agents

- A mobile agent is a software entity which exists in a software environment.
 - It inherits some of the characteristics of an agent.
 - A mobile agent must contain all of the following models:
 - An agent model, a life-cycle model, a computational model, a security model, a communication model, a navigation model

Mobile Agents

- A mobile agent environment is built top of a host system.
- Mobile agents travel between mobile agent environments.
- Mobile agents can communicate each other either locally and remotely.
- Communication can also take place between a mobile agent and a host service.

Mobile Agents

- A mobile agent environment is a software system which is distributed over a NW of heterogeneous computers.
 - Its primary task is to provide an environment in which mobile agents can execute.
 - The mobile agent environment implements the majority of the models which appear in the mobile agent definition.

Mobile Agents

- A **mobile agent environment** may also provide
 - Support services which relate to the mobile agent environment itself
 - Support services pertaining to the environments on which the mobile agent environment is built
 - Services to support access to other mobile agent systems
 - Support for openness when accessing non-agent-based SW environment

Detailed Survey

- Intelligent User Interfaces
- Distributed Agent Technology
- Mobile Agent Technology

Intelligent User Interfaces

- To clarify exactly what is meant by the term "Intelligent Interface Agents"
- Adaptive user interfaces
 - Attempt to modify their behavior to maximize the productivity of the current users interaction with the system
 - Which **aspects** of the user's behavior is it useful to capture?
 - What information does such behavior gives us on the **actual intentions and preferences** of the user?
 - Finally, what use can be made of any such information captured?

Intelligent User Interfaces

- Intelligent interface agents
 - Autonomy
 - Proactive
 - Assisting the user in communicating their task to the rest of the system
 - Learning the user profile
 - Selecting for presentation components of the system's functionality

Intelligent User Interfaces

- Bates, Carnegie-Melon Univ.
 - OZ project, Human emotions, virtual reality
 - <http://www-2.cs.cmu.edu/afs/cs/project/oz/web/oz.html>
- Schneiderman, Univ. of Maryland
 - HCI
 - <http://www.cs.umd.edu/~ben/>
- Maes, MIT
 - Agent-based software
 - <http://agents.media.mit.edu/>

Distributed Agent Technology

- **Distributed AI (DAI)** is concerned with problem solving in which groups of agents solve tasks.
- **Multi-Agents Systems**
- **Distributed Problem Solving (DPS)**
- Research topics
 - Coordination
 - Negotiation
 - Communication

Distributed Agent Technology

- **DAI** is a sub-field of AI which has been investigating knowledge models, as well as communication and reasoning techniques that computational agents might need to participate in societies composed of computers and people.
- **DAI** is concerned with a society of problem solvers or agents interacting in order to solve a common problem: computers, persons, sensors, aircraft, robots, etc.

Distributed Agent Technology

- Such a society of problem solvers (agents) is termed a **Multi-Agent System**, which can be defined as "a loosely-coupled network of problem solvers that work together to solve problems that are beyond their individual capabilities".

Distributed Agent Technology

- The motivation for the increasing interest in MAS research includes their ability:
 - To solve problems that are too large for a single centralized agent to solve due to resource limitations or the risk of having one centralized system
 - To allow for the interconnecting and interoperation of multiple existing legacy systems, e.g., expert systems, decision support systems, etc.

Distributed Agent Technology

- To provide solutions to inherently distributed problems, e.g., air traffic control
- To provide solutions which draw from distributed information sources
- To provide solutions where the expertise is distributed, e.g., in health care provisioning

Distributed Agent Technology

- To enhance **speed** (if communication is kept minimal), **reliability** (capability to recover from the failure of individual components, with graceful degradation in performance), **extensibility** (capability to alter the number of processors applied to a problem), **the ability to tolerate** uncertain data and knowledge
- To offer conceptual clarity and simplicity of design

Distributed Agent Technology

- **Cooperative** Distributed Problem Solving or **Cooperative** Multi-Agent Systems (CMAS)
 - Designed by a single designer
 - Concerned with increasing the general system's performance
- **Self-Interested** Multi-Agent Systems (SMAS)
 - Individually motivated agents designed by independent designers
 - Self-interested, competitive or non-cooperative
 - May exhibit antagonistic behavior

Distributed Agent Technology

- Research in different types of multi-agent systems
 - Bond and Gasser (1998)
 - Rosenschein and Zlotkin (1994)
 - Genesereth et al. (1986)
 - Rosenschein and Genesereth (1985)

Distributed Agent Technology

- The problem solving performed by agents in a MAS is termed **Distributed Problem Solving (DPS)** and involves research in the areas **coordination**, **negotiation** and **communication**.
- In order to solve common problems coherently, the agents must
 - **Communicate** amongst themselves
 - **Coordinate** their activities, and
 - **Negotiate** once they find themselves in conflict.

Distributed Agent Technology

- **Coordination** is central to a MAS, for without it, any benefits of interaction vanish and the group of agents quickly degenerates into a collection of individuals with a chaotic behavior.
 - Why coordinate?
 - Prevent chaos
 - Meet global constraints
 - Posses different capabilities and expertise
 - Interdependent actions

Distributed Agent Technology

- Negotiation techniques
- Agents use negotiation for conflict resolution and hence coordination.
- There is no common and clear definition of what negotiation is.
- Bussmann and Muller (1992)
 - Negotiation is the communication process of a group of agents in order to reach a mutually accepted agreement on some matter.
- Negotiation is reaching a consensus.

Distributed Agent Technology

- Stronger definitions on **negotiation** argue that **in order to negotiate effectively**, agents must **reason about beliefs, desires and intentions of other agents** [Rao and Georgeff 1995].
 - Lead to the usage of all sorts of AI and mathematical techniques including logic, case-based reasoning, belief revisions, distributed truth maintenance, optimization and game theory

Distributed Agent Technology

- **Negotiation** can be **competitive** or **cooperative**.
- **Competitive** Negotiation in a SMAS
 - Involves independent machines with independent goals that interact with each other
- **Cooperative** Negotiation in a CMAS
 - Centrally designed to pursue a single global goal

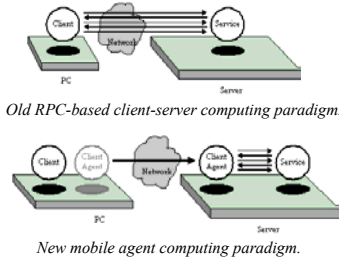
Distributed Agent Technology

- To achieve **coordination**, agents
 - Might have to **negotiate**, however, they
 - Must **interact and exchange information**
 - Agents need to **communicate**
- Need to understand a **communication language**

Mobile Agent Technology

- A mobile agent is a program that can migrate from machine to machine in a heterogeneous network.
 - A mobile agent chooses when and where to migrate.
 - A mobile agent can suspend its execution at an arbitrary point, transport itself to another machine and resume execution.

Mobile Agent Technology



Mobile Agent Technology

- Mobile agents research
 - Distributed systems [Cardelli 1995]
 - Itinerant agents [Chess et al. 1995]
 - Transportable agents [Kotz et al. 1996]
 - Re-locatable objects [Joseph et al. 1995]
 - White (1995)
 - Nwana (1996)

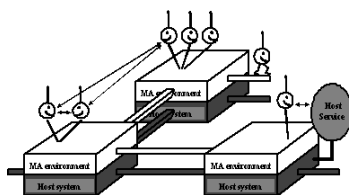
Mobile Agent Technology

- Essence of a mobile agent system
 - A **mobile agent** is a software entity which exists in a software environment.
 - It inherits some of the characteristics of an agent.
 - A mobile agent must contain all of the following models:
 - an agent model, a life-cycle model, a computational model, a security model, a communication model, a navigation model

Mobile Agent Technology

- A **mobile agent environment** is a software system which is distributed over a network of heterogeneous computers. Its primary task is to provide an environment in which mobile agents can execute. The mobile agent environment implements the majority of the models which appear in the mobile agent definition. It may also provide: support services which relate to the mobile agent environment itself, support services pertaining to the environments on which the mobile agent environment is built, services to support access to other mobile agent systems, and finally support for openness when accessing non-agent-based software environment.

Mobile Agent Technology



Basic mobile agent architecture

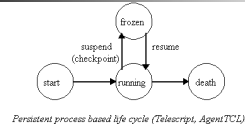
Mobile Agent Technology

- Agent model
 - Defines internal structure of the intelligent agent part of a mobile agent
 - Autonomy, learning and cooperative characteristics
 - Reactive and proactive nature

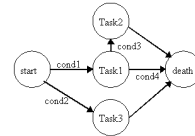
Mobile Agent Technology

- Life-cycle model
 - Defines the different execution states of a mobile agent and the events that cause the movement from one state to another
 - Close related to the computational model which describes how the execution occurs
 - Life-cycle models
 - Persistent process model, Telescript [White 1995] and AgentTCL [Kotz et al. 1996]
 - Task based model, Aglets [Chang and Lange 1996]

Mobile Agent Technology



Persistent process based life cycle (Telescript, AgentTCL).



Task based life cycle (Aglets).

- Persistent process model, Telescript [White 1995] and AgentTCL [Kotz et al. 1996]

- Task based model, Aglets [Chang and Lange 1996]

Mobile Agent Technology

- Computational model
 - Defines how a mobile agent executes when it is in a running state
 - Ousterhout (1994), Lindholm et al. (1996)
 - The computation takes place in an environment and is facilitated by some form of processor.
 - A set of primitive instruction must be specified – this defines the computational abilities of an agent – data manipulation/thread control instructions

Mobile Agent Technology

- Security model
 - Mobile agent security can be split into two broad areas [Chess 1996].
 - Protection of host nodes from destructive mobile agents
 - Protection of mobile agents from destructive hosts

Mobile Agent Technology

- Security model
 - Protection of hosts from malicious agents
 - Attacks on host security
 - Leakage (unauthorized acquisition), tampering (alteration), resource stealing, vandalism (malicious interfaces)
 - Various degree of granularity
 - Process (agent) safety and security, system safety, network security
 - Protection of agents from malicious hosts
 - Protect not to scan the agent for information, alter the agents state or code, or kill the agent

Mobile Agent Technology

- Communication model
 - Communication with other entities: users, other agents (static or mobile), host mobile agent environment, other systems (CORBA, DCOM, .NET, etc.)
 - Communication is used when accessing services outside of the mobile agent, during cooperation and coordination between mobile agents and other entities, and finally to facilitate competitive behavior between self-interested agents.
 - A protocol is an implementation of a communication model.
 - Email, RPC, KQML



Mobile Agent Technology

- Navigation model

- Concerns about all aspects of agent mobility from the discovery and resolution of destination hosts to the manner in which a mobile agent is transported
- Naming conventions for all entities (agents, hosts, services)
- Access to information regarding a remote mobile agent environment
- The ability to move a mobile agent into a suspended life-cycle state ready for transportation to a remote host
- The ability to transport a mobile agent, which is in the suspended state, to a remote mobile agent environment
- The ability to receive a suspended mobile agent from a remote host and reconstitute it in a new environment



References

- Acknowledgement

- These notes are summarized mainly from the following references.
- Intelligent Agents Group (IAG), Trinity College Dublin and Broadcom Ireland, Software Agents: A review, http://www.cs.tcd.ie/research_groups/aig/iag/iag2.html, 2003.
- Intelligent Agents Group (IAG), Trinity College Dublin and Broadcom Ireland, Intelligent Agents in Telecommunications, http://www.cs.tcd.ie/research_groups/aig/iag/tereport.html, 2003.
- Intelligent Agents Group (IAG), Trinity College Dublin and Broadcom Ireland, A Survey on Intelligent Agents in Telecommunications, http://www.cs.tcd.ie/research_groups/aig/iag/survey.html, 2003.