Medical applications of Multi-Agent Systems

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Overview of the talk

• Agents and Multi-Agent Systems
• Applying MAS to Health Care problems
• Exemplar applications
  – Management of organ transplants
  – Ubiquitous access to medical information
  – Management of palliative patients
• Conclusion
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Intelligent agents

• One of the most exciting fields within Artificial Intelligence.

• A **software agent** is a program that applies Artificial Intelligence methods and techniques to decide, autonomously, which is the best course of action to follow in order to try to accomplish a set of goals.
Agent properties

• Autonomy
• Reactivity
• Proactiveness
• Reasoning/Planning
• Learning
• Social ability
Multi-agent systems

- A **multi-agent system** is a set of autonomous agents that can communicate (exchange information) and thus negotiate and cooperate in the joint solution of a distributed problem.
Domains of application of MAS

- Distributed knowledge
- Joint effort of a set of autonomous entities
- Problem decomposable in subproblems
  - Possibly inter-dependent
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Health Care problems

• Distributed knowledge
  – E.g. different units of a hospital

• Coordinated effort
  – E.g. receptionist, general and specialised doctors, nurses, tests personnel, ...

• Complex problems
  – E.g. organ transplant management

• Great amount of information
  – E.g. medical information in Internet
MAS applied to HC problems

- Distributed system
- Social ability
- Distributed problem solving
- Information agents
- Proactivity
- Autonomy

- Distributed knowledge
- Cooperation
- Decomposition of a complex problem
- Access to medical information
- Proactive and personalised info.
- Modelling independent entities
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Finding the most adequate receiver

*Spanish Model*

Process defined by the Spanish Transplant Organisation (ONT)

- 0-Emergency Patients in all Spain
- Donor’s hospital
- Other hospitals in the same city
- Other cities of the same region
- Other regions of the same zone
- Rest of Spain
Analysing and ranking the patients

- Filtering and ranking
  - *Multi-Criteria Decision Aid* techniques
- Some of the considered criteria:
  - *Type of organ*: exact matching
  - *Blood type*: some compatibilities
  - *Age, weight & size*: maximum difference
  - *Waiting time*
MASs involved in the transplant management process

• Hierarchical MAS for finding the most appropriate recipient of an organ
• MAS for determining the fastest transport route for the organ
• MAS for scheduling the human/material resources needed to perform the transplant operation
Implementation details

• Written in JADE (FIPA compliant)
• Developed by URV undergraduate students
• Different MASs that should be integrated
• All the agents of the MAS are running in the same computer
Advantages of this system

• We can guarantee the autonomy of each entity: coordinators, hospitals, ...
• Agents behave following ONT’s search model
• The system is distributed, flexible and extensible
• It would save time, and the transplants results should be better
• We ease the work of the transplant coordinator that selects the receiver
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AgentCities.NET

- **AgentCities**: European project that aims to build a network of open systems that provide intelligent services associated to a city.

  www.agentcities.org/EUNET

- Our problem: to allow citizens and visitors of a city to have easy, flexible and secure access to medical information
Services provided by the MAS

• Searching appropriate medical centres

• Booking a visit to a doctor

• Management of medical records
  – Access by patients
  – Access and update by doctors during examination
Searching appropriate medical centres

• Search constraints:
  – String in the medical centre’s name
  – City of the medical centre
  – Presence of a certain department

Output ordered with respect to distance to the user’s location
Booking a visit to a doctor

- We provide the *kind of problem*, its *urgency*, and a *problem’s description*
- The centre begins a *negotiation with the doctors* in order to find the best option to the user (the visit that can be made sooner)
Medical Ontology

• Represent knowledge about medical centres, departments, doctors, medical visits, ...

• Study of medical ontology standards
  – UMLS, HL7, OpenGALEN, ASTM, ...

• The new ontology is implemented in RDF, and is available at the project’s home page:
  http://grusma.etse.urv.es/~agentcities/
Security mechanisms

• The system is implemented in Jade 2.61, with the addition of the Jade-S security plug-in.

• Messages are encrypted by Jade-S, using a method based on SSL.

• Personal agents only can communicate with the Personal_Broker, that controls the access the medical system.

• Authentication mechanism based on a PKI, using the RSA algorithm.
Summary of the system

- MAS fully implemented in Jade 2.61
- New ontology designed and implemented in RDF
- Implementation of security measures that ensure the confidentiality of medical data
- Services available at a platform of the AgentCities network
- Work awarded two prizes at the AgentCities Agent Technology Competition
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PalliaSys Project

• Integration of Information Technologies and Multi-Agent Systems to improve the care given to palliative patients.
• Work conducted between the Research Group on Artificial Intelligence at URV and the Palliative Care Unit of the Hospital de la Santa Creu i Sant Pau of Barcelona.
Palliative care

- Palliative patients are in a very advanced stage of a fatal disease. The aim of their care is to ease their pain.
- These patients may be located in hospitals (Palliative Care Units-PCU), specialised hospice centres or at their own homes.
Aims of the Palliasys project

• To improve the process of collecting information from the palliative patients.
• To improve the access to this information by patients and doctors.
• To help to schedule the tasks of the doctors of the PCU.
• To monitor the state of the patients.
• To apply intelligent data analysis techniques on the data of the PCU.
Information collection (I)

- Patients have to send periodically non-technical information relative to their state (weakness, pain, dizziness, medicines and food taken, etc).
  - By sending SMS messages with mobile phones.
  - By sending electronic messages (e-mails).
  - By filling forms in web pages.
Information collection (II)

• We plan to associate an agent to each bed in the PCU, that can periodically send information about the patient status.
• A doctor may also send information to the system when he is performing a home visit, through an agent running on a PDA.
Information access

• All the data of the palliative patients is stored in a central Data Base at the PCU of the hospital.

• Patients and doctors may also make queries on the stored information using any Information Technology (SMS, e-mail, web page, wireless communication through PDAs).
Data Base at the PCU

• All the data of the patients and doctors (and also their queries) are received by an agent called **Communicator Manager**, that forwards this information to an agent that controls the access to the Data Base (the **DataBase Wrapper**). This agent has to implement security mechanisms to protect the privacy of the medical data.
Patient agents

- There is a patient agent associated to each palliative patient.
- It has to continuously monitor the status of the patient, and send reminders/alarms to the doctor associated to the patient if something goes wrong.
  - The patient reports increasing pain.
  - The patient fails to send a periodic report.
Doctor agents

• A **doctor agent** is an agent associated to each doctor of the PCU, which would be running in the doctor’s desktop computer.

• It provides a graphical interface to help:
  – Manage the schedule of the doctor.
  – Request information about his patients.
  – Receive alarms from patient agents.
PCU Coordinator

- The **PCU Coordinator** provides a gateway between the information received by the Communication Manager and Doctor Agents.

- It should know which is the doctor responsible of each patient, so that it can forward requests properly.
Intelligent Data Analysis

- The **Data Analyser** applies *Data Mining* and *Machine Learning* techniques to analyse the information of the Data Base.
  - Generation of patient models (e.g. *Clustering*).
  - Generation of models of patient evolution.
    - Possibility of making predictions on future states and anticipate and prevent undesired situations.
  - Generation of medical protocols (from patient and evolution models).
Conclusion - Main ideas

• Information technologies and Intelligent agents may be used to build useful systems in the Health Care domain.
• The PalliaSys system, which has just started, is an example of such a system.
• Most of the ideas underlying this project may be also applied in elderly care or home care.
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Adequacy of MAS to HC

• We can model autonomous proactive entities, who can communicate between themselves to cooperate in the joint resolution of a distributed complex problem.
MAS and Health Care

- Special issue of *AI in Medicine* (March 2003)
- Special issue of *AI Communications* (end 2003)
  - Workshop at *European Conference on AI 2002*
- Workshop at *Autonomous Agents 2000*
- International Workshop on Applications of Intelligent Agents in Health Care (February 2003)
  - Volume of WhiteStein Series on Agent Technology, Ed. Birkhäuser
- *AgentCities WG on HealthCare Applications*
  [http://wwwcms.brookes.ac.uk/hcwg/](http://wwwcms.brookes.ac.uk/hcwg/)
Some research topics on the use of MAS in Health Care

• Communication standards
• Medical ontologies
• Security mechanisms
• Implementation of agents in mobile devices
  – PDAs, mobile phones
• Personalised access to information
  – Less social and professional reluctance to adopt agent technology
• Legal issues
General research topics on MAS

• Service description
• Service discovery
• Service composition
• Standard agent communication languages and protocols
• Trust
• Human-agent interaction
• Integration with legacy software
• ...

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