



# ATRACO

Adaptive and Trusted Ambient Ecologies

## PROJECT OVERVIEW

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# Adaptive Intelligent Environments

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- Intelligent environments (IEs) are (usually closed) spaces equipped with a variety of sensors, devices and services.
  - Applications are formed as compositions of devices or orchestrations of the services
  - The high degree of heterogeneity of these components makes their configuration and maintenance as part of an integrated system a non-trivial task
- After the first IEs have been developed and tested, research is gradually shifting towards the development of adaptation mechanisms, in order to
  - Enhance people's trust in the system
  - Help people achieve their goals in a better way

# Our standpoint

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- Compared to previous research, we adopt a unique standpoint in that we assume that
  - (a) various IEs are available, and
  - (b) devices and services of an IE
    - (1) are inherently heterogeneous and
    - (2) as such contain heterogeneous descriptions of their capabilities and services that can only be accessed from but not modified by other components.
- In **ATRACO** we propose an ontology-based adaptation approach, which can be tailored to the task description, applied by intelligent agents that realize task execution, and maintained dynamically by re-calculating on-demand the interfaces between the constituent local ontologies.

- In order to achieve realization of tasks by orchestrating IE services, one has to deal with the heterogeneity of IE components, while at the same time achieving independence between a task description and its respective realization within a specific IE
  - ▣ To this end, we employ ontology alignment mechanisms
- Moreover, the system aims to establish only a transient collaboration between resource of an IE in order to support a specific user activity in changing context
  - ▣ In order to achieve this, we use a set of intelligent agents to support adaptive planning, task realisation and enhanced human-system interaction

# The ATRACO Consortium

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- The German *Ulm University* is Project Leader  
Fields of Interest: Reasoning & Planning, Privacy & Trust, Speech Dialogue Management
- *University of Essex* in the UK  
Fields of Interest: Computational Intelligence (Fuzzy Systems, Neural Network, Evolutionary Computation), Social Sciences and Technology
- *Research Academic Computer Technology Institute* in Greece  
Fields of Interest: Ubiquitous Computing Systems Architectures, Semantic Modelling And Ontology Matching
- The *Computer Sciences Laboratory for Mechanics and Engineering Sciences* in France  
Fields of Interest: Adaptive Dialogue, Multimodal Interaction
- *inAccess Networks* in Greece  
Fields of Interest: Home Controllers, Network Adaptation

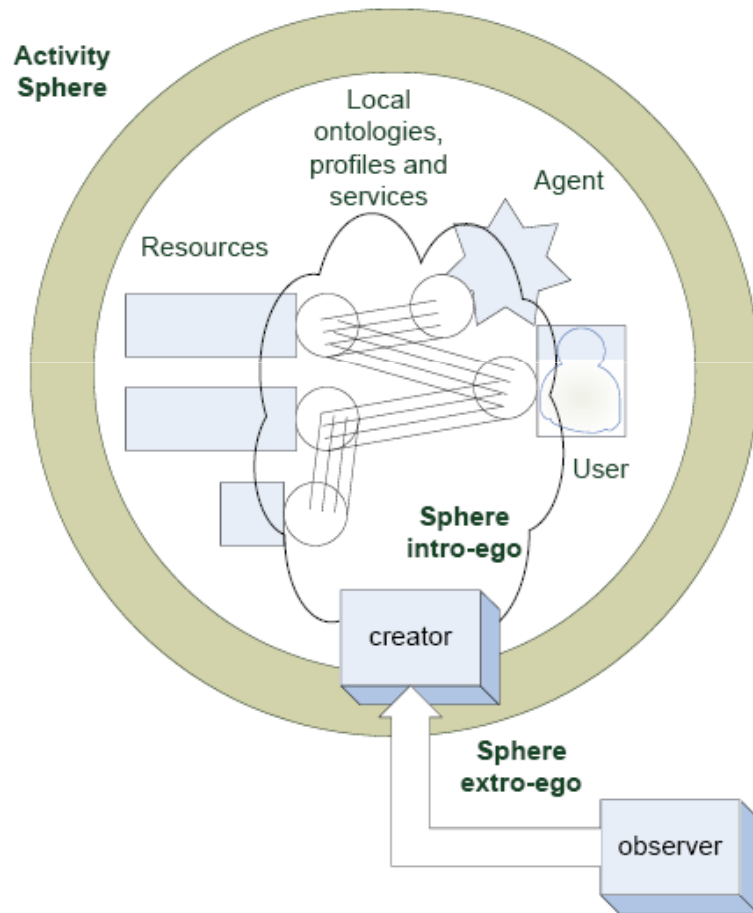
# Basic concepts

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- At the basis of our approach is the assumption that the end-user(s) want(s) to fulfil aims or goals such as *feel comfortable, go shopping or prepare dinner*.
- These goals are composed of a number of interrelated tasks and subtasks, each requiring the use of resources from an ambient ecology.
- Goals and tasks are independent from any ecology, but always must be realized within some ecology.
- The realization of a goal requires the binding of ecology resources to the goal-specific tasks.

# Activity spheres

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- For each goal, an activity sphere is formed.
- The formation of activity spheres is supported by a service-oriented ambient ecology architecture, which includes
  - ▣ APIs to interface with existing hardware modules and communication protocols,
  - ▣ ontologies and ontology management modules,
  - ▣ decision making mechanisms, planning modules,
  - ▣ negotiation and learning mechanisms,
  - ▣ intelligent agents,
  - ▣ trust policies and privacy enforcement mechanisms and
  - ▣ compose-able interaction components.

# The ATRACO architecture

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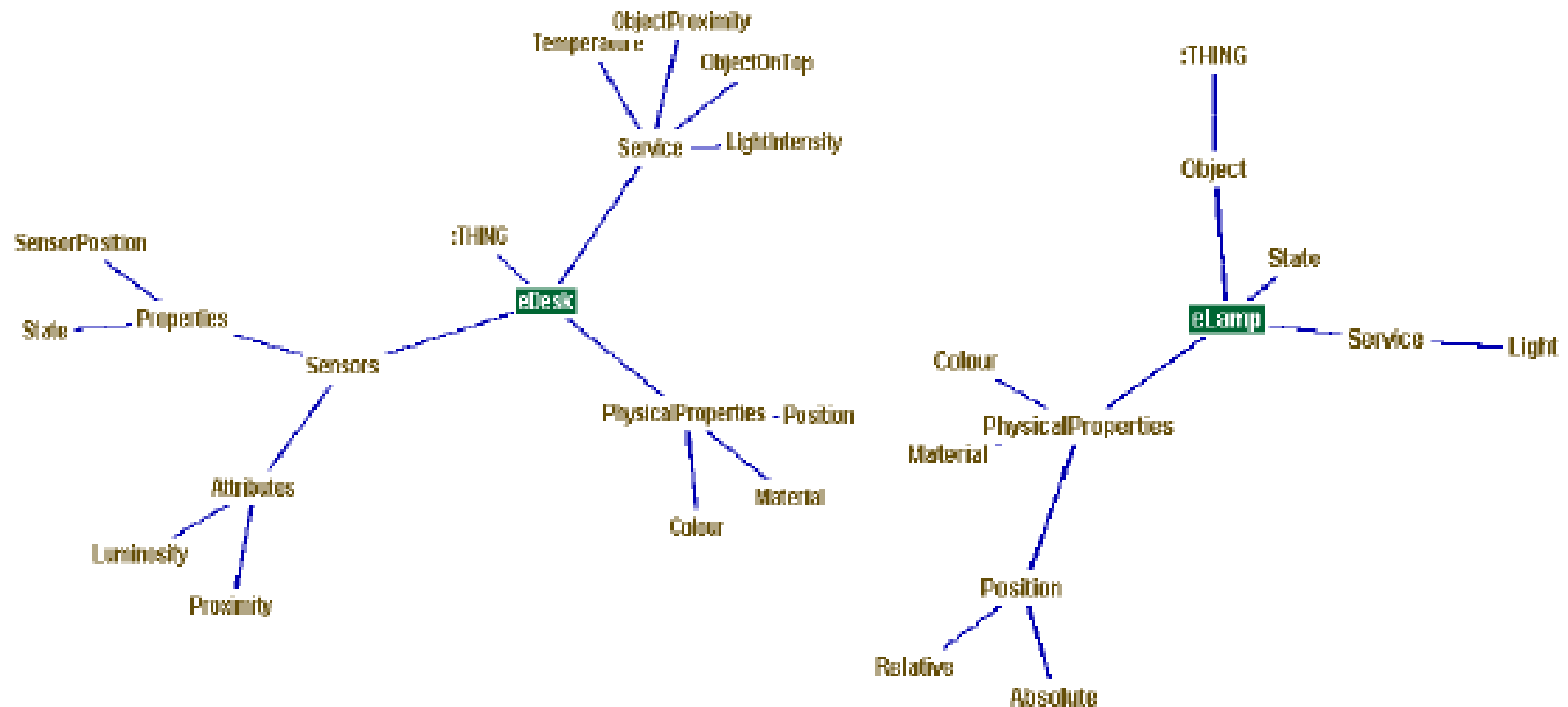


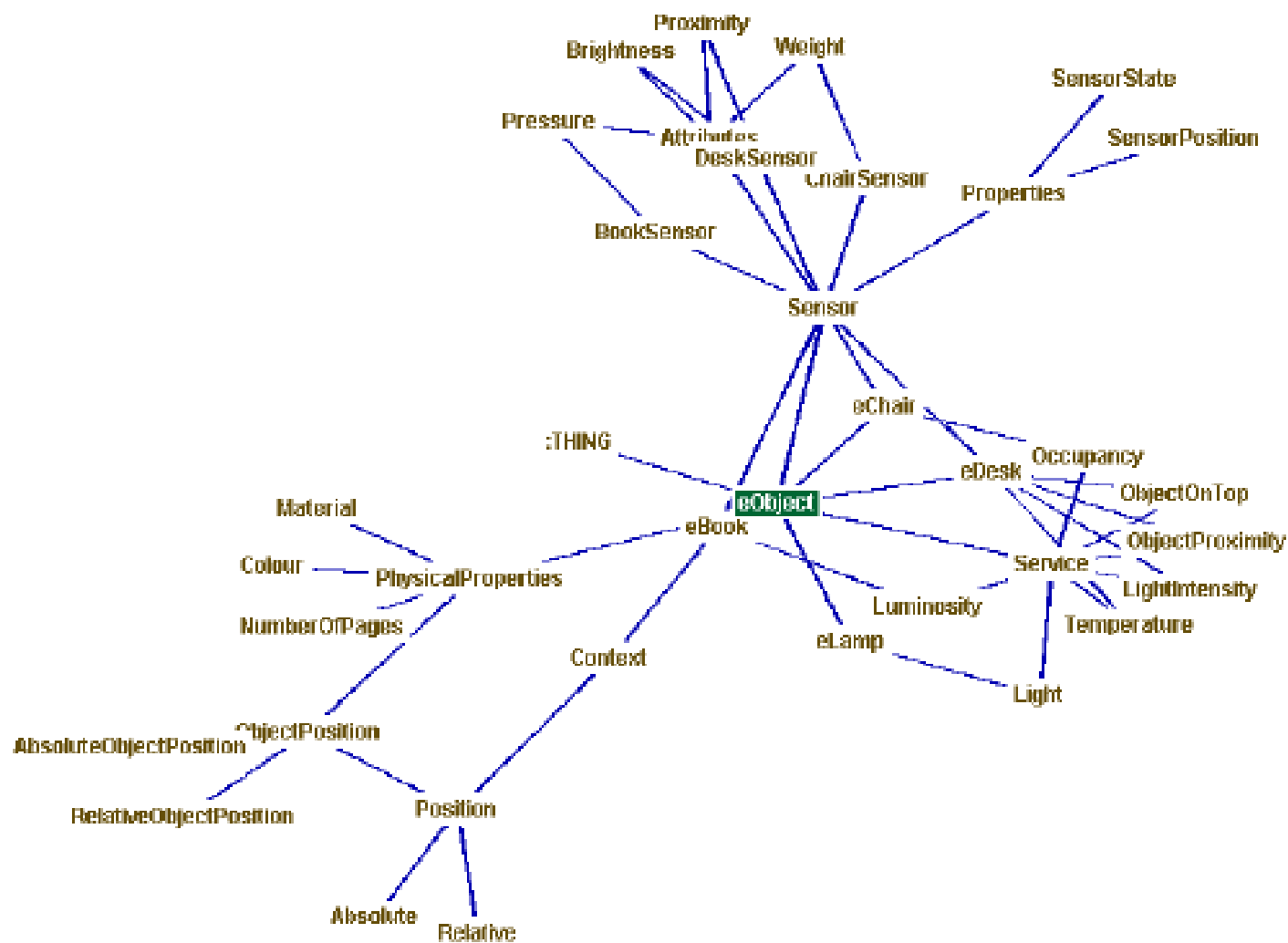
- Each activity sphere is realized as a ubiquitous computing application based on a service oriented approach.
- Each sphere consists of:
  - ▣ **Active entities**, which manage the binding or resources, allocate and realize the tasks and manage knowledge and information exchange
    - Ontology manager
    - Sphere manager
  - ▣ **Passive entities**, which provide services and local knowledge
  - ▣ **Intelligent agents**, which realize adaptation
    - Planning agent
    - Fuzzy Task agent
    - Interaction agent
  - ▣ **Ontologies**, which encode global and local knowledge and state-related information
    - Sphere ontology

# The role of ontologies

- An ontology is a structure of knowledge, used as a means of knowledge sharing within a community of heterogeneous entities.
- Activity sphere ontologies:
  - **Local ontologies** are provided by both active and passive entities and encode their state, properties, capabilities and services.
  - The **user profile**, as the user is at the centre of each activity sphere.
  - **Policy ontologies**, representing privacy, interaction, etc.
  - **Interaction ontology**, which describes the elements of domain independent context aware interaction
  - The **sphere ontology**, an information and knowledge pool which is constantly evolving and being updated. Different ways of forming this ontology are possible, by aligning, merging and mapping of entities' local ontologies.
- In ATRACO, we avoid merging ontologies, as the merged ontology would have to evolve independently of the local ontologies.

# Sphere ontology





# Passive and active entities

- **Passive entities:**
  - **Devices** such as interaction devices (touch screens, speakers, microphones, etc.), actuators and sensors including televisions, radio receivers and HVACs, etc.
  - **Services** such as remote or external web-services (e.g., online banking) and local or internal services (e.g., personal calendar).
- **Active entities:**
  - The **ontology manager** is responsible for keeping the sphere ontology up-to-date and for handling events within the sphere.
  - The **sphere manager** is responsible for the formation, the integration into and releasing from activity spheres of passive entities as well as the spheres' dissolving.

# Agents

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- Agents are responsible for automated adaptation, resolving conflicts, interacting with the user, establishing plans and in general realizing the concrete tasks in the task model.
- Three types of agents are used:
  - Planning agent
  - Fuzzy Task Agent
  - Interaction Agent

# Planning agent

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- The Planning Agent (PA) is able to solve combinatorial problems that have a relative small number of consistent plans (solutions) with respect to all possible plans.
- Its aim is to resolve all goals into concrete tasks given a specific ecology.
- During the reasoning process or the evolution of the sphere, a situation may occur, that may require re-planning or where the user input is needed
  - ▣ Direct user-system interaction will then be initiated by involving the Interaction Agent.

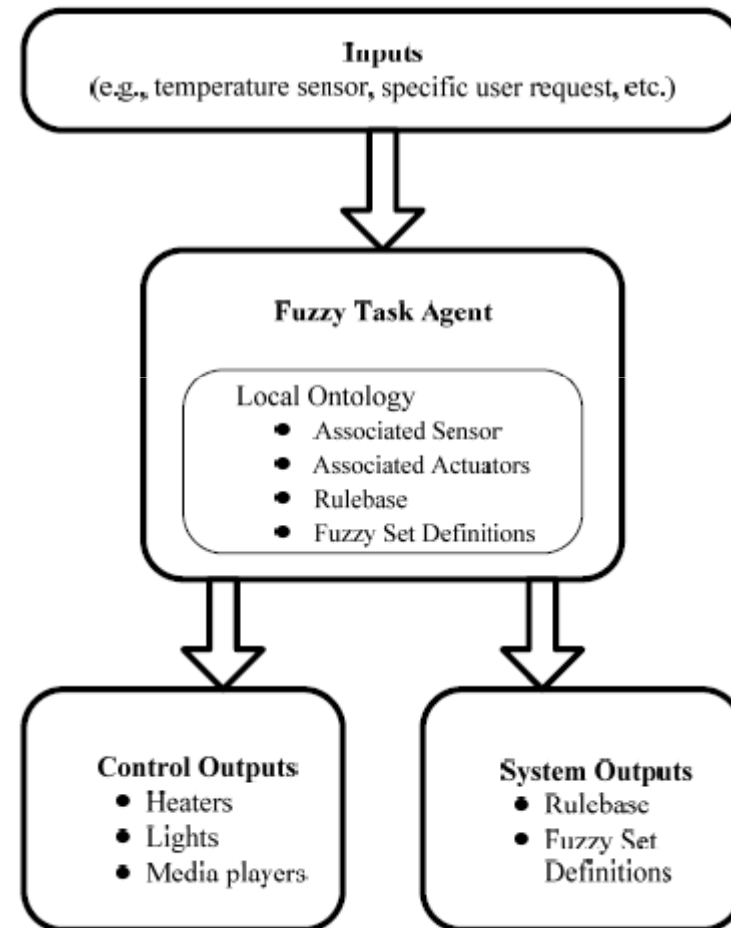
# Fuzzy task agent

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- The Fuzzy Task Agent (FTA) is responsible for the realization of one concrete task.
- The FTA is associated with the input entities (e.g. sensors) and output entities (e.g. actuators) which have been identified by the PA in order to realize the current task.
- If a specific task has previously occurred, the FTA will incorporate any rule sets and fuzzy set definitions which have previously been defined and stored in local ontologies of the respective involved entities (e.g. the user).
- If the task is considered novel, the FTA will start monitoring the entities it has been associated with for a specified amount of time, recording the combination of their individual states as they change within the ecology (e.g. heater setting modified by user, temperature sensor, etc.).
- After the monitoring phase is complete, the recorded set of input-output combinations is evaluated and a number of fuzzy membership functions are created which model the individual states of the entities. The number of fuzzy membership functions as well as the linguistic labels for each of these functions is retrieved from the sphere ontology.

- After the fuzzy sets have been created, a rulebase, which incorporates the different input-output mappings from the gathered data and applies them to the fuzzy sets, is generated.
- During its operation, the FTA continually monitors the entities which are associated with its inputs and controls the entities associated with its outputs according to its rulebase which is constantly adapted.

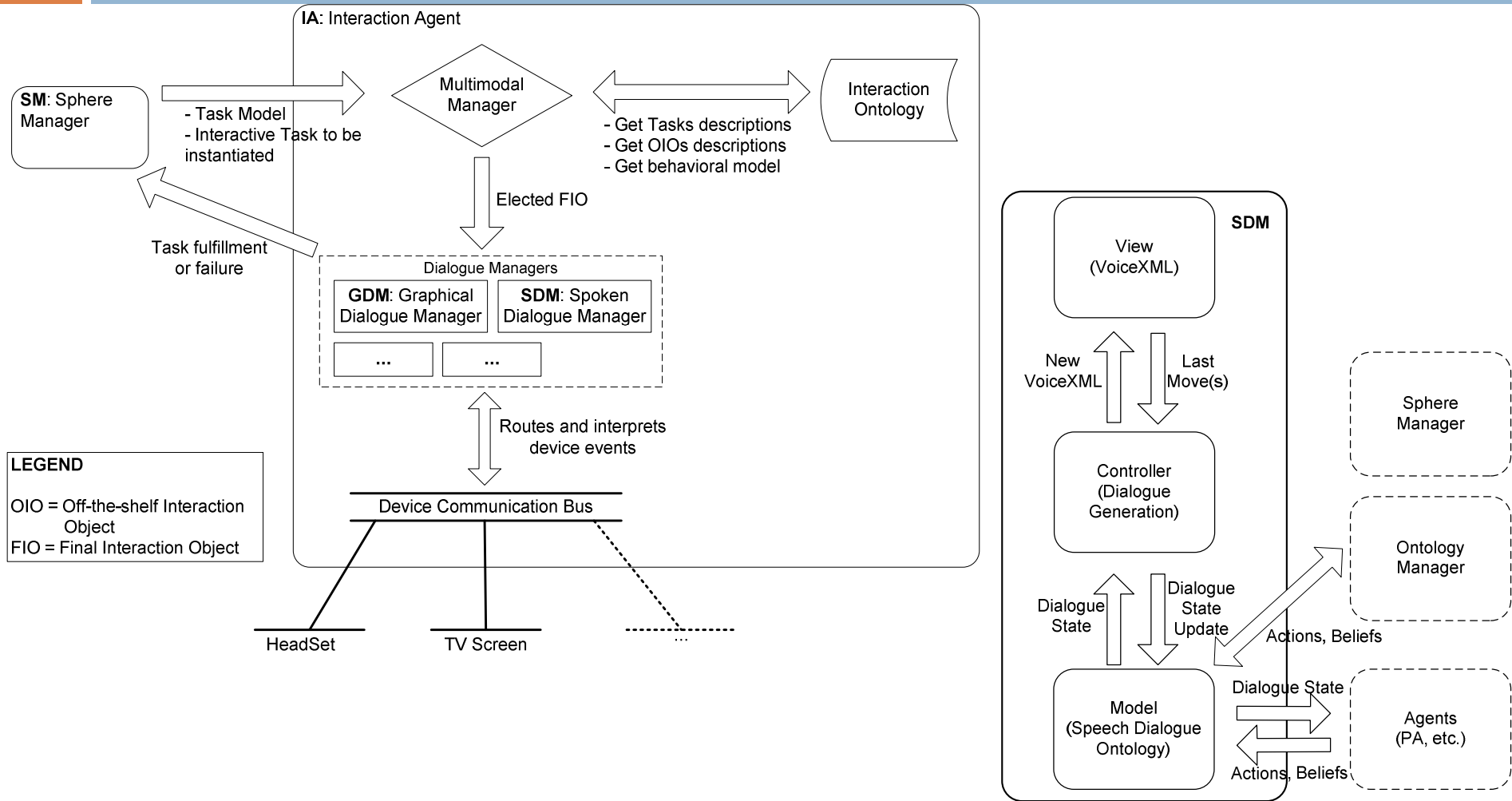


# Interaction agent

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- The Interaction Agent (IA) is responsible for the direct interaction between the user and the system within the current ecology.
- It is in charge of the interpretation of the messages produced by the user and the presentation of messages produced by the system (through the PA).
- Different communication modalities may be used, either by the user or the IA, to express messages (speech, touch buttons, text, graphics, avatars, etc.). The IA has to determine the best means of interaction (modalities and devices) according to the current ecology.
- The IA consists of
  - ▣ The Multimodal Manager (MM) that is responsible to decide which modes and modalities should be instantiated by the use of which media and how, and
  - ▣ The Spoken Dialogue Manager (SDM) that is dedicated to provide a coherent rich spoken dialogue that enables evolution of an ongoing dialogue
- The IA uses an interaction ontology to identify the best interaction components (modalities and devices) with respect to the interaction task and the current ecology



# Five dimensions of adaptation

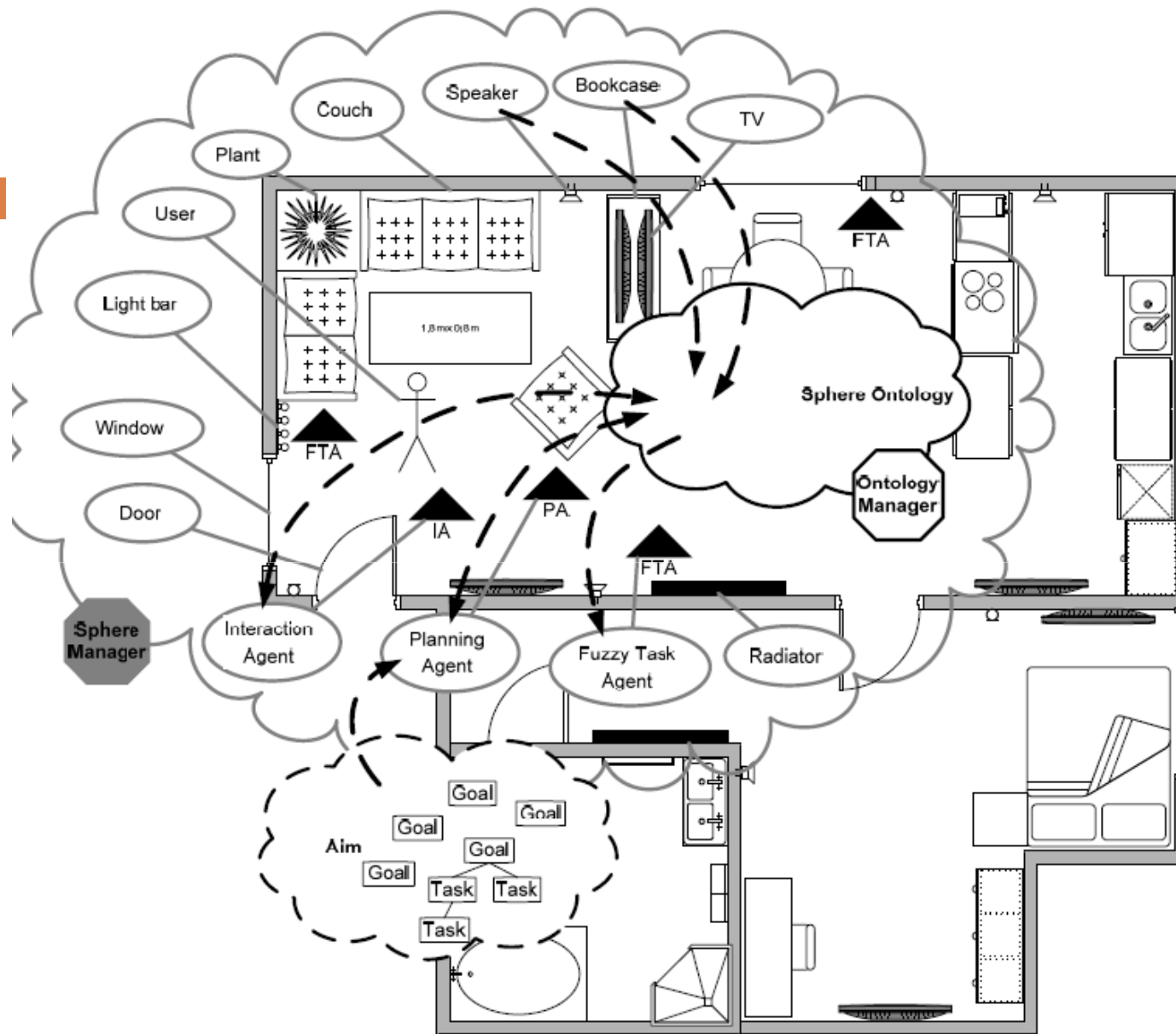
- **Artifact adaptation:** is related to artifact behaviour adaptation in the context of a task/goal. ATRACO will realize a set of strategies based on general type-2 fuzzy sets that will allow the artifacts to adapt to the uncertainties associated with the changes in the artifacts characteristics and context as well as changes in the user(s) preferences regarding these artifacts and their operation.
- **User behavior adaptation:** describes the system capability to adapt the developed user model to different changes in the environment and user preferences over short and long intervals to realise given tasks; UBA is realised via Fuzzy Task Agents (FTAs)

- **User interaction adaptation:** the modes, modalities, and media that are utilized for interaction between user and system will be adaptive according to user profile and behaviour, physical environment characteristics and available interaction devices. In this way users are able to tailor the ambient ecology and the human-computer interface itself to their needs without the restrictions of any fixed modes, modalities, or media. We propose a knowledge-based system that addresses three levels of adaptation:
  - *allocation* which is the problem of selecting the modalities and devices through which the user interface will be expressed,
  - *instantiation* which is the issue of selecting the appropriate parameters for an allocated user interface, and
  - *evolution* which addresses the evolution of the user interface during interaction.

- **Sphere adaptation:** It happens along three dimensions:
  - ▣ Functional adaptation. At the functional level, our system should support the realization of the same activity sphere in different ambient ecologies
  - ▣ Structural adaptation. Refers to the persistent achievement of the goal when changes on the type of the available resources occur (as agents and users may come and go, devices and services may appear and disappear in time) and when changes on the cardinality of the available resources occur (as the numbers of devices, or users that participate in the realization of an activity sphere may differ in time).
  - ▣ Semantic adaptation. Semantic adaptation refers to changes in order to deal with any disturbance that would affect meaning.
- **Network adaptation:** allows devices and services to be used seamlessly by the ATRACO system and to simplifies the access to networks in the IE (control, data sharing, communications, and entertainment).

# Deployment

- The **iDorm-2** Living Lab is at the heart of the Digital Lifestyles Centre at the University of Essex. This new apartment makes possible ubiquitous networked sensors and actuators, the infra-structure for which is accommodated within the specially constructed walls, so that the heterogeneous networking infrastructure is hidden from view. The iDorm-2 offers the possibility for examining the deployment of embedded agents and sophisticated user interfaces within the intelligent environments of tomorrow.
- The **AmlnOffice** is a new testbed under development in the premises of RACTI. It consists of a variety of sensors deployed in the office environment, a set of smart objects that support office tasks and the appropriate network infrastructure. The AmlnOffice will be used to test specific components in order to evaluate adaptation and portability.



# Results so far

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- Research on system
  - ATRACO concepts and architecture
  - Sphere manager, Ontology manager
  - Fuzzy Task agent, Interaction agent, Spoken Dialogue manager
  - Network adaptation component
  - Deployment of prototype
- Research on ontologies
  - ATRACO-specific ontology engineering methodology
  - Device ontologies, user profile ontology, privacy policy ontology
  - Interaction ontology, spoken dialogue ontology
  - Testing of ontology alignment algorithms
- Research on agents
  - Classification of uncertainties in les
  - Classification of interaction with activity spheres
  - Novel Theoretical Development on General Type-2 Fuzzy Systems (zFLS)
  - A conceptual model called WWHT (What, Which, How, Then) for multimodal interaction adaptation has been defined already and can be used within the IA

# Key knowledge gap

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- Scaling, in terms of:
  - Multiple users and activity spheres
  - A very large number / volume of IE resources, data and meta-data
  - Performance of alignment algorithms
  - Interfacing with GFOs
  - Uncertainty caused by dynamic context

# Future application scenarios

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- Multiple activity spheres instantiated in the same IE
  - ▣ Efficiency given time and resource constraints
  - ▣ Conflict resolution policy
- Multiple users occupying an IE
  - ▣ Optimization
  - ▣ Privacy
- Personalization
  - ▣ Storage and reuse of knowledge developed for an activity sphere
- Autonomous sphere operation
  - ▣ Learning and evolution of sphere and sphere ontology
  - ▣ Automated alignment