Abstract: Objects in augmented reality can be seen as parts of virtual entities whose semantic abstractions wrap physical and virtual resources. An object in augmented reality is not only what an original definition can say of it; an object can become what other entities need to perceive of it, including semantic contents and actions not naturally belonging to that object.

This approach is discussed in the paper by means of a model which was thought to be compliant with the FIPA standard. First the paper gives a brief architectural description of the model along with a deeper look at the semantic layer. Then, a FIPA agent compliant description of the model follows, along with some UML diagrams dealing with a mixed reality case study.

Keywords: augmented reality, mixed reality, ubiquitous computing, context awareness, FIPA agent

1 Introduction

Augmented reality is the composition of visible beings and things, (natural or artificial), and invisible virtual objects (software processes running in a hidden network) [1]. Interactions between objects can take place in a visible or in an invisible space, or it can deal with both spaces [2]. According to our vision, both real and virtual objects can be the resources of autonomous virtual entities which cooperate, join groups, fund societies, and take part of composed autonomous entities.

We also consider the invisible part as something high in a composition relationship, where visible resources are mostly used by means of some vertical protocol as in a service providing hierarchy. As an example, let us look at a natural occurrence: I am a visitor in a museum who is looking at a statue. I am a human: an entity which uses its eyes to see a physical object. The interaction between my eyes and the statue is performed on a physical layer. Nevertheless, I am looking at the statue to perceive some feeling to be given by a process which runs in my brain and uses some internal protocol to get a service from my eyes. This is to say that an interaction between an entity and an external physical object needs to be brought up to a semantic layer.

This approach is described in our model [3], which faces mixed reality (hereafter MR) from an ontological point of view.

Dealing with MR, other projects can be found in literature with the common goal of arranging interaction rules between natural and artificial objects to be involved in some MR application. Among these, the hypermedia paradigm [2], along with an object-oriented framework on a hypertext Reference Model [4] and a hypermedia data model, represent information data by atomic components, to integrate the physical world and virtual documents and worlds. In [5] a tagging system is proposed based on three main categories: object, collectional and tool, to be used in a work setting of landscape architects.

As far as heritage site applications are concerned, in [6] the authors discuss how a virtual archaeologist can explore a museum along with virtual history outdoors and hybrid physical-digital artifacts. This is a project by the SHAPE consortium in Sweden mostly dealing with disappearing hardware and augmented reality. Among others, the Archeoguide project [7] needs to be mentioned as an augmented reality application with the aim of a VRML reconstruction of Olympia archaeological sites in Greece.

As for context aware applications, many mixed reality systems, including the one in our project, are based on some location aware model, as in [8] and [9], and some enabling technologies such as Bluetooth [10], ultrasound and Infrared [11] for proximity detection.

2 The model

Our model faces the MR problem from an ontological point of view. All objects in augmented reality are parts of virtual entities whose semantic abstractions wrap physical and virtual resources. An object in AR is not only what a vocabulary can say of it in; an object can become what other entities need to perceive of it, including semantic contents and actions not naturally belonging to that object.

The HAREM model[3] aims at being a reference structure for any virtual entity representation and interaction in AR. This is based on a three layer
stack (Fig.1), each hosting a virtual entity different projection:
- a semantic projection for semantic interaction, knowledge maintenance and knowledge management,
- a middleware projection allowing entities to be implemented according to some development platform
- a physical projection for physical interaction and physical resource management.

Semantic and middleware projections are the non-visible part of an AR virtual entity. This includes a knowledge base and a collection of methods, along with an overall execution logic which implements knowledge processing and method activation.

Physical projection accounts for physical resource management in the AR visible part. It acts through a sequence of exposition - perception cycles and allows an entity to interact with physical projections of other entities by means of multimedia devices.

Each projection layer works in a multithread execution fashion, thus letting entity multi-projections interact with many other entities at a time.

2.1 Semantic projection
Semantic projection is split in a set of sub-layers, each defining a different entity capability. Each sub-layer is implemented according to a common ontology and a given middleware structure, thus enabling an entity to use a peer to peer protocol for semantic interaction. The main semantic sub-layers are:
- **Maintenance**: entity creation, suppression and update;
- **Consistency**: entity features and reason of being. At no time an entity can accomplish a task or a cooperation request if it does not comply with the rules in its consistency layer. As an implementation note, the consistency sub-layer can include the setup parameters of an entity, according to a specific entity class;
- **Vocation**: logic selection and coordination;
- **Role**: permanent knowledge for mission accomplishment;
- **Task**: transient knowledge for mission accomplishment;
− **Ability**: access rules to a knowledge base, on request from other sub-layers or other entities calling for cooperation. At this moment the ability sub-layer also includes strategies for quality of service and performance improvement;
− **Survival**: knowledge, rules and methods dealing with security and fault tolerance issues;
− **Instinct**: default reaction behavior of an entity, to be called by the sub-layer selection logic.

First time, after its creation, sub-layers are started according to a top-down schedule. Next, sub-layer selection depends on incoming message types. In some cases a sub-layer can call another sub-layer directly; in other cases **vocation** provides the correct schedule according to a mission to be pursued.

### 3 FIPA Agent Implementation

FIPA specifications for intelligent agents provide full interoperability among agents [12]. Therefore FIPA agents are a suitable solution for augmented reality collaborative environments.

According to the FIPA standard, an agent can pursue its goal by playing several roles, each corresponding to a particular subgoal. Each role may use one or more tasks, each consisting in a sequence of elementary actions. HAREM entities can be implemented as FIPA agents, along with application specific operating roles (Fig. 2):

1) a **Request Message (RM) dispatcher** role, which accepts requests addressed to the entity for context sensing and cooperation aims;
2) a **vocation** role, which selects the operating role(s) to be activated for request accomplishment, based on request examination;
3) an **ability** role, which looks for external resources when these are needed for correct execution of some role.
4) a **survival** role, which contains safety reactions to requests which are recognized as dangerous and can activate fault tolerance strategies;
5) an **instinct** role, which activates entity first exhibition and default reactions to generic unknown requests.

Diagram in Fig. 3 describes the HAREM role interaction protocol according to the representation proposed by [13]. Each request addressed to a HAREM entity is first processed by **RM dispatcher**, which forwards it to **survival** and **vocation**. If **survival** detects some danger, it alerts **vocation**. If no danger is detected, **vocation** selects the application specific operating roles to comply with the request. Communication between **vocation** and operating roles takes place according to the FIPA specifications on Agent Interaction Protocols [14].

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**Fig. 2. HAREM static UML description**
and to communicative act semantics in [15]. Each operating role may send a request to ability for external resource lookup. This is performed by a request sent by ability to other HAREM agents. Finally, vocation sends the request to the instinct default role only if no other operating role can comply with it.

4 Case Study
We are currently setting up a HAREM based application for service providing in cultural heritage environments. The project aims at turning a cultural heritage site into augmented reality for tourist service providing. For example, if a visitor is near some interesting object (e.g. a sculpture, a painting, some ruins), he should be automatically provided with information and facilities about it. In AR this is accomplished by interaction between the visitor and the surrounding environment. Similar to other projects, our approach requires that visitors are provided with some mobile device (e.g. a PDA or a cellular phone with suitable connectivity features).

A Site Positioning System (SPS), which is currently based on Bluetooth [16] and Infrared technologies, accomplishes position tracking of each visitor and stores 2 or 3 fixed coordinates of each interesting physical object in the environment, thus enabling proximity detection for context aware service providing.

Here we show a simple example from our application. As hinted in introduction, suppose that a statue is placed in some point of our site. Some spotlights and a remote display are placed next to the statue (Fig. 4).

We want the AR environment to fulfil the following requirements:
1) when some visitor gets near the statue, the spotlights are switched on and a brief presentation of the statue is showed on the remote display.
2) when some visitor near the statue shows interest in it, a presentation is shown on the display, which matches visitor’s interests.
3) when there is no visitor around, all the spotlights and the remote display are switched off.
4) when someone gets too close to the statue, an alarm system is activated.

Fig. 3. HAREM agents interaction protocol
HAREM entities involved in this scenario are the Statue entity, the Visitor entity and the SPS entity. A possible interaction case is described in [3]. In that case we supposed for simplicity that SPS entity only performs proximity detection for context aware service providing. The SPS entity is enriched by adding a compass detection functionality for visitor orientation recognition. This is useful because a visitor may casually happen to be near a statue (for example because he’s just walking to go elsewhere). In this case, the SPS system should ignore proximity detection. If compass detection is performed, the SPS system can distinguish two fuzzy situations:
1) a visitor near the statue is staring at the statue (proximity detection probably significant).
2) a visitor near the statue is staring elsewhere (proximity detection probably to be ignored).

The compass detection functionality is implemented by providing each visitor at site entrance with a marker and detecting the marker position by color segmentation on the visitor’s image (acquired by digital cameras available in the environment). Therefore, The SPS entity has an operating role (Fig. 5) for visitor Bluetooth positioning (BT_role) and an operating role for visitor compass detection (C_role). When a visitor approaches the statue, the SPS Bluetooth role detects proximity, and the Compass role detects visitor orientation. If the visitor is near the statue and is staring at the statue, an SPS request triggers the overall statue-visitor interaction [3] BT_role and C_role roles exploit external resources (bluetooth hardware, digital camera, etc.) through SPS entity ability invocation. Compass information, enclosed in SPS request, can be used by the Statue entity to select the right spotlights to be switched on, according to the visitor orientation.

5 Conclusions
In this work we presented a FIPA implementation of a model which was arranged to describe any virtual entity in augmented reality. A case study on relationships between artefacts and tourists was discussed to prove HAREM applicability to a specific AR environment. In particular, an interaction among a positioning system and other entities in the AR environment was presented, which allows context aware service providing. Future works will deal with HAREM application to population entities.

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7 References


