# Intelligent Objects to Facilitate Human Participation in Virtual Institutions

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## Abstract

*Our research combines electronic institutions and 3D virtual worlds for the construction of virtual institutions which are virtual worlds with normative regulation of interactions. That is, a virtual world where participants actions have to comply with predefined institutional rules. In this context, the actions a participant may perform depend on the institutional rules and the current execution state. We propose to include iObjects, intelligent objects, as entities having both visualization properties and decision mechanisms in the virtual institution. They are a new key element to improve users participation in virtual institutions. We situate them in a middleware infrastructure in order to be independent of 3D virtual world platform and to provide a general solution in which participants could be connected from different immersive environment platforms.*

## 1 Introduction

Nowadays with the expansion of the Internet, there is a growing demand for systems where humans and software agents can interact successfully. Potential domains of application are e-commerce, e-learning and e-goverment. This kind of systems can be constructed by defining a regulatory environment establishing what participants are permitted and forbidden to do along with the consequences of their actions. These environments make more effective the achievement of participant goals and reduce the complexity of taking part in them.

Notice that regulatory environments are a kind of open systems [7] populated by heterogeneous and self-interested entities that interact to achieve their common and/or individual goals. Hence, a multiagent systems (MAS) view is perfectly suitable for them. However, few efforts have been devoted within the MAS community for direct human participation. Generally human role is limited to acting behind the scenes by customising agent templates that participate in the system on their behalf. We advocate that the technological synthesis from both MAS and virtual worlds technologies can be used for constructing systems where both human and software agents can participate succesfully. One way of realising such synthesis is offered by the so-called virtual institution (VI) technology [4], which joins together electronic institutions [5], a well known MAS methodology, and 3D virtual worlds.

Participating in a VI is not an easy task as the actions participants may perform depend on both the institutional rules and the current execution state kept by the run time infrastructure. Hence, participants have to be aware of both issues.

In this paper, we propose to include iObjects, intelligent objects, to facilitate human participation and interaction in virtual institutions. An iObject is an entity in a 3D virtual world (VW) with dynamic visualization and interaction attributes according to the execution state of a VI. First, iObjects can provide an intuitive way to participate in the VI by interacting with them in a similar way that we do with objects in real life. Second, iObjects can help users to be aware of the current execution state and the institutional rules. Third, they can collaborate with the other elements of the infrastructure in the enforcement of the institutional rules. As iObjects are independent of the VW client used, they can be exploited to connect and visualize the same VI to several VW clients.

## 2 Related work

A system that incorporated intelligent agents within virtual environments was mVITAL (multi-agent VITAL) [2] which allowed the definition of agent societies so that intelligent agents could communicate through simple speech acts, co-operate and help each other to achieve goals. The mVITAL viewer allowed human supervisors to observe the activity inside the environment. We propose to allow the user not only to supervise but to control his avatar and communicate with a regulated multi-agent system in order to test whether his actions are allowed. We introduce the so-called iObjects (see section 4) in order to provide facilities for avatar-object interaction and the visualization of the VI execution context. A detail description of iObjects integration at MAS level by means of an Interaction Language can be found in [11].

A first approximation to the concept of intelligent object presented the object specific reasoning paradigm where object's inherent properties and object-avatar interactions were stored in a database [9]. A more general framework of object-avatar interactions was presented by Kallmann in [8] but a limitation of this work was found when several avatars had to use the object simultaneously. Peters presented user slots and usage steps as a way of improving the control of several avatars interacting with a single smart object [10]. Successive approaches extended the type of data stored within the object. An extended smart object [1] was defined to add planning information -such as preconditions, actions and effects- to the basic object features.

Guyot merged MAS and role-playing games (RPG)[6]. They compared agent-based participatory simulations and the MAS/RPG approach and explained the advantages: "actions and interactions can be registered and used for learning purposes, the gap between the agent model and the participants can be decreased and the user interface with an assistant agent may improve the understanding of the model by the participants". Our system, exploiting iObjects in the context of virtual institutions, aims to work along those advantages too.

## 3 Development and deployment of VIs

The development of virtual institutions is divided into two independent phases: (i) specification of the institutional rules and (ii) 3D VW generation.

For the *specification of the institutional rules*, we use electronic institutions, a well-known MAS methodology. The institutional rules establish the valid interactions agents may have and the consequences of those interactions. Institution designers should define the following components (more details in [3]): dialogical framework (i.e ontology and communication language), social structure (i.e roles), scenes (i.e interaction protocol), performative structure (i.e role flow policy among scenes and transitions) and norms (i.e consequences of agents' actions).The specification also includes the definition of the information model that the institution uses to keep the state of participants and activities going on at run time. For instance, an auction house may keep for each buyer her current credit and the list of purchased goods. At specification time no assumptions are made about the internal architecture of participating agents. Hence, participants can be human and software agents.

Once the institutional rules have been specified, the *3D virtual world can be generated*. The floor plan of the building is automatically generated from the specification. Each scene and transition is mapped to a room, while connections among them are visualized as doors connecting the corresponding rooms. Thereafter, in the *annotation* step, each room is designed using a predefined set of textures and 3D objects. Different institutional roles (e.g. employees, supervisors) are represented by different avatar appearances. Finally, in order to facilitate users participation, in the *integration* step communication language expressions are mapped into actions in the VW. For instance, the bidding message in an auction house may be mapped to raising a hand.

After generation steps, the VI is ready to be executed. This is done by a three layer execution environment. The top level is the 3D virtual world. The bottom level is the electronic institution infrastructure (i.e AMELI) [3], and in the middle the causal connection server is in charge of connecting the other two layers. Notice that the system supports the participation of both human and software agents.

## 4 Incorporating iObjects to VI

iObjects are entities having both visualization properties and decision mechanisms, that help to improve human participation in a VI in four ways: (1)*Representation of execution context*: iObjects provide an effective mapping of the VI state into the 3D virtual world. Hence, it facilitates participants perception of the current state and of changes in it. (2)*User participation*: they provide an intuitive way to participate in the institution by interacting with them. For instance, by opening a door to leave a room. (3)*Enforcement of norms*: iObjects collaborate with the other elements of the run time environment in the enforcement of the institutional rules. Furthermore, they can inform users when a norm has been violated and, optionally, they can guide a user in order to avoid a new wrong action. (4)*Guiadance and learning of user actions*: iObjects can incorporate a knowledge base to guide user participation (i.e actions) inside the virtual environment. An iObject with learning abilities may gain knowledge about user actions within the simulated environment and after that, apply this knowledge to facilitate future user participation.

### 4.1 An iObject structure

An iObject may have several sensors (to capture events from the environment) and some effectors (to act upon

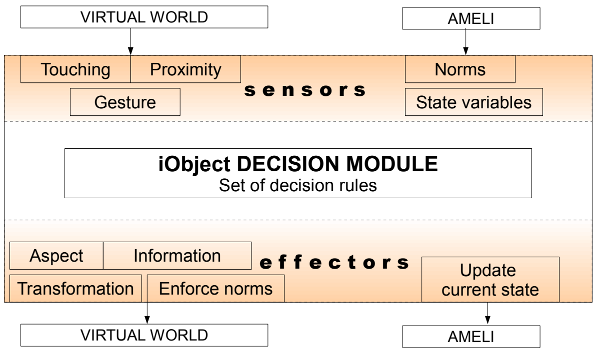


**Figure 1. Structural components of an iObject**

the environment). In the context of VI, by environment we mean both the virtual world and AMELI. AMELI is the component maintaing the executional state and capable of verifying than an action complies with the institutional rules. As shown in Figure 1, a decision module determines, taking into account sensors inputs, iObject's effectors actions. Sensors and effectors characterize an iObject as actionable, state modifier, self-configurable and learnable.

Though their sensors, iObjects can perceive events occurring at the VW due to avatar actions and movements. For instance, *touching* sensors allow iObjects to perceive avatars interacting with them, while *proximity* sensors allow them to react to avatars presence. An iObject can also interpret *gesture* events which allow it to act according to avatar gestures, for example a shaking head meaning "I disagree" in an e-business meeting or a raising hand meaning "I want to bid" in an auction house. Another source of events for iObjects is AMELI. That is, iObjects should be aware of changes in the execution state, in Figure 1 named *state variables*. For example, changes in the interaction context within a scene (e.g current price of a good in an auction house), the fulfilment of a pending obligation by a participant, or *norms* changes (e.g. a door has been opened to everyone because a scene activity has finished).

When an iObject's sensor captures an event from the environment, an iObject's effector reacts to the event. It is worth mentioning that in some cases, although the required reaction can be situated in the virtual world (e.g opening a door), that reaction may depend on the compliance of the avatar action with the institutional rules. If this is the case, the iObject requests for institutional verification of the action to AMELI by using its *enforce norm* effectors. Then, the door will only open if the avatar is allowed to leave the room, which is checked by contacting AMELI. Furthermore, iObjects can also be informed about the result, executed or failed, of the actions for which they requested institutional verification, in this way, they can inform the user about the result of the action in a friendly way.

Effectors act upon the VW changing several properties of the iObject itself: the *aspect* (e.g color), the *information* that some types of iObjects provide (e.g notice board) and *transformation* properties (e.g position, rotation and scale). An intelligent e-business room may scale if there is an increasing number of clients populating the space, or if it is difficult to overcome the change of its dimensions by a scaling transformation may even replicate itself. An iObject's effectors also maintain AMELI informed about changes of the *current state* of execution, for example a door iObject informs that an avatar has moved from one scene to another one.

## 4.2 iObjects at generation time

In section 3, we described an initial approach of VW generation from institutional rules. In this section, we incorporate iObjects in an extended version of that generation. They can be incorporated in the automatic creation of a building, as we consider them essential for the correct execution of any VI. Examples of iObjects are: rooms, doors and scene notice boards. Notice that rooms or doors were already part of any VI, but the difference is that now they are iObjects. The number of doors is determined by the connections within the performative structure, while the size of each room or the position of each door is established by the algorithm generating the building floor plan. A scene notice board shows the interaction context of a scene, and there is one notice board per room representing a scene execution. The notice board is placed in one of the room walls. At least, it shows the current interaction state and the participants along with their role. The rest of the iObjects are added during the annotation step moment in which institution designers add the iObjects they think are necessary to facilitate human participation. Some iObjects may be merely informative, as for instance a brochure, while others may facilitate participation within the institution, like a remote control to submit bids during an auction.

The integration step defines a mapping between actions at VW and the messages understood and generated by AMELI. An Action/Message table contains data about which perceived events (i.e actions) have to be transformed into messages to inform AMELI and how they have to change their appearance after receiving a message from AMELI. Notice that a received message may provoke changes in several iObjects. For instance, an authorisation to leave a room will provoke the opening of the door and the removing of the avatar from the list of participants in the scene notice board.

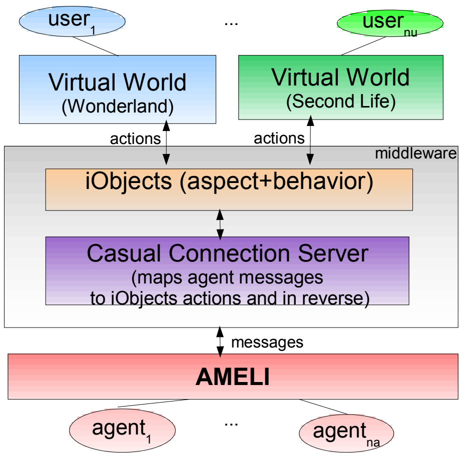


**Figure 2. Extended architecture of a VI**

### 4.3 iObjects at run time

Figure 2 shows the VI run time environment incorporing an iObject layer in the middleware along with the causal connection server (CCS). We situate them there in order to be independent of the VW platform and thus provide a general solution in which participants can be connected from different immersive environment platforms. Nowadays, interoperability between different VW technologies is almost inexistent and some of our efforts go in that direction. The iObjects layer and the CCS collaborate to transform those actions that require institutional verification within the virtual worlds to messages understood by AMELI and to update the visualization in the different virtual worlds after receiving a message from AMELI.

We distinguish between iObjects at *scene/institution level* and *participant level*. The first one correspond to the iObjects added to the VW during its generation as explained in the previous section. iObjects at *participant level* give the user personal information about the participation in the VI. Hence, each user perceives their own iObjects at this level containing their information. They are placed in the user interface but not in the VW. This is the reason for which we didn't mention them in the previous section. At participant level there are three types of iObjects, namely the backpack (keeps the user pending obligations), the information model notice board (current values of the user information model) and the historial (a register of the user participation within the institution).

## 5 Conclusions

In this research we have introduced iObjects to provide feedback on activities to participants in a VI. Our main contributions are to provide a generic framework to incorporate norms in current virtual worlds and to facilitate user participation. This is addressed by means of a middleware infrastructure including both iObjects and a causal connection server. We have the interoperability between different VW technologies in mind and thus, the middleware infrastructure aims to provide a general solution in which participants can be connected from different immersive environment platforms. We rely on iObjects to provide interaction facilities to users participating in the VI and to give a user friendly and comprehensive understanding of the institution state. As future work, shape grammars, semantic annotion and template based techniques could help us to generate and populate an initial design efficiently. iObjects could also incorporate sound sensors to obey voiced commands.

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