Completing the Virtual Analogy of Real Institutions via iObjects

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Abstract.

Electronic Institutions are regulated environments populated by autonomous software agents that perform tasks on behalf of users. 3D Electronic Institutions extend EI with 3D Virtual Worlds, which provide an inmersive user interface so that humans can observe their agents' behaviors. In this manner, they represent a virtual analogy to real institutions. We propose to gain on realism on this analogy by adding intelligent objects to these institutions. Intelligent institutional objects (iObjects) exhibit autonomous and reactive behaviors. Furthermore, they present a limited level of proactivity such as self-configuration. Their inclusion has the advantage of improving the 3D Electronic Institutions architecture and both agent and user interactions within the institution.

1. INTRODUCTION

The implementation of successful complex multi-agent systems requires both taking care of the social issues underlying the activities the system models [11] and having a strong methodology to provide reliable interaction between the agents [3]. 3D Virtual Worlds cover the social issues by providing an inmersive environment that offers a realistic experience. Electronic Institutions (EI) introduce regulatory structures establishing what agents are permitted and forbidden to do and hence provide reliable interactions.

3D Electronic Institutions (3D-EI) allow its users to interact with an Electronic Institution by means of a 3D Virtual World resembling the real world institution. However, objects and non-verbal communication are key social activities that are not present in 3D Electronic Institutions up to date. Their inclusion makes both the Electronic Institution and its 3D façade more similar to the real institution being modelled. In this paper we propose to extend Electronic Institutions by adding institutional objects (iObjects) with intelligent capabilities.

The paper is organized as follows. Section 2 reviews the related work on intelligent objects. Section 3 introduces the concept of EI, 3D-EI and details the integration of iObjects in Electronic Institutions. Next Section describes the architecture of the application

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that communicates EI and its counterpart in 3D, i.e., 3D-EI. Finally, in Section 5 we conclude the paper describing the benefits of this new proposal.

2. RELATED WORK

The first approximation to the concept of intelligent object was given by Levison [6]. He presented the object specific reasoning paradigm where object's inherent properties and object-avatar interactions (e.g., hand gesture to open a drawer) were stored in a database. The drawback was that each new extension of the object interaction properties would need an adjustment of the data stored in the interaction database.

A posterior research proposed a general framework of object-avatar interactions [5]. In this work, Kallmann and Thalmann introduced the *smart object* concept. An *smart object* included intrinsic features, interaction data and information relative both to avatar and object behaviors during their interaction. The goal was to encapsulate object specific data in smart objects so that different applications could incorporate them and exploit their interaction data as required. In this manner, object rendering control is transferred from the main loop in charge of the overall simulation to each specific object. Furthermore, they added these interaction features by means of a general feature modeling technique applied to CAD systems [14]. The limitation of this work was found when several avatars had to use the object simultaneously (e.g., several avatars trying to go through a "smart" door with a limited "physical" entrance points). This would imply either to modify the object or to have a specific concurrency control module.

Afterwards, based on the smart object definition, Peters [10] presented *user slots* and *usage steps* as a way of improving the control of several avatars interacting with a single *smart object*. A user slot defines the kind of avatar that can interact with the object (e.g., for a smart object 'bar', user slot 1 is a barman and user slot 2 is a customer). A user slot defines the avatar interaction with the object as a set of usage steps. A usage step contains the following information: animation that should be generated during the step, conditions to move to the following usage step, changes of state variables during the step, information that should be given to users of the object after that step, and points to focus the agent's attention.

Successive approaches to the intelligent/smart object concept have extended the type of data stored within the object. Recently, an *extended smart object* [2] has been defined to add planning information –such as preconditions, actions and effects– to the basic object features in Kallmann's initial smart object definition. The objective is to avoid working with fixed behaviors but to generate interaction plans and to relieve the avatar from interaction details. This approach is based on a standard STRIPS-like planner named Sensory Graphplan (SGP). Before the execution of the plan, avatars controlled by the SGP contingent planner try to generate a robust plan that deals with all eventualities. In fact, the resulting contingent plan may include sensing actions for gathering data that may be later used to choose among different plan branches.

Next section introduces our proposal of intelligent institutional object (*iObject*), which situates the concept of *smart object* in a deeper level (farther from the user interface than those mentioned above which locate *smart objects* at 3D rendering level). As shown below, we have an object named *iObject3D* at 3D scene level which is in charge of iObject3D's aspect and behaviour and a multi-agent system at a lower level that contains its intelligent counterpart (named *iObject*) .

3. ELECTRONIC INSTITUTIONS AND iOBJECTS

Our proposal based on introducing iObjects into EI aims to generate a reliable and proactive environment that gives more realism to the simulated institution. First of all, in this section, we formally define an Electronic Institution. Afterwards, we detail how to integrate iObjects into EI.

3.1. Introduction to Electronic Institutions

An Electronic Institution (EI) is a regulated virtual environment where the relevant interactions among participating entities (i.e., agents) take place [9]. An electronic institution defines (for further details refer to [8,12,4]):

- a common language that allows agents[2] to exchange information.
- the activities that agents may do within the institution.
- the consequences of their actions (obligations or prohibitions by means of normative rules).

Interactions between agents are articulated through agent meetings, which we call *scenes*, that follow well-defined communication protocols. Scene protocols are patterns of multi-role conversation. A distinguishing feature of scenes is that they allow agents, depending on their role, either to enter or to leave a scene at some particular moments (*states*) of an ongoing conversation. On the other hand, the protocol of each scene restricts the possible dialogical interactions between roles. For example, in an auction house, when a good is offered, the only action buyers can take is to rise their hand, indicating they take the bid; any other action is meaningless or inadmissible (and interpreted as a silent "no" to the bid). If a buyer wins a bid, the auctioneer will adjudicate the good to the buyer, charge the buyer and pay the seller for it; thus making the interactions involved relevant and meaningful to all participants.

A scene protocol is specified by a directed graph whose nodes represent the different conversation states and the arcs are labelled with illocution schemes[3] or timeouts that make the conversation state evolve. Moreover, arcs can have some constraints associated which impose restrictions on the valid illocutions and on the paths that the conversation can follow. For instance, in an auction scene, following the English auction protocol, buyers' bids must be always greater than the last submitted bid.

Figure 1 shows an EI as a "workflow" (*transitions* between scenes) of multi-agent protocols (*scenes*) along with a collection of (*norms*) rules that can be triggered by agents' actions (*speech acts*).

We need to settle on a common illocutory language that serves to tag all pertinent interactions that can be produced inside a scene, i.e., the valid speech acts or illocutory formulas:

$$\iota(speaker, hearer, \phi, t) \tag{1}$$

[2] Autonomous entities capables of flexible interaction: reactive, proactive, and social.

[3] An illocution scheme represents a speech act [13] with some terms abstracted and represented as variables.

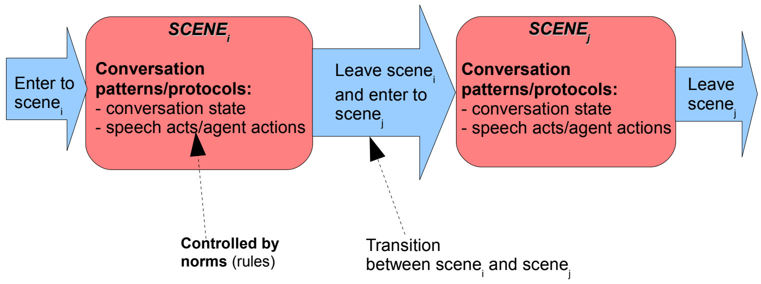

Figure 1. An Electronic Institution workflow

Speech acts start with an illocutory particle, such as *declare*, *request* or *promise*, that a $speaker$ addresses to a $hearer$, at a time t, and the content ϕ of the illocution is expressed in some object language whose vocabulary is the EI's ontology.[4]

To make clear what are all the available illocutions for agent dialogues in a given institution we define a *Dialogical Framework* as a tuple:

$DF = \langle O, L, I, R_I, R_E, R_S \rangle$, where

1. O stands for the EI domain ontology;
2. L stands for a content language to express the information exchanged between agents;
3. I is the set of illocutionary particles;
4. R_I is the set of internal roles (e.g., auctioneer in an auction house);
5. R_E is the set of external roles (e.g., sellers and buyers in an auction house);
6. R_S is the set of relationships over roles (e.g., roles that cannot played simultaneously, roles with authority over others).

In order to capture the relationship between scenes we use a special type of scenes: *transitions* (i.e., gateways between scenes or a change of conversation, see Figure 1). The type of transition allows to express agents synchronization: choice points where agents can decide which path to follow or parallelization points where agents are sent to more than one scene. An initial and a final scene determine the entry and exit points of the institution respectively.

Participating agents in the institution do not interact directly as done in traditional approaches. Therefore, an EI is composed by an external layer containing external agents taking part in the institution, a social layer controlling interactions between agents (e.g., AMELI [7]) and a communication layer providing a reliable and orderly transport service in a distributed architecture.

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[4] We take a strong nominalistic view, the institutional ontology is made of every entity referred to in any admissible speech act or in any of the norms (conventions) that govern those acts and their consequences.

AMELI provides external agents with the information they need to successfully participate in the institution, takes care of the institutional enforcement: guaranteeing the correct evolution of each scene execution (preventing errors made by the participating agents by filtering erroneous illocutions, thus protecting the institution). AMELI also guarantees that agents' movements between scene executions comply with the specification and controls which obligations participating agents acquire and fulfil. The current implementation of AMELI is composed of four types of agents:

- *Institution Manager* (IM). It is in charge of starting an EI, authorizing agents to enter the institution, as well as managing the creation of new scene executions. It keeps information about all participants and all scene executions. There is one institution manager per institution execution.
- *Transition Manager* (TM). It is in charge of managing a transition which controls agents' movements to scenes. There is one transition manager per transition.
- *Scene manager* (SM). Responsible for governing a scene execution (one scene manager per scene execution).
- *Governor* (G). Each one is devoted to mediating the participation of an external agent within the institution. There is one governor per participating agent.

3.2. From Electronic Institutions to 3D-Electronic Institutions

Electronic Institutions (EI) allow agents to communicate and interact with each other in order to fulfill an objective. However, EIs lack of a 3D graphical user interface giving the user an intuitive feedback on what is happening inside the EI. 3D Electronic Institutions (3D-EI) are environments that enable humans to participate in a heterogeneous society of individuals visualized in a 3-dimensional virtual world. Therefore, 3D-EI broadens the agents view on Electronic Institutions, taking a human-centered perspective and concentrating on the relation between humans and agents in the amalgamation of EI and 3D virtual worlds.

Figure 2 shows an EI and its 3D counterpart, a 3D-EI. A 3D Electronic Institution is constructed doing a mapping from EI elements (i.e., scenes, transitions, agents, iObjects) to 3D-EI elements (i.e., rooms, corridor, avatars, iObjects3D). Dotted arrows in the figure show how iObjects and iObjects3D are incorporated into EI and 3D-EI respectively.

3.3. Integrating iObjects within Electronic Institutions

We propose the concept of intelligent institutional object (iObject) as a new element inside EIs. Although an iObject lacks of social behaviors, it perceives and eventually changes the state of the institution. It also presents a limited level of proactivity and can be manipulated by agents. Some examples of iObjects are:

- A door connecting two scenes. It will open or close depending on the agent that tries to pass through it.
- A remote control that submits bids to an auction when an agent presses a button, only if it fulfills the conditions established by the protocol.
- A brochure that shows advertisements adapted to the interests of surrounding agents.
- An item on sale that changes its features (e.g., a color change) to increase its attractiveness for a buyer agent.

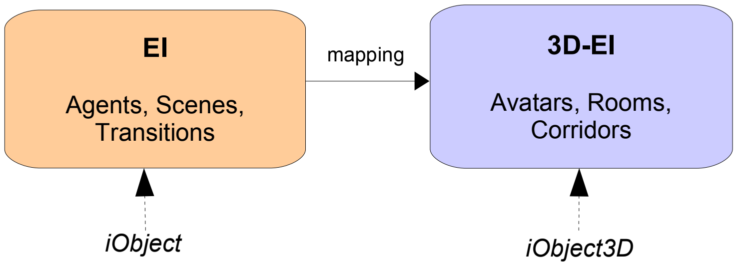

Figure 2. From EI to 3D-EI

- A playing jukebox with a button that allows the agent to skip to another song, that will be selected according to his musical preferences.

Every iObject has one or more properties which define its communication with the agent. The list of properties is:

- *State modifiers / non-state-modifiers*: Some objects, such as the door or the remote control, will change the EI state. In the first case by moving agents from one scene to another, and in the second one by modifying the current winner of an auction. On the contrary, a brochure, a jukebox or an item on sale are merely informative. We can further classify state modifiers as those that are part of the institutional infrastructure (such as a door) and those, such as remote controls, that provide an aid to incorporate non-verbal communication (actions) into specified protocols.
- *Actionable / non-actionable*: Actionable objects offer the agent the possibility to act on them. An example of an actionable object is a jukebox and a non-actionable one is a brochure.
- *Self-configurable / non-self-configurable*: A self-configurable object (e.g., a brochure or an item on sale) adapts its features according to changes in its environment. A door or a remote control are examples of non-self-configurable objects.

Any agent within an electronic institution is required to adopt some role conditioning the conversations he can be involved in and the illocution schemes (i.e., message patterns) he is allowed to use on those conversations. Similarly, an iObject is required to fulfill *interfaces*, that provide sets of action schemes that an agent can perform on it.

For example: A concrete object *door_23* fulfils the door interface which contains a single action. This action allows an agent to request to go through it.

We propose to extend the EI framework, currently containing the Communication Language (CL), with an Interaction Language (IL) that agents will use to interact with iObjects. CL let agents interact among them by following a dialog protocol (see illocutory formula 1 in §3.1). As shown below, an IL illocution scheme is mapped onto an CL illocution scheme.

An example of illocution scheme (belonging to a CL) allowing a buyer (*?b*) in an auction to communicate the auctioneer (*?a*) that he wants to bid for a certain price (*?p*) at an instant of time (*?t*) is formalized as follows:

$$request(?b : buyer, ?a : autioneer, bid(?p), ?t) \tag{2}$$

An example of illocution scheme (belonging to an IL) allowing a buyer (*?b*) to press a remote control button (*?r*) to submit a bid will use the following action scheme:

$$press(?b : buyer, ?r : remote, ?t) \tag{3}$$

This will isolate the buyer from knowing neither who the auctioneer is and its illocution schemes. Therefore, the remote control will be in charge of knowing how to translate the action (see Eq. 3) into the corresponding illocution (see Eq. 4) and will ensure that the protocol is satisfied. As a consequence, the Governor (see §3.1) is released from this task. In this specific case, the illocution associated with the action *press* could be:

$$request(?r : remote, ?a : auctioneer, says(?b : buyer, bid(?p)), ?t) \tag{4}$$

The remote encapsulates the functionality that the buyer's governor had until now. Therefore, it has to communicate to the auctioneer the content of the illocution given by the buyer as $says(?b : buyer, bid(?p)), ?t)$.

Another example of iObject application can be scene transitions. These transitions can now be directly controlled by doors through the *open* action scheme:

$$open(?b : buyer, ?d : door, ?t) \tag{5}$$

This partially relieves the Governor from intermediating with the Scene Manager (see §3.1) to perform this task. In a similar way, some other functions that are currently centralized into the Governor can be effectively split among different iObjects for a better responsibility distribution inside the EI.

4. 3D-Electronic Institutions including iObjects

Our proposal is to enhance the EI metaphor by including iObjects into EI specification (see §3.3) that are relevant to the real world institution. These iObjects will have their corresponding 3D virtual world objects, iObject3D. As a consequence, both the EI and its 3D façade become more similar to the real institution being modelled.

In a 3D-Electronic Institution [3] [1], scenes and transitions (see Figure 1) are mapped onto rooms and corridors, respectively. Doors in 3D-EI are to limit the access between rooms (i.e scenes in AMELI). In the 3D world, an avatar interaction such as *open-door* has to be translated in a query to AMELI infrastructure in order to allow/deny the avatar's action. Therefore, we need to communicate AMELI infrastructure to a module maintaining shared virtual world data.

As shown in Figure 3, a 3D-Electronic Institution is a multi-user networked 3D virtual environment based on a client-server architecture. On the client side, the user receives the current state of the institution and performs/receives changes to/from the scene state. An user selects an avatar that will represent him in the 3D world and the user's requests are communicated to the server via http request/response mechanisms. For example, if an user moves its avatar by means of a keyboard event, this event may be propagated to the server so that it could inform the change to the rest of users.

On the server side the multi-agent infrastructure will be provided by AMELI run-time environment which will maintain communication with the Shared World Module in order to force avatars to fulfill Electronic Institutions norms and commitments.

The shared world module stores a reference to each user's browser execution context in order to update the virtual world after each avatar movement or avatar-object3D interaction. This module also has to maintain scene data such as number of user connected, correspondence between users, avatars and agents, avatars positions in the 3D scene, etc.

3D scenes, including *iObject3D*, are also stored in the server and sent to the browser when the client requests the connection to a concrete shared world, i.e., an institution. Note that yellow elliptical shapes in the figure represent iObjects in AMELI and theirs corresponding iObjects3D in the 3D virtual world. The initial EI configuration is given by a module named ISLANDER by means of an XML file. This file is read by the conversion module and converted into a 3D scene.

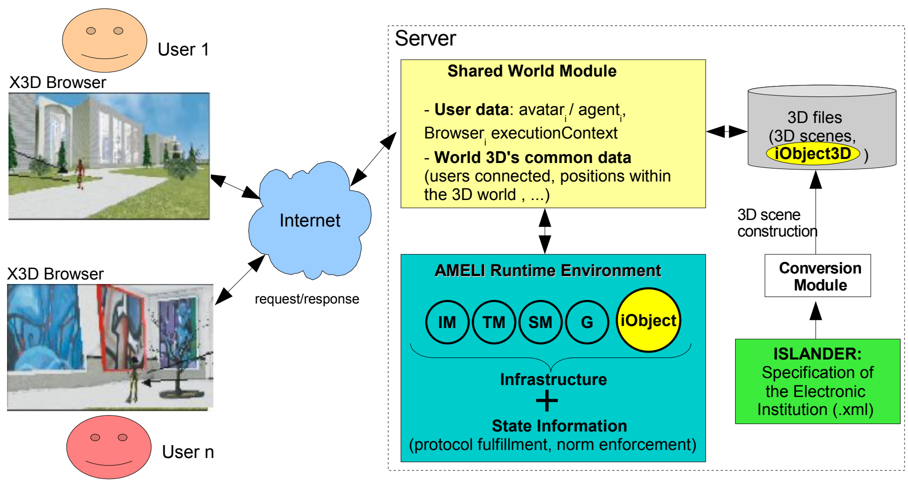

Figure 3. 3D-EI architecture including iObject and iObject3D

5. CONCLUSION

3D virtual worlds provide an inmersive environment that offers a realistic experience. 3D-EI are virtual worlds which show to the user a more realistic view of an EI.

In this paper, we define an intelligent institutional object (iObject) as a new element inside EIs. An iObject perceives and changes the state of the institution. Moreover, it can be actionable and self-configurable. The key concept of iObjects addition is the extension of Communication Language (CL) to the Interaction Language (IL). We have illustrated the idea of iObjects through several examples of iObjects. An application of iObjects would be an e-commerce system where the buying/selling experience could be attractive on the client side and effective on the seller side. For example, an iobject3D, based on user profile or on the last user activities inside the EI, changes its appearance in order to tempt the client to buy. Additionally, iObjects can be packaged smartly, depending on how the sales are running, as a marketing strategy essential for selling success.

The metaphor of iObjects: (i) provides a more realistic and operational 3D visualization of the current state of the EI; (ii) facilitates the addition of intelligent behavior to 3D objects through a three layer architecture; (iii) eases and makes more intuitive the communication between the agents and the EI; and (iv) allows for a better separation of concerns inside an EI.

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