An Infrastructure for Human Inclusion in MAS

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Abstract. The field of Multi-Agent Systems (MAS) focuses on the design and development of systems composed of autonomous entities (i.e. agents) which interact in order to perform specific activities. In general, direct human participation in these systems is not considered. We advocate that 3D Virtual Worlds technology can be used to facilitate human inclusion in a MAS system. In this demo we present an infrastructure, the *Virtual Institutions eXEcution Environment* (VIXEE), which allows direct human participation in MAS providing an immersive experience.

1 INTRODUCTION

Multi-Agent Systems (MAS) are systems composed by autonomous entities which interact within an environment in order to achieve their individual or common goals. Engineering a MAS usually involves the specification of a coordination model and the development of an infrastructure in charge of enacting it. Organisations define such a coordination model and thus, Organisation Centred MAS (OCMAS) are effective in structuring agent interactions in open MAS. We consider a system to be open when participants are developed by third parties and vary at runtime, i.e., they can enter and exit at any time. Usually, these systems are solely populated by software (SW) agents so that human participation is limited to agent design and implementation. Therefore, in order to take humans in the loop of MAS, we propose the use of *Virtual Institutions* (VI) to combine the notions of *Electronic Institution* (EI [4]), an OCMAS, and 3D *Virtual Worlds* (VWs [2]). On the one hand, EIs provide an infrastructure to structure participants interactions, where participants can be human or SW agents. On the other hand, VWs offer an intuitive 3D interface to allow humans to be aware of the MAS state as well as to participate in a seamless way.

In this demo we present an infrastructure for direct human inclusion in MAS. We name it *Virtual Institutions eXEcution Environment* (VIXEE) since it enables the execution of a VI. Notice that EIs and VIs have a conceptual difference. EIs define what is permitted and the rest is prohibited. On the contrary, in VIs, only those actions in the VW platform that have institutional meaning are regulated, while everything else is permitted.

In the line of connecting MAS and VW, Ranathunga et al provide a framework which connects a Jason BDI agent platform to the VW server Second Life (http://secondlife.com/) [5]. Another related work that is worth mentioning is the Environment Interface Standard (EIS) [3], a standard proposal of middleware that connects several MAS platforms (2APL, GOAL, JADEX and Jason) with different environments (e.g. GUI applications or videogame worlds).

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2 VIXEE AS A COMMUNICATION INFRASTRUCTURE

VIXEE is a *Virtual Institutions eXEcution Environment* that provides a robust communication infrastructure between an EI and several VWs (see Fig. 1). It allows to validate some VW events prior to their execution. It also updates both VWs and EI states to maintain a causal dependence. Notice that VIXEE is not limited to connect an EI to a single VW but also supports multi-verse communication, i.e., the connection to several VWs. Therefore, it permits the visualisation of all VI participants in all connected VWs as well as the dynamic manipulation of all VWs contents. It is worth mentioning that VIXEE runs as a stand-alone tool with its own user interface.

The **Normative Control Layer** on the left side of Fig. 1 is liable for the correct execution of the institution. It is composed by an *EI Specification* and AMELI [4], a general purpose EI infrastructure. Using the *EI specification* which defines the interactions of participants, AMELI mediates and coordinates the participation of every agent within the MAS. Software agents (robot-alike icons on the left of Fig. 1) have a direct connection to AMELI which, as depicted in Fig. 1 has a bidirectional communication with the *middleware*.

The **Visual Interaction Layer** on the right side of Fig. 1 is composed by several 3D VWs. VWs can intuitively represent interaction spaces (e.g. a room) and show the progression of activities that participants are engaged in. For example, an auction activity can be represented as a room with chairs for bidders, a desktop for the auctioneer and information panels to display dynamic information about the ongoing auction.

The **Causal connection layer** –or *middleware*– constitutes the main component of VIXEE (see Fig. 1). Causal connection refers to a state-consistency relation, so that state changes are propagated along both communication directions. In one communication direction, it connects human participants from multiple VWs to the *Normative Control Layer* with the aim of regulating their actions. In the reverse communication direction, it supports the visualisation of SW agent participants as bots in the VWs (representing their presence as well as their actions). This layer is divided between the *Extended Connection Server* (ECS) and a *Virtual World Manager* (VWM). The ECS (left box inside the *middleware* in Fig. 1) mediates all the communication with AMELI. Its main elements are the *Agent Manager*, which creates an external agent (E. Agent in Fig. 1) for each connected (human-controlled) avatar in order to represent it within the EI; and the *Message / Action Dispatchers* (on top of *Agent Manager* in Fig. 1), which mediate both AMELI messages and virtual world actions. They use the so called *movie script* mechanism to define the mapping between AMELI messages and VW actions and vice versa. The VWM (right box inside the *middleware* in Fig. 1) mediates all VWs-ECS communications and dynamically updates the 3D representation of all connected virtual worlds.

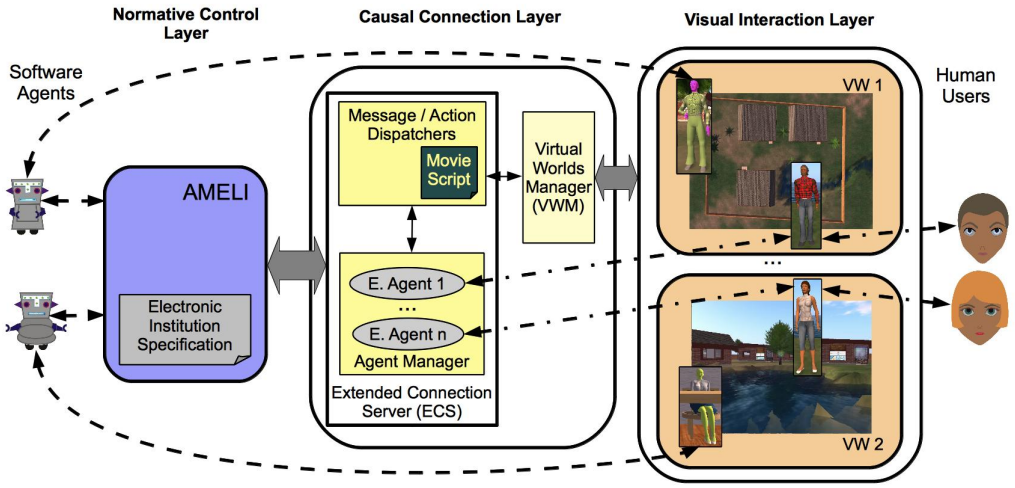

Figure 1. VIXEE Architecture. The *Causal Connection Layer* as middleware between the *Normative Control Layer* (an Electronic Institution populated by agents) and the *Visual Interaction Layer* (Virtual Worlds populated by 3D virtual characters).

3 AGENTS INTERACTIONS

Overall, we consider three types of participants' interaction mechanisms: *illocution*, *motion*, and *information request*.

First, *illocutions* are interactions uttered by participants within activities' protocols. Human avatars interact by means of illocutions by performing gestures and sending chat messages. Bot avatars can do the same except for those representing institutional agents, which can also send public messages by updating information panels. Second, *motions* correspond to movements to enter and exit activities. Human avatars show their intention to (and ask for permission to) enter and exit activities by touching the door of the corresponding room in the VW. As for bots, they are simply teleported between rooms. Third, *information requests* include asking to the institution for information about i) activities reachable from a transition and the other way around, ii) activities' protocols states and iii) activities' participants. These interactions have been implemented by both sending messages (e.g the institution manager sends a private message to an avatar specifying that is not allowed to enter /exit an activity) and drawing on information panels (e.g. the state of an auction is indicated in a panel on the wall of the auction room).

For example, a human within an auction activity bids by performing a raising hand gesture with her avatar. Then the VWM catches the action and communicates the gesture to the middleware, which uses the *Dispatchers* to translate this gesture to the corresponding AMELI message *"bid"*. Afterwards, the *Agent Manager* in the middleware sends such a message to the normative layer. The message is sent by means of the participant's external agent. Next, AMELI processes the message and sends back a response with the message's result (ok or failure) to the middleware. As a consequence, the middleware uses the VWM to cause (trigger) the action of the auctioneer sending a chat message with the response to all participants (humans and bots) within the auction. Regarding SW agents, they are connected to the normative layer, and thus, they send bid messages to AMELI directly. In this case, only valid messages are sent to the middleware, which uses the VWM to trigger the aforementioned auctioneer's action and also the action of the related bot avatar raising its hand. Thus, the human user can perceive bot's bid visually. Overall, the human can bid and be aware of all other participants' bids. As we have seen, this mechanism allows bots and humans in the same auction activity to interact in a structured and seamless way. This interaction have been further illustrated in a water market scenario[3] [1].

4 CONCLUSIONS

In this demo we have presented VIXEE, the *Virtual Institutions eXEcution Environment* infrastructure, as a means for taking humans in the loop of MAS. VIXEE combines EI to structure participants' interactions and VWs to provide a visual interface for human inclusion. In this system human participants are able to interact with other participants (software agents and humans) in a structured and seamless way. As future work, we plan to extend the VIXEE infrastructure with assistance services that improve both participation and the overall system performance.

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[3] See http://youtu.be/hJzw40lQvUY for a complete visualisation