NORMATIVE VIRTUAL ENVIRONMENTS:
Integrating Physical and Virtual under the One Umbrella

Anton Bogdanovych, Simeon Simoff
School of Computing and Mathematics, University of Western Sydney, NSW, Australia
a.bogdanovych@uws.edu.au, s.simoff@uws.edu.au

Marc Esteva
Artificial Intelligence Research Institute (IIIA-CSIC), Campus UAB, Barcelona, Catalonia, Spain
esteva@iiia.csic.es

Keywords: Normative Multiagent Systems, Virtual Institutions, Causal Connection.

Abstract: The paper outlines a normative approach to the design of distributed applications that must consistently integrate a number of environments (i.e. form-based interfaces, 3D Virtual Worlds, physical world). The application of the described ideas is illustrated on the example of a fish market, which is an application that can simultaneously be accessed by the people from the physical world, people using form-based interfaces and people embodied in a 3D Virtual World as avatars. The Normative Virtual Environments approach in this case allows for maintaining a consistent causal connection amongst all these environments.

1 INTRODUCTION

In order to survive in today's highly competitive market it has become a requirement for the employees of many companies to be able to conduct their business not only directly at the work place, but also at home, using portable computers, or even "on the go", with the help of mobile devices (Umar, 2005). The fact that many people continuously have to switch between conducting their activities in the physical environment and within various virtual environments has generated a demand for consistent integration of these environments and the corresponding interfaces. The need for bridging the gap between physical and virtual has become a major concern of researchers working in such areas as *ubiquitous computing* (Weiser, 1999) and *augmented reality* (Azuma, 1997).

Both ubiquitous computing and augmented reality applications primarily focus on creating a mixed reality space and hiding the fact that virtual and physical environments are in fact logically different spaces. In some situations, however, a clear logical separation between such spaces is highly desirable.

To illustrate this demand we offer an example of a fish market accessible via three different types of interfaces. First of all, there is a possibility to participate in the actual physical fish market, where sellers can demonstrate the quality of their fish and let buyers purchase it, both acting in the physical world. Those, who can't be physically present in the actual fish market may decide to buy their fish through the Internet using a form-based interface. This is particularly useful for mobile devices, which are employed by users who are moving around and do not require a high level immersion from the provided interface. Finally, there is also a possibility to have a life-like 3-dimensional representation of a fish market, where the location of the fish market and the fish being auctioned are reconstructed as realistic 3D models based on the provided specifications. Such an interface solution is useful for participants wishing to access the fish market remotely, while still having a high degree of realism to help them making informed decisions.

Clearly, each of the three types of interfaces presented above is oriented towards a separate class of users. For the users accessing the fish market remotely it is not an option to be present at the physical location and, therefore, technological integration of the corresponding virtual environments with the physical world is not possible. The application of augmented reality or ubiquitous computing techniques is not beneficial in this case, while the need to logically integrate all the three environments so that they all maintain a single logical state is evident. For the participants acting within the fish market remotely it is absolutely vital to be updated on the changes of the environment states (i.e. that the fish they are prepared to buy was already purchased in the physical world and is not in stock anymore) as well as it is important to have a logically consistent environment.

For the development of systems requiring a logical integration of the physical world with a number of virtual environments we propose a new conceptual solution called *normative virtual environments (NVE)*. These are environments that provide a unified way of controlling the interactions of participants through normative regulation of these interactions and are capable of maintaining a *causal connection* (Maes and Nardi, 1988) between all the existing environments. This means that the state of any environment could be changed through acting upon any other environment.

Further we present the architectural solution supporting such causal connection. The proposed approach is quite general and has a wide range of applications from electronic markets to e-procurement systems. For the clarity of this presentation, however, we limit the problem domain to fish markets. The remainder of the paper is structured as follows. Section 2 introduces the fish market domain. Section 3 explains the concept of normative virtual environments and outlines the underlying technological solution. Section 4 shows the implementation of the fish market as a normative virtual environment. Finally, Section 5 presents some concluding remarks.

2 PROBLEM DOMAIN

In the Mediterranean fresh fish has been traditionally sold through auction houses. There, fish is grouped into sets of boxes (*lots*) and auctioned following the Dutch protocol: price is progressively and quickly decreased by a small amount until a buyer submits a bid or the price descent reaches a withdraw price.

Some contemporary fish markets automate their selling methods via information technology. Figure 1 presents an example of such contemporary fish market in Spain. Here the auction process is visualized on the big electronic board. For each lot the board shows the identification number of the product, type of product, number of items in the lot and the current price. The buyers are supplied with infrared devices that can communicate with the main server. Pressing the "bid" button on this device would stop the clock, finish the auction and announce the buyer who has placed the bid as the auction winner.

Even in such contemporary fish markets the presence of human buyers at the auction houses is still necessary. This imposes two main barriers. First, it restricts the potential buyers to those present in the auction house. Second, it makes the participation in several auctions simultaneously costly, as companies have to send a representative to each one. The elimination of such limitations would be very profitable

Figure 1: Contemporary Fish Market in Spain.

for both buyers and sellers. Increasing the number of buyers makes the market more competitive and thus increases the buying price to the benefit of sellers. It also permits the participation of buyers without intermediaries saving costs to the buyers. Next, we outline the normative virtual environments approach offering a general solution for eliminating these constraints.

3 NVE

The need for remote participation in fish markets was expressed by the MASFIT project (Cuní et al., 2004), which suggests using normative multiagent systems for accomplishing this task. In particular, the participation of buyers in fish market auctions is mediated by a trusted third party called the *electronic institution*. An electronic institution formalizes the rules of the fish market environment and establishes what the participants are permitted and forbidden to do.

Such rules include the roles the participants can play, the activities each role can engage into, the interaction protocols associated to each of the activities and a set of actions that can be performed. The target environment is separated into a number of logical groups of activities (scenes). Scenes are interconnected to form a network that represents sequences of activities, concurrency of activities or dependencies among them. Only participants playing particular roles are admitted to a given scene, where they should follow the interaction protocol specified for the scene. Once the rules associated with an Electronic Institution are formalized, a software component called *AMELI* can be used to launch the institution, let participants join it and communicate within and will maintain the correct institutional state.

The MASFIT project wasn't focused on integrating physical and virtual environments, instead it developed the mechanisms for software agents to participate in a fish market simulation with similar conditions as the humans do in the physical world. In our approach we follow the path taken by the MASFIT project for consistent integration of the virtual end physical environments. Next, we present our solution to extending the MASFIT approach.

3.1 Causal Connection

Our solution to integrating the physical world and a number of virtual environments is to utilize the

AMELI system and causally connect it to each of the environments. We call this approach *Virtual Institutions*. Figure 2 outlines the fish market scenario implemented using Virtual Institutions. Here a number of fish auctions are conducted in the physical world by a number of auction houses. Each auction house connects to the virtual institution through the Auction Software running on their servers. The same Virtual Institution is used by the participants in a number of virtual environments. On the picture these are 3D Virtual World (3-dimensional representation of a fish market), 2D Form-Based Environment (a 2D representation suitable for portable and stationary computers) and 2D Mobile Environment (a simplified 2-dimensional representation for mobile devices).

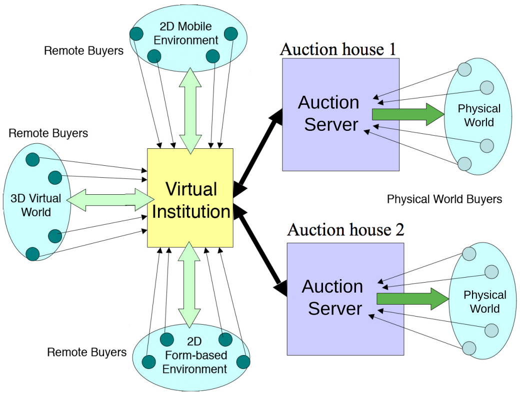

Figure 2: The system architecture example.

Having a causal connection allows any participant to connect to the system through any environment and the participants' representation in every other environment will be automatically created and the result of any action will be propagated there. The technological component that enables the causal connection of all the environments to a single institution is the "Causal Connection Server". It utilizes the functionality of the AMELI system. For every participant entering some environment the Causal Connection Server sends a request to AMELI requesting the permission to join the institution. Then, every participant's action is first validated with AMELI and if accepted – its performance is propagated to every connected environment. Figure 3 illustrates the causal connection mechanism for a 3D Virtual World.

The figure presents an example of how the institution controls the admission of participants to certain activities (rooms). An event is generated as the result of the participant positioning the mouse pointer over the door handle and clicking the left mouse button (requesting the avatar in the Virtual World to open a door by pushing the door handle). Each event that requires institutional verification has an associated script and the name of this script is stored in the Action/Message

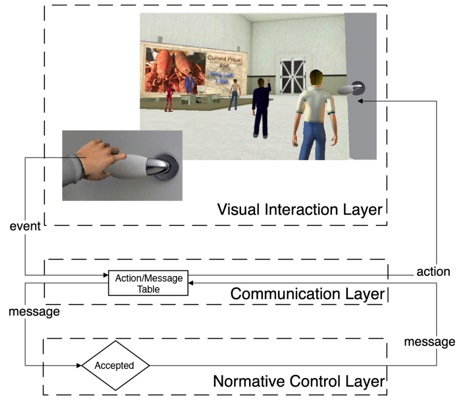

Figure 3: Causal Connection.

table. The Causal Connection Server consults with the Action/Message Table to find the institutional message that represents this event in AMELI. In case such a message is accepted by the AMELI, the response message is sent back and the Causal Connection Server again consults the Action/Message table to transform this response into the name of the action that has to be executed in the Virtual World. Next, the action is performed by executing the corresponding script. In the given example this action will result in opening the door and moving the avatar through it.

3.2 Technological solution

Figure 4 outlines the Virtual Institutions approach with the detailed focus on the architecture of the Causal Connection Server. The AMELI system is featured with two additional components: Federation Monitor and Institution Monitor. These components offer an interface to AMELI, allowing the observation of all messages within a single Electronic Institution platform. The Causal Connection Server is connected to AMELI through sockets provided by these monitors and collects available messages.

The Causal Connection Server is supplied with the number of components. The Agent Launcher component creates agents representing humans inside the AMELI. The Communicator is a gateway between AMELI, Agent Launcher and the connected environments. The StringToMessageProcessor translates the institutional messages into a special Message class that can be used for easy access to the message parameters. Two Message Monitors observe the incoming messages and forward them for further processing.

The processing of the messages received from AMELI is done by the Action Composer. This component consults the Action/Message table to the selected environment. The Message Composer does the opposite: it transforms events received from the Atmosphere Player into messages that should be sent to AMELI for verification. In order to create the correspondence between avatars and agents, the AvatarID/AgentID table stores their identifiers and

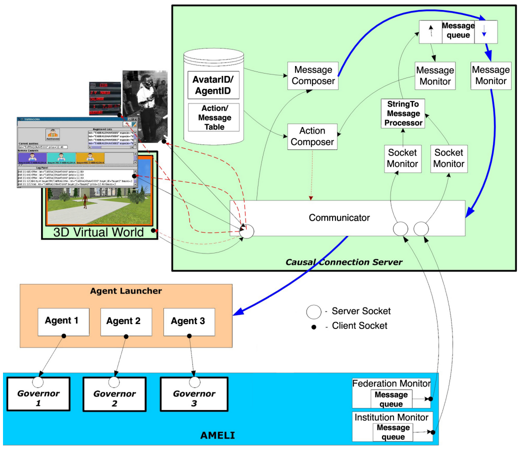

Figure 4: Causal Connection Server Architecture.

helps in making the mapping between them. Such a mapping is necessary for being able to correctly dispatch messages and actions to recipients.

4 FISH MARKET INSTITUTION

To demonstrate how the above-described architecture can be enacted we illustrate its application to the fish market scenario. The developed system consistently connects all the environments outlined in Figure 2.

4.1 Physical World

Physical world is the environment where several fish auctions are conducted by a number of auction houses. The participants perform their activities through specific devices, which communicate with the auction software through an infrared port. All the responses of the virtual institution (associated with the messages of participants from other connected environments) are communicated back to the auction software, which then decides which of those to display on the auction board. Figure 5 a) gives an impression about the interface used by participants.

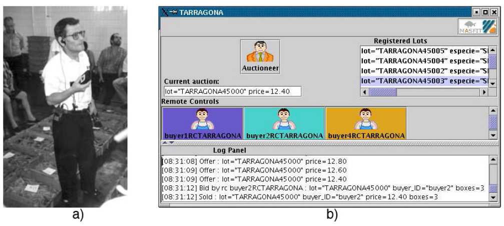

Figure 5: Physical World and Form-Based Environment.

4.2 Form-based Environments

There are also two form-based environments connected to the system: a simplistic version for participants with mobile devices and the environment used by users with personal computers. Apart from the more functional interface the users of the non-mobile environment can employ software agents to act in the system on their behalf. The detailed presentation of this functionality is given in (Cuní et al., 2004). Figure 5 b) outlines the form-based interface.

As in the previous case the actions of the participants are first verified with the institution and only then propagated to all the connected environments. The validated actions of the participants from other environments also result the update of the interface.

4.3 3D Virtual World

The 3D Virtual World is presented in Figure 6. Here all the participants are visualized as avatars and can observe each other's actions. In the current limited implementation we do not present a detailed 3D visualization of the auctioned lots, but simply put its picture on the auction board (together with all the related information and the price). When a buyer decides to purchase the lot – its avatar is raising a hand to give a visual clue to other participants. The details of the auction winner are then displayed on the auction board. To maintain the causal connection, every participant from any connected environment is visualized as an avatar. Participants' actions are also consistently mapped to the avatars and the environment.

Figure 6: Fish Market as a 3D Virtual World.

5 CONCLUSIONS

The paper has presented normative virtual environments as an approach for consistent logical integration of physical and virtual environments. The technological solution supporting this concept was illustrated on the example of a fish market, which can be jointly used by participants from the physical world and a number of remote virtual environments.

REFERENCES

Azuma, R. (1997). A survey of augmented reality. *Presence*, 6(4):355–385.

Cuní, G., Esteva, M., Garcia, P., Puertas, E., Sierra, C., and Solchaga, T. (2004). MASFIT: Multi-Agent Systems for Fish Trading. In *Proceedings of the European Conference on Artificial Intelligence*, pages 710–714.

Maes, P. and Nardi, D. (1988). *Meta-Level Architectures and Reflection*. Elsevier Science Inc., NY, USA.

Umar, A. (2005). IT Infrastructure to Enable Next Generation Enterprises. *Information Systems Frontiers*, 7(3):217–256.

Weiser, M. (1999). Some computer science issues in ubiquitous computing. *SIGMOBILE: Mobile Computing and Communications Review*, 3(3):12.