Using Simulation, Collaboration, and 3D Visualization for Design Learning: A Case Study in Domotics

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Abstract. Computer-assisted educational environments are an excellent complement to the learning process. However, when domains are complex, the expected learning support objectives may not be achieved. We are interested in the exploration, study and application of new interactive technologies suitable for their use in the classroom. We propose the use of Computer Supported Collaborative Learning combined with Simulation and 3D representation for assisting in learning processes. We believe in the potential of this synergy to support learning in a case study: the teaching of Domotics, i.e., the design of automated control facilities in buildings and housings.

1 Introduction

Computer-assisted educational environments are an excellent complement to learning processes. Especially, design and simulation environments are tools offering contrasted benefits for discovery learning in multiple domains. However, when these domains are complex, the expected learning support objectives could not be achieved. This complexity justify the necessity to carry out the design activity itself in groups. From this the perspective of modelling and simulation in collaboration, we developed DomoSim-TPC [1], a system supporting collaborative learning in Domotics. This domain studies the integral automation of housings and buildings. The system provides shared workspaces integrating tools for domain problem solving with communication and coordination tools.

This system was improved with support for 3D simulation, allowing the learners to achieve additional cognitive benefits. Using Virtual Reality for learning should articulate mechanisms that enhance effective learning. These techniques will allow users greater interaction possibilities. Using this new tool the students can interact with the generated virtual scenario. This scenario, which is built under a variety of constraints, represents a solution to a proposed problem. This way, this 3D simulation tool allows the students to test their proposal of solution in a more realistic way.

Currently, most of the systems treats Virtual Reality and Computer Supported Cooperative Work separately. This occurs in Domosim-TPC, when the 3D simulation is

Y. Luo (Ed.): CDVE 2004, LNCS 3190, pp. 164-171, 2004.

a single user tool. Now, our objective is combining them in a collaborative virtual simulation workspace.

But this 3D approach makes the interaction between users and shared objects more difficult, so that the complexity of multiple users sharing the same workspace has to be studied [2]. This work will show the way in which CSCL combined with simulation and 3D representation can help in the discovery learning process, in which the students are responsible for what they learn.

The paper is organized in this way: in the following section, the problem and the application domain is introduced; next, we explain the way followed by our research group in the development of educational applications in Domotics; we have developed a tool called Domo3D for 3D representation of domotical building projects, which is briefly described in the following section; next, we describe our objective of combining CSCL, Simulation and 3D representation for learning processes. Finally, we will draw some conclusions and outline the future work we plan to develop.

2 The Problem: Teaching Design in Domotics

The domain where the necessity appeared and where our investigation is being applied is the learning of Domotics, i.e., the design of automated control facilities in buildings and housings.

In Spain the new Formación Profesional (Technical Training) defined in the LOGSE (Spanish Law for Primary and Secondary Education) takes professional profiles into account where training in Domotics is considered as a necessity. Some learning stages in electricity and electronic courses are centered on the study of the design and maintenance of singular installations and automation of buildings dedicated to housing. In this area the design of domotical installations have a fundamental role.

In this kind of training, the realization of practical experiments is specially important. However, the necessary material to carry out these works is usually expensive and in many cases its readiness is low. This problem is increased by the difficulty to bring the student to real situations, to reproduce accidents and to outline chaotic situations which can happen in the real world and whose designs should be prepared.

This situation creates an ideal framework for learning an incipient discipline like Domotics. A 3D representation allows a better understanding of spatial and visual aspects of a project of domotical building.

2.1 The Application Domain: Domotics

The term Domotics is associated to the set of elements that, when installed, interconnected and automatically controlled at home, release the user from the routine of intervening in everyday actions and, at the same time, they provide optimized control over comfort, energetic consumption, security and communications.

There are three types of domotical elements [3]: sensors, actuators and systems or controllers. *Sensors*, also called receivers, are elements that receive the information from the atmosphere, for example, atmospheric or luminosity variables. They can also obtain information on the actions humans carry out in their daily interaction at home, such as pressing a switch or coming into a room. These include sensors of temperature, luminosity, gas, smoke, intrusion, etc. *Actuators* are elements that receive the order to be activated or deactivated. They consist of actions such as switching a light on/off or opening/closing a shutter. As in the case of sensors, there are a great variety of actuators. Among these actuators we can include, for example, the heating system, air conditioning, the alarm, etc. Finally, the *systems* or *controllers* are in charge of processing the information coming from the sensors and, by means of the appropriate control programming, they activate or deactivate the actuators.

The domotical elements are grouped by means of links into different *management areas*. Four such areas could be Thermal Comfort, Control over Luminosity, Security and Energy Control. Basically these four areas include most of the domotical elements although their number and functionality is constantly increasing.

2.2 Teaching Design Procedures in Domotics

When creating educational applications for teaching Domotics, we take in account Direct Manipulation [4-7] as interaction style. To create a visual system for the installation of domotical elements in buildings, we developed a domotical simulation environment [8]. In this environment, and by means of Direct Manipulation, the student use a set of domotical elements contained in a toolbar. This elements can be located, connected and parameterized using actions such as “drag and drop”. The great variety of elements and the actions on them makes this type of design a complex problem in which the student can easily get lost and be unable to complete it satisfactorily. To tackle this complex problem we follow the ideas of Soloway [9], and Bonar and Cunningham [10], who proposed the development of intermediate solutions in their programming environments. We have developed a tool called PlanEdit [1]. With this editor, the student carries out a first approach to solving the problem by making a plan with abstract actions of design. Thus, by working abstractly, they should be able to manage the first approach to the solution without any great difficulty.

In pursuit of the traditional model of the classroom where students work collaboratively to perform practical tasks, we decided to develop our system in order to support group work.

Tools based on asynchronous communication are used in order to specify, discuss and organize the general approaches to the solution to the design problem [11]. An editor is available for the individual drawing up of design strategies by means of a specification language with a high level of abstraction. The elements of this language have a visual representation associated which facilitates their use by means of the typical procedures of direct manipulation. Once built, the models are presented to the other members of the group. The group, by using a method of argumentative discussion, comment and request explanations about the decisions taken. The author is forced to react to these comments by arguing, justifying and refining their decisions. All this is carry out in a constructive and collaborative process that leads to learning.

The results generated from this process are organized in a table of contents which can be accessed and visualized.

These results are a good starting point for the second phase. But it is necessary to list and to organize attributes associated with the elements comprising the model. This is carried out by means of a collaborative tool based on the direct manipulation of the domain objects. With this tool you can select, insert, eliminate, move operators, etc [12]. The tasks associated with this design process can be distributed among the participants following various criteria. As the objective of the design is to obtain a model fulfilling certain requirements, this is verified by means of the hypotheses approach matched against the simulation of the model. This simulation, in which all the members can interact in real time by direct manipulation and synchronous communication, will contribute to error detection, the result of reflection and the discovery of inconsistencies in the approach. These processes should lead the group to a self-directed learning [13].

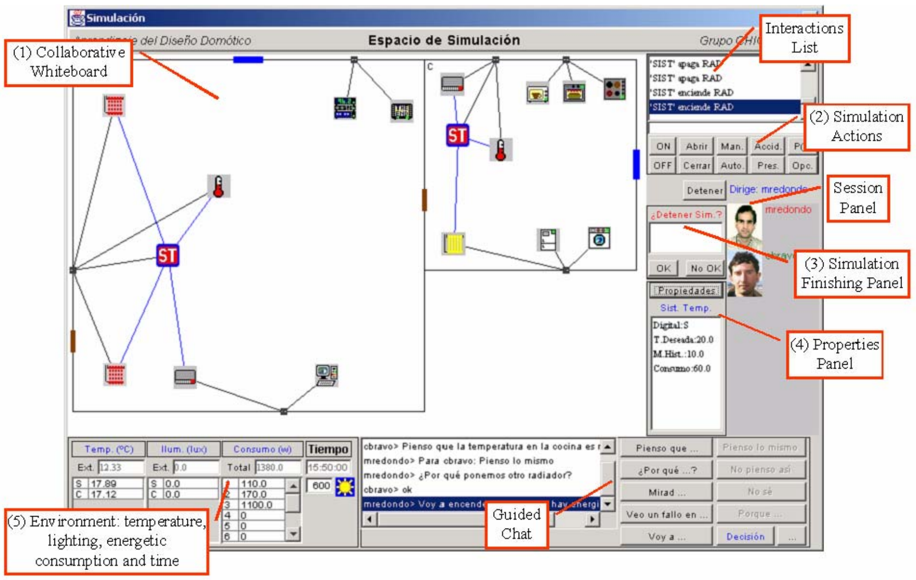

Fig. 1. Space for bi-dimensional simulation in Domosim-TPC.

Figure 1 shows the user interface of the collaborative simulation tool. The different elements of the simulation tool are: the whiteboard with the designed model (1), buttons to carry out simulation actions (2), a panel to propose the finishing of the simulation (3), a panel of operator properties (4), and simulation information (temperature, illumination, consumptions and clock) (5). It also contains the awareness and discussion elements: the Session Panel, the interactions list and the Guided Chat. This figure shows a simulation session of a designed model by the students. This model contains, in the lounge (left room), 2 radiators, 1 air conditioner, 1 temperature sensor and the regulator system, as well as some appliances (computer, television, and stereo). In the kitchen (right room), the students have inserted another thermal comfort subsystem and the appliances that the problem demands (microwave, oven, cooker, refrigerator and washing machine). The operators are connected to the plugs to obtain electricity and to facilitate the regulation control, according to the domotical system of Power-Line Carrier. With a different color link to the electrical connection, the receivers and activators are linked to the systems that regulate them. The students have defined parameters of each operator such as the energy consumption, the calories...

3 Support for 3D Simulation: The Workspace Domo3d

The aforementioned system, Domosim-TPC, was improved with an additional workspace, called Domo3D, to make a 3D interaction possible during simulation. Inmersion and direct interaction with a 3D representation of the problem allows a better internalization of the user's acquired knowledge. Using this new workspace adds some advantages: better perception of areas and a greater emotional and semantic communication.

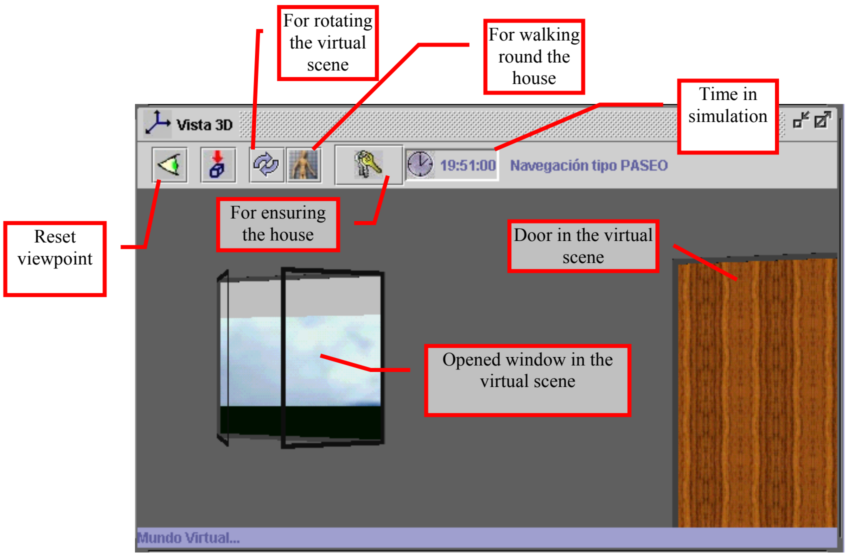

Fig. 2. Three-dimensional view of the domotical building.

Figure 2 shows the appearance of the interface of the tool Domo3D. For its implementation Java technology has been used; including the Java3D API for creating the three-dimensional housing model.

There are several factors that add a degree of interest to the user that uses the new workspace Domo3D; these are *events*, *realism*, *animation* and *power to answering*.

But this feature has been, up to now, individual: this 3D experimentation space is not available to all the participants in the same view. Now, our objective is to incorporate a collaborative virtual simulation tool like an additional workspace in Domosim-TPC. For this, we propose a participative 3D simulation, in which the participants are agents in a simulation such as players in computer-supported games.

4 Towards a 3D Collaborative Simulation Workspace in Domosim-TPC

The next step is to develop a 3D collaborative simulation wokspace. Using this new tool for supporting Domotics learning adds some advantages:

- The additional dimension (height) introduces new possibilities, and enriches the simulation. Using a 3D model enhances realism during the simulation.
- New interaction possibilities. Users, immersed in 3D simulations, improve their spatial and navigations abilities thanks to practising real tasks in the virtual scene. Operating in this kind of environments is more simple and natural for the users. However, interaction with other users immersed in the shared virtual workspace also improve their social and negotiating skills.
- A most realistic perception is provided. The purpose of this kind of interfaces is to obtain immersion systems that emulate a real environment and produce a most effective learning. A shared workspace provides a natural and intuitive way to interact with other students.
- Also, new kind of information is accessible (visual attention and physical movements, position and orientation, …). It will allow us to characterize users. Also, information related with interaction between the virtual human inside the virtual scene, and with the shared objects, is available.

This new tool in Domosim-TPC raises several aspects to be considered:

- Controlling the concurrency problems when several users interact with the same object in the 3D representation.
- Solving the distribution of events between several users in the virtual scene. All the interactions must be distributed immediately to the group members to be to shown in the shared space. Being able to ascertain order between events is very important for understanding the sequence of actions in distributed systems. We propose the use of the Schiper-Eggli-Sandoz protocol [14] with the aim of eliminating the problems related to maintain the consistency during the simulation and ensure the same view to all participants.
- Including awareness mechanisms during the simulation that allows the users to know what the other students are doing. The essence of a collaborative virtual environment is that users are explicitly represented to each other within a shared space.
- The system must inform of the interactions in a textual way. This information allows following the trace of actions that are activated whereas the user interact

with the domotical elements in the house. In this way, not only changes are shown in visual mode, but also additional information in supplied (for example, numerical data), which makes a deeper knowledge possible.

During the simulation users can play different roles (owner of the home or intruder) and interact on the model to provoke reactions. Simulation actions (to switch on/off, to open/close, to break a link, to simulate human presence in a room…) are used to modify the behavior of the objects in the model and to check if the model behavior is what was expected. This behavior is reflected in real time in the 3D visualization.

5 Conclusions and Future Works

The way followed by our research group in the development of educational environments began with Direct Manipulation. The need for collaboration between students showed the need to use Collaborative Teaching/Learning Systems when the problems to be solved are of a certain complexity. In this paper, we have described our motivation and design principles to add a 3D representation during simulation in a collaborative e-learning environment of domotical design, which is taken as starting point in our research. In order to include a Collaborative Virtual Simulation Workspace we propose the combined use of collaborative capacities, 3D representation and simulation. This approach can offers new possibilities of interaction and benefits in many activities of learning related to engineering, architecture and other areas. It improves the understanding of the mechanisms that govern the simulated reality or simulated process and enhances visualization aspects.

From a technological point of view, this tool is achieved. Our proposal for the future includes the experimental evaluation of the system using obtained results in the use of Domosim-TPC(not including the 3D simulation space) as a reference point. Also, usability studies must be elaborated and applied.

Acknowledgements

This work was partially supported by the Junta de Comunidades de Castilla – La Mancha and the Ministerio de Ciencia y Tecnología in the project TIC2002-01387**.**

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