

COLLABORATIVE ENVIRONMENT ARCHITECTURE PROPOSAL

A study of virtual environments for learning purposes in control engineering

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Abstract: This work presents first studies towards an architecture for Computer Supported Collaborative Environments (CSCE) to aid education and training in the control engineering. The expansion of social networks, virtual environments and Web technologies such as Web 2.0 has shed the light on learning technologies. Employing virtual worlds as breeding grounds to create an infinite range of learning and didactical materials are becoming more and more common as educational institutions realize the hidden potential of this endeavor. Despite several efforts and various implementations there are few standardizations or studies of interoperation between most of the tools and technologies available for CSCEs. This study focuses directly on a reference model architecture undisclosed when developers implement their solution to this complex theme. Presented are the some relevant technologies available and a possible link scheme between them. Concepts like: remote experiments for enhance learning; autonomous tutoring; and collaboration awareness supports integrated to CSCEs are described. As results, case studies and a prototype are presented with each chosen technology discussed.

1 INTRODUCTION

Since it has been recognized that skilled engineers are one of the main elements for the development of innovative products and services, as well as for the optimization of production processes, to ensure high productivity and quality, most developed countries have treated this subject as a key aspect of their educational strategy. Considering control engineering education, a key issue is the reduction of the gap between classical theoretical courses and real industrial practice.

Unfortunately, to reproduce real industrial plants in an academic environment are not a trivial task as they are, in general, very expensive (in terms of acquisition, installation, operation, and maintenance costs). Furthermore, safety constraints always restrict the access of costly equipments that are only available for research and not in undergraduate academic laboratories courses. This way, most of them are structured only as small-scale experiments with little connection to industrial reality.

Within this context, industrial lab facilities that are

accessible via Web and therefore available at flexible times, to a larger number of individuals, helps to improve the overall cost-effectiveness of such solution. Moreover they offer perspectives of shaping teaching scenarios, which are close to practical engineering team-work.

The availability of remote experiments is not a sufficient condition to ensure success in learning. Stand-alone remote experiments without connection to adequate learning material usually lead students to the use of a trial and error strategy, which has a lower learning impact than originally expected (Schaf and Pereira, 2007). Moreover, remote facilities are available 24-7 increasing the demand in the number of faculty members and tutors required to provide on-line guidance.

Still focusing learning technologies it is widely believed that collaborative experiences are powerful drivers of cognitive processes and can significantly enhance learning efficiency. There are researches advocating that well constructed group activities used in conjunction with remote labs generate an added

value in regard to team skills and remote engineering competences (Ma and Nickerson, 2006). Regardless of the varying theoretical emphasis in different approaches on collaborative learning (e.g. social constructivism), research clearly indicates that in many (not all) cases students learn more effectively through collaborative interaction with others.

How to effectively use computer technologies to support people in their learning and work, in particular when doing collaborative activities with coordination constraints is a topic that has been extensively researched for several years. Researchers recognize that this is not only a technological challenge but an organizational and social topic (Grudin, 1988; Kaptelinin, 1996). However, only recently a major shift of focus on the difference between cooperation and collaboration occurred. The former being some kind of protocol to avoid conflicts and provide harmonic synchronization of task oriented work (assembly line model), whereas the later being a struggle for new products, tools, work-processes and a higher quality of all (creative workgroup model) (Carroll et al., 2003).

Following this trend is not difficult to foresee a large spread of implementations of Computer Supported Collaborative Environments (CSCEs) in the scientific community. A research study of such environment capabilities and interoperability is therefore highly required. This work tries to comprise some studies and propose a CSCE architecture with relevant technologies and concepts aimed to education in engineering control.

The remainder of this paper is organized as follows: Section 2 presents virtual collaborative environments background theory; Section 3 describes collaboration in labs employed in education via Web; in section 4, the proposed architecture is described; Section 5 outlines developed case studies and a prototype for validating the proposed environment architecture. Finally, Section 6 draws conclusions.

2 VIRTUAL COLLABORATIVE ENVIRONMENTS

Virtuality among several other utilities aims to close up dispersed or distributed users in a common locus. This "site" called commonly as environment is not physically real but virtual. Two well-known acronyms are directly related to virtual environments: the MUVES (Multi-User Virtual Environments) and the MMORPG (Massively Multiplayer Online Role-Playing Game). While the first is a more generic term associated to all kinds of implementations of virtual worlds, the second is specifically employed in the en-

tertainment field. There are several types of virtual environments that can be classified in areas of applications: work, learning, social and entertainment.

To achieve higher levels of human-human interactions, which are required to solve complex engineering problems, a strong support of collaboration and multi-perspectivity is required. Most of the MUVES allow and facilitate collaboration among users. The following subsections describe with more details three types of environments in relevance with this work.

2.1 Learning Environments

Virtual collaborative environments applied in education are commonly called CSCL Environments (Stahl et al., 2006). Concepts of collaboration are closely related to learning. On collaborative activities humans interact employing self-critiquing (reflection), inquiring and arguing skills; these skills propel the knowledge building. This is the very essence of the (social) constructivism pedagogy employed nowadays in virtual environments and even in some special dedicated schools.

CSCL is a major method for bringing the benefits of collaborative and cooperative learning to users of distance learning via networked computers, such as the courses offered via the Internet. The purpose of CSCL is to scaffold or support students in learning together effectively. It supports the communication of ideas and information among learners, collaborative accessing of information and documents, and instructor and peer feedback on learning activities. Also supports and facilitates group processes and group dynamics in ways that are not achievable by face-to-face communication (such as having learners label aspects of their communication).

Like many educational activities, it is difficult to evaluate the effectiveness and efficiency of CSCL activities. Historically, the lack of evidence that technological innovations have improved learning in formal education highlights the need for evidence of whether, how and when expected improvements in learning take place. Computers have become important in this, with education related personnel and institutions around the world setting goals of increasing student access to computers and the Internet. However, the ability to combine these two ideas (computer support and collaborative learning, or technology and education) to effectively enhance learning remains a challenge (Stahl et al., 2006).

Virtual Learning Environments or Learning/Course Management System (LMS/CMS) are the most common tools employed for organize

digital media learning objects/materials in the Web. Perhaps one of the most common free VLE implementation is MOODLE (Dougiamas and Taylor, 2003). MOODLE is an open source project that is based on the social constructivism pedagogy. Most VLE implementations aid teachers with sufficient abstraction and intuitive graphical tools to create, host and link their didactic materials. They also provide user control and logging information that help to trace users' interactions.

2.2 Working Environments

Environments with work purposes, generally related to the term CSCW, are characterized to join task forces into common projects. Based on the literature, five levels of work coupling were identified: light-weighted interactions, information sharing, coordination, collaboration, and cooperation. Light-weighted interactions are only loosely tied to the work itself. Coordination, collaboration, and cooperation are much more tightly coupled than the previous two. Coordination requires group members to coordinate both the activities and communication. Collaboration levels of work coupling involve group members who work toward a common goal. They often are performing separate tasks that have a high degree of interdependence, but work is still done by individual members. They share goals, tasks, and a desire to maintain a high state of shared knowledge. Cooperation is the highest level of work coupling, and it demands the greatest amount and highest quality of communication. People at this level of work coupling have shared goals, common plans, shared tasks, and significant consultation with others about how to proceed with the work.

As work moves from the 3C Model: coordination (also referred as communication), collaboration, to cooperation; team coordination becomes a significant aspect of the group work (Fuks et al., 2008). This way coordination can only occur if people are aware. Common ground is the product of joint awareness or mutual knowledge, and grounding behaviors is the process of maintaining joint awareness (Neale et al., 2004).

Working environments that involve synchronous multi-users activities often use a common shared workspace to help in online collaboration.

2.3 Social Environments

While software may be designed to achieve closer social ties or specific deliverables, it is hard to support collaboration without also enabling relationships

to form, and to support a social interaction without some kind of shared co-authored works. The increasing audience of game or socialware implementations, like Second Life (Kemp and Livingstone, 2007) and Active Worlds AWEDU (Corbit, 2002), point out to a more game-like solution applied to virtual environments with more interactive contents. Play ethic (methods) applied to work turn activities that employ computers a more comfortable experience. This is commonly referred to game-like interface. Socialware implementations can have a 3D representation aiming to display more realistic (virtual) worlds to its users. An alternative association from social learning environments captive more attention from students while can focus on collaboration for education. Virtual environments that employ game-like interfaces in their design with purposes other than entertainment are referred as serious game.

3 COMPUTER SUPPORTED LABS

In this section some of the lab technologies commonly used in education will be discussed.

3.1 Remote and Virtual Labs

A key aspect of electronic/electrical engineering education is the application and evaluation of theory to real circuits where students apply stimulus to circuits via instrumentation and monitor the outputs (Wolf and Madsen, 2000). Web accessible laboratories with remote experiments have become an attractive economical solution for the increasing number of students (Cooper, 2000).

While the remote access of real laboratory equipment has several advantages, there are also some issues to be considered for teaching control and automation concepts: i. the number of students / students groups working simultaneously is equal to the number of physical experiments available; ii. real systems with a slow dynamic lead to long waiting times; iii. interlocking systems have to be carefully developed in order to avoid damage of components via improper actuation. Such drawbacks can be overcome by employing simulated components. Simulations, although sometimes unrealistic, have some intrinsic characteristics that can be explored in different learning scenarios. One of the main advantages of using executable simulation models is that they can be easily replicated. Students can use multiple copies (replicas) of the same simulation simultaneously. Another advantage of using simulation is that students

can speed up slow dynamics systems for quick visualization. Safety concerns involving simulation variables limits are not as important as in real experiments since the models cannot be damaged. Web accessible simulations used as experiments are commonly referred as virtual labs.

Our experience has shown that the availability of remote experiments is not a sufficient condition to ensure success in the learning process of control and automation engineers. Remote lab experiments offered as *stand-alone* settings, without connection to adequate learning material (explaining the topics that are to be learned in the experiment), usually lead students to a *trial and error strategy*, which has a lower learning impact than originally expected. Moreover, remote labs are available 24/7 for a large audience of students increasing the demand in the number of faculty members and tutors that are necessary to provide on-line guidance to students.

3.2 Mixed Reality Labs

By analyzing the pros and cons of real vs. simulated experiments, one can see that in some sense they are complementary so that a combination of both possibilities seems interesting. The interchangeable components strategy has been developed to allow the combination of both real and virtual components (Schaf and Pereira, 2009) supporting this way the definition of a variety of learning scenarios.

Mixed reality interfaces can overlay graphics, video, and audio onto the real world. This allows the creation of shared workspaces that combine the advantages of both virtual environments and seamless collaboration with the real environment (Müller et al., 2007). The information overlay is employed by remote collaborators to annotate the user's view, or may enhance face-to-face conversation producing shared interactive virtual models. In this way, Mixed reality techniques can produce a shared sense of presence and reality (Enlund, 2001). Thus, mixed reality approaches are ideal for multi-user collaborative lab and work applications (Müller et al., 2007).

4 PROPOSED ARCHITECTURE

Computer Supported Collaborative Environments (CSCE) can be implemented in a way which is suitable for work, training as well as for learning applications. The former would allow a shared workspace, the later a shared learnspace, with floating boards. Thus, the same technical function can be applied with more productive or more didactical aims.

Including a social serious game interface with a 3D world representation gives the environment a skin or metaverse (Hendaoui et al., 2008). The project SLOODLE present the merge of 3D world representation of Second Life with the MOODLE to mirror Web-based classrooms with in-world learning spaces and interactive objects (Kemp and Livingstone, 2007). Compared to other electronic tools for distance communication (Computer Mediated Communication CMC), the metaverse representation improve the sense of being there (in a classroom) (Kemp and Livingstone, 2007), rather than of being a disembodied observer, like most 2D virtual environments. This representation employs state of art technologies that support collaboration, creativity and sharing over the Web. Simulations of industrial plants and engineering concepts illustration examples within social 3D interfaces are being deployed currently in SL metaverse and these works indicate the future trend of CSCEs (Callaghan et al., 2008).

Educational tools to enhance system awareness of student's learning status, as proposed by (Chastine et al., 2006), near CSCE's to automatic learning systems capable of autonomous or automatic tutoring. Environment's collaboration awareness demonstrates also automatic capabilities associated to CMC. Following this trend, ideas to implement awareness agents (from Multi-Agent Systems MAS) developed in Java (JADE - Java Agent Development Environment) that monitor and capture students (avatars) interactions with the MOODLE (Scutelnicu et al., 2007; Otsuka, 2007) can be employed in the CSCE.

Within this context, an CSCE architecture can be envisioned with play-like social interactive interface, 3D representation and with as much autonomous support as possible is under development and subject of this work. Each of the underlying technology or concept of CSCE are depicted in the diagram of Figure 1 as modules. Modularization has the purpose to bring distribution, expansion and reusability to the CSCE's architecture design. Each illustrated module is responsible for one or more related characteristic(s):

- i. VLEs: central educational tool;
- ii. 3D social metaverse: interface;
- iii Awareness Agents (MAS), Collaboration Support and Tutoring Systems: *intelligence* and *adaptability* ;
- iv Mixed Reality, Remote Experiments and Shared Workspaces: collaboration tools and flexibility;
- v Middleware: communication, integration, interoperability.

The network infrastructure is perhaps the most obvious solution to spread the CSCE and although also

depicted but not a module. How to get all this functionalities/modules of the CSCE to work together is a very complex task addressed to the middleware.

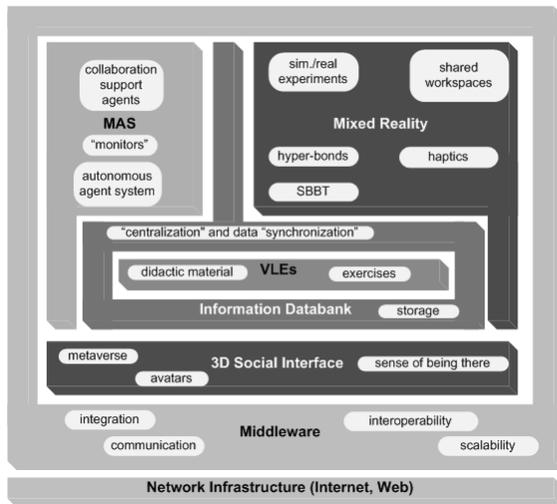


Figure 1: CSCE reference model architecture.

Collaborative environments are based on distributed technologies to facilitate teamwork between geographically dispersed groups. More concretely, the design of a good distributed architecture can be the ground of any kind of application. Interoperability must be carried out in order to provide new services to end users with total integration into the platform.

The simplest way to grant interoperability is to employ common, simple, widely spread and standard technologies. The use of Web services like, SOA and/or XML-RPC is in this case strongly recommended.

The system awareness of gestures or references from remote teachers/students within CSCEs increase CMC (Computer Mediated Communication) to levels compared to face-to-face communication in shared workspaces (Gutwin and Greenberg, 1996). The inter reference awareness of a CSCE allows a participant to refer to a set of objects of a collaborative environment and that reference be understood by other physical dispersed participants virtually present in the environment.

5 CASE STUDIES

Several case studies were proposed with the goal to achieve one primary prototype. The prototype as envisioned in Figure 2 is in phase of development and was dismembered into four related case studies of minor complexity but each one with a specific goal and concept related to the primary prototype.

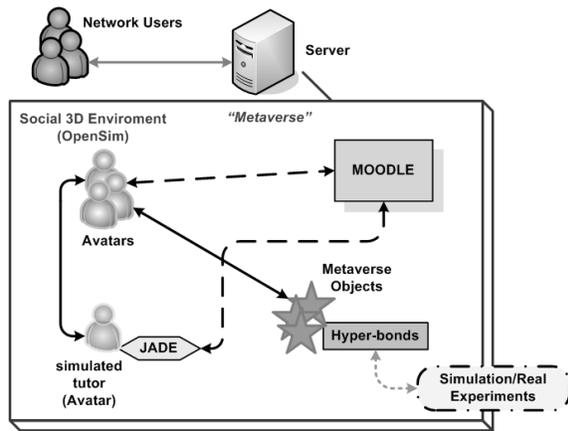


Figure 2: CSCE architecture prototype.

Among the state of art of CSCE involved technologies and concepts several were hardly studied. The use of MOODLE as standard VLE was previously advocated in (Schaf and Pereira, 2009). OpenSim, Open Simulator, one Second Life closely related free and open implementation was chosen as 3D social interface. Similar implementations were also tested and studied, like Active Worlds, Wonderland. Although Wonderland also offer free open source code and Java advantages, this implementation demands more computational power. OpenSim on the other side requires low computational power (server), can be freely explored, has a large developer community and runs in several platforms.

The first case study, a implementation of a MAS for monitoring experiment bookings, was developed using normal booking system developed previously using PHP linked with MySQL database associated with the JADE framework for development of MAS. JADE is based on Java and uses standardized FIPA agents using common Java RMI for agents intercommunication. This implementation has proved the efficiency of MAS associations with VLEs for common but also for complex tasks.

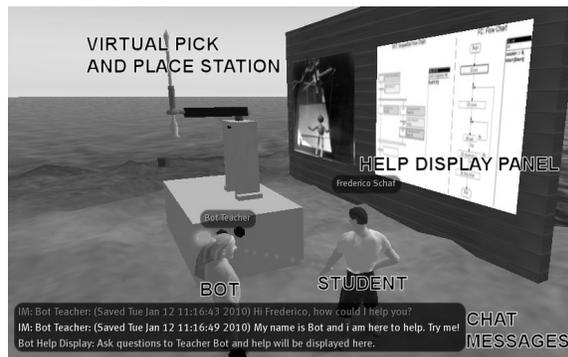


Figure 3: Bots as autonomous tutors.

The second case study uses the LibOpenMetaVerse to create automated bots. These bots act

autonomously according to a list of predefined instructions responding to metaverse (objects and other avatars) interactions (follow, react, write on chat) and chat commands (see Fig. 3).

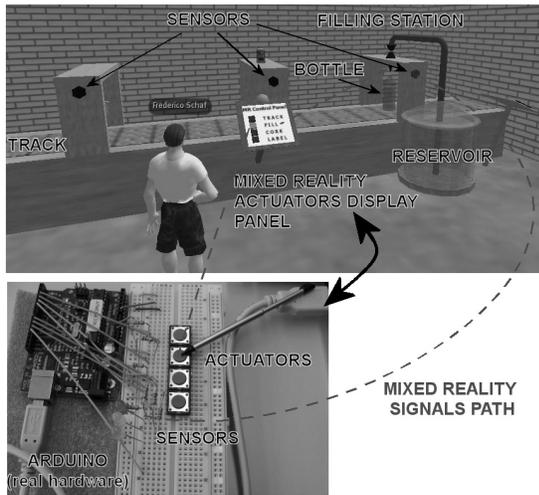


Figure 4: Mixed reality bottling system.

The last developed case study uses OpenSim as mixed reality environment. Associations with metaverse objects with external real and simulated equipments where successfully tested using the open library for metaverse development, called LibOpenMetaverse, designed in C# based on .Net and XML-RPC technologies. The Figure 4 illustrates the mixed reality scenario when using the Arduino development board (real hardware) to control the bottling station (virtual, located in the metaverse). Informations like sensor readings (virtual) are send to the controller (real), via USB/RS-232 and XML-RPC gateway software, and this according to the readings sends messages to the actuators (virtual) automatizing the bottling production system (virtual) (see Fig. 5).

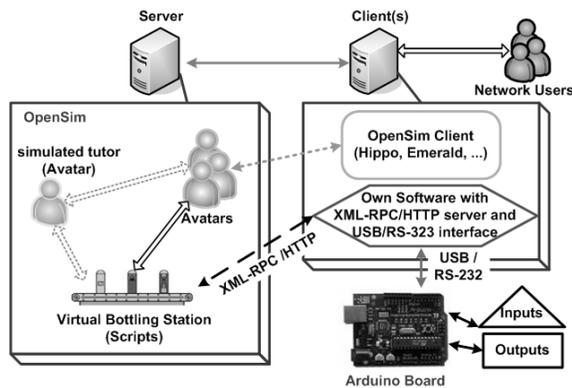


Figure 5: MR bottling system communication schema.

The Figure 6 displays the metaverse created to host most of the prototype results. OpenSim was used as metaverse, link with remote experiments was im-

plemented through in-world HTTP calls, scripts with XML-RPC link, and also using modified bots employing a link with real hardware.



Figure 6: Environment interface or metaverse .

6 CONCLUSIONS

Although many studies do not prove the efficiency or the educational success of remote/simulated/hybrid labs as well as CSCEs, the lack of a better methodology, or even the lack of support by the educational institutions seem not to reject the scientific collaboration of this research field. Maybe the new outcomes of this technology will be better understood and employed with effort of today's studies.

The prototype is under development and in the future will be evaluated by our students using usability ratings that focus on the mechanics of collaboration. Of course there is a trade-off in having geographically distributed applications and the higher communication times that are required. However, there are several benefits in exchange for these problems and also technologies are still in development to overcome delays in the transport of information. Among the advantages, the possibility to collaborate with more and previously hard reachable experts and resources. In the educational sphere, researches clearly indicates that in many (not all) cases students learn more effectively through collaborative interaction with others. This motivates to prepare remote labs for collaborative learning (called collaboratories) and to use them in distributed teaching scenarios with simulation tools, hands-on laboratories and practical workshops. As a whole, there is a necessity to improve the usability of collaborative remote laboratory tools, because otherwise learners may quickly get frustrated and stop working with it.

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