

TOWARD VIRTUAL CAMPUSES: COLLABORATIVE VIRTUAL LABS & PERSONALIZED LEARNING SERVICES IN A REAL-LIFE CONTEXT

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ABSTRACT

Virtual campuses are gradually becoming a reality with the advances in e-learning and Web technologies, distributed systems and broadband communication, as well as the emerging needs of remote Universities for collaboration on offering common programs. The advances in grid-based distributed infrastructures have further significantly contributed to this fact providing optimized and real-time system performance and support for virtual communities even under synchronous distributed multi-user usage contexts executing complex simulations in virtual lab applications. This paper focuses on realizing fundamental rich-media e-learning services for synchronous shared and interactive virtual labs offerings and asynchronous personalized learning paradigms towards enabling virtual campuses in a real-life context. The paper further presents evaluation results of the developed e-learning services on both learning and usability aspects in real-life learning contexts involving participation of student communities from remote collaborating Universities. The evaluation results showcase the interest of learning communities in such systems as they evolve to be more advanced and user-friendly and their impact in realizing virtual campuses.

KEY WORDS

Scientific web-based laboratories and virtual labs, virtual universities and colleges, e-learning, virtual campus

1. Introduction

The advances in distance learning, life-long learning and e-learning systems, combined with the advances in Web technologies, distributed systems and broadband communications have led many educational institutes to adopt novel learning practice paradigms and join forces to realize the vision of Virtual Campuses. This is already evidenced by some of the top Universities in the world already offering degree-granting programs among geographically dispersed campuses, pioneering towards realizing the first forms of Virtual Campuses. Students from all these campuses form a virtual class and community to attend in real-time and shared mode the

lectures of the institutions' instructors. The MSIN program (www.ini.cmu.edu) is such a graduate program in Information Networking offered jointly by the Carnegie Mellon University in Pittsburgh, PA, USA and Athens Information Technology (www.ait.edu.gr) operating as the CMU campus in Athens, Greece. The program courses are taught in auditoriums equipped with large high definition video-walls and cameras transmitting between the auditoriums in real-time what is happening in the other class. As a result, instructors and students at both auditoriums participate in an essentially unified but distributed virtual classroom where they enjoy full interactivity with every participant in the auditoriums at all times. Real-time audio-visual interaction is achieved through several dedicated high-speed communication links between the two campuses. The educational process is complemented with the use of an appropriately configured document repository where course related documents are placed and discussion forums for course related subjects are supported to allow students asynchronous access to learning material. However, support for student personalized self-study and self-evaluation is not supported. Furthermore, several courses expect students to do their coursework in teams in a laboratory environment. These teams are currently formed locally, meaning that students at the AIT campus form their own teams and students at the CMU campus form their own teams but teams across the two campuses can not currently be easily formed because of lack of support of a distributed laboratory environment that would enable closer student interaction and collaboration.

Interactive synchronous virtual laboratory experiments run together by teams of students unrestricted by geographic location would enhance the formation of community ties between all members of the same class independent of their location. Furthermore, personalized learning based on the level of student skills and knowledge would motivate students to self-study and would allow collaborating institutions to practice common learning practices within the virtual class community and the same processes for student knowledge level evaluation in a more effective and automatic manner. For these reasons, we have designed, implemented and evaluated e-learning system components for executing

synchronous common interactive virtual scientific experiments within virtual labs as well as learning material configuration and publishing for individual personalized student self-study complementing thus the existing distance learning infrastructure.

The paper initially presents a brief overview of the system context of use and targeted virtual campus use cases in Section 2. Then, the use cases realization is described in Section 3. Section 4 includes results after user evaluation of the developed e-learning services while Section 5 summarizes the conclusions of the present investigation.

2. Virtual Campus Use Cases

The targeted virtual campus use cases are the following:

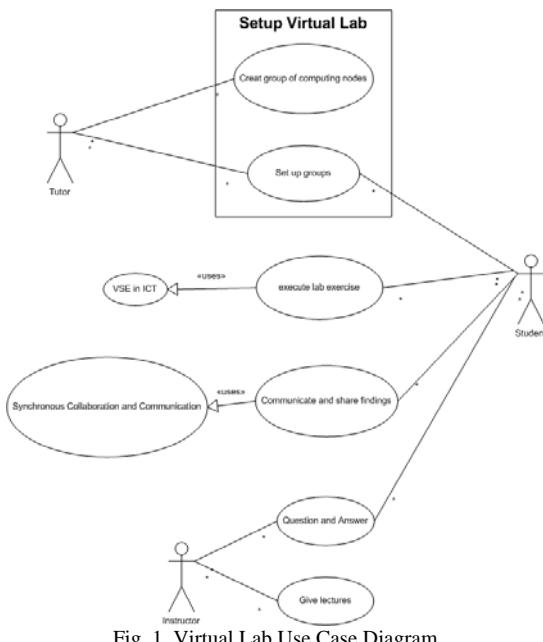


Fig. 1. Virtual Lab Use Case Diagram

• Wireless Networks Virtual Laboratory (WiNeVL)

- **VSEs in ICT:** formal collaboration of remote classes during a live lab session (Virtual Lab) in synchronously executing virtual scientific experiments including:

- o **SENSASIM based VSEs [1]:** grid based collaborative simulation of wireless sensor networking. The basic simulation engine is SENSASIM, a Wireless Sensor Network simulator written in Java, which was extended to grid-based so as to allow users to alter the execution of the simulator in real time.
- o **WiFiVL based VSEs [2]:** GRID based collaborative simulation of wireless Wi-Fi networking (IEEE 802.11).

The top-level use case diagram presenting the involved processes is shown in Figure 1.

• **Personalised learner access to published LOs – Lifelong Learning:** asynchronous formal learning activity where the tutor publishes VSE related, properly designed Learning Objects (LOs) and personalized Units

of Learning (UoLs), before and after a synchronous Virtual Lab/VSE session for the participating students' benefits to aid them initially in understanding, on an

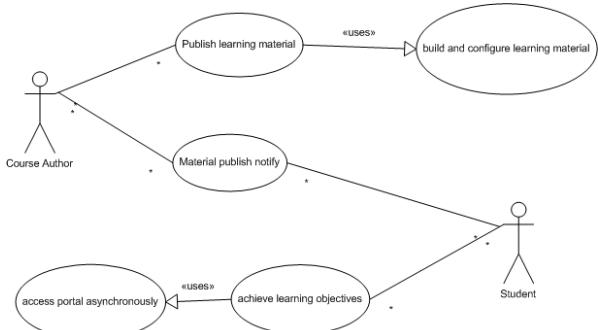


Fig. 2. Personalised Learner Access Use Case Diagram

individual basis based on their skills and acquired knowledge, the VSEs to be executed, as well as report back on results taken after the VSE execution. The goals for this activity are:

- o to support the synchronous virtual lab/VSE session preparation in a common manner for the virtual community of students as well as report on results (before and after the synchronous session)
- o to form the basis for lifelong learning

The top-level use case diagram presenting the involved processes is shown in Figure 2.

The MSIN course selected to deploy the advanced virtual campus services is the Wireless Sensor Networks course, students of which have been involved in the evaluation of the developed components.

3. Use Cases Realization

Below, the processes involved in the use cases realization and real life usage are described, including newly designed and implemented components (such as the WiNeVL collaborative parameter setup and Grid-based Sensasim) for execution of shared interactive virtual labs.

3.1 WiNeVL – VSEs in ICT Realization

The processes within this use case involve scheduling of a synchronous virtual laboratory session among the remote teams, announcement to the participating students prior to the session, presentation of the learning objectives and course material during the synchronous class session, collaborative execution of virtual scientific experiments by collaboratively setting parameters of the experiments and viewing the results, synchronous collaboration and exchange of ideas and opinions among the remote teams.

In synchronous Virtual Laboratory cases, there is synchronous collaboration and communication availability. The system enables enhanced audio-visual and data communications between users together and with the tutor and provides a combination of a chatting service integrated together with a video-conferencing facility.

Video-conferencing is done with FlashMeeting [5] and during the conference, instant messaging is available through SENSASIM Instant Message among participants. Concerning the Wireless Network Virtual Laboratory case, course material has been decided upon, created and configured as a UoL through KRT/Reload authoring tools and IWT-GA [4], the tutor creates the groups and configures accordingly the VSE to be executed. Scheduling and announcement of the Virtual Lab class session is performed. The principal instructor/tutor and their team run the VSE using either the Grid-based SENSASIM Simulator [6] or the WiFiVL Simulator [2]

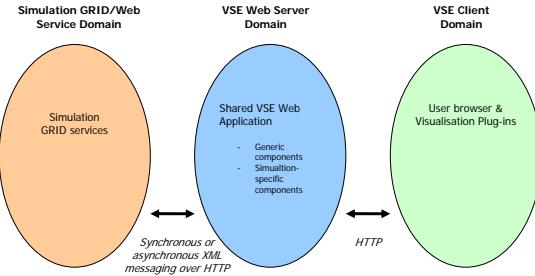


Fig. 3. Collaborative simulation-based VSE domains.

through a collaborative Web interface, modifying parameters on-the-fly when needed while the simulation is running in real time.

It has been possible to provide an architecture for the collaborative parameter setup as well as the visualization



Fig. 4. Grid-based SENSASIM simulator while modifying parameters of experiment.

and the interaction management of simulation-oriented VSEs that includes: (i) a number of simulation components, which can be computation-intensive and can be executed using a GRID infrastructure; (ii) a generic component to support the collaboration mechanisms of VSEs that is not computation-intensive and can be executed as a Web application; (iii) support for the additional simulation specific components on the Web application for parameter setup, visualization and the communication between the Web application and the computation-intensive GRID services that perform the simulations.

As shown in Figure 3, this architecture considers three distinct domains: the Web Services/GRID domain with the computation-intensive simulation GRID services, the

VSE Web Server domain with the shared Web application for collaborative parameter setup and simulation visualization and the VSE client domain with the browsers of the users of the VSE applications including the necessary visualization plug-ins. The newly introduced component is called *Collaborative Simulation Management Component (CSMC)*.

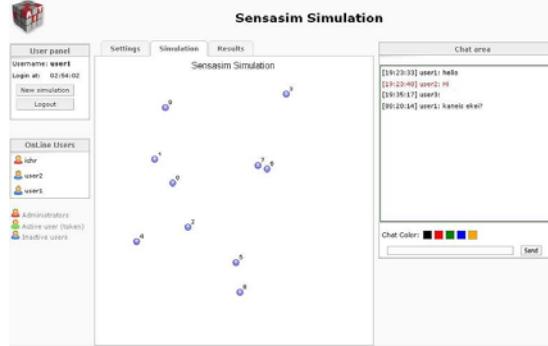


Fig. 5. Grid-based SENSASIM simulator while running the experiment and viewing the results.

The CSMC allows a virtual community to collaboratively setup generic and specific parameters of simulation-based VSEs and the mechanisms for the communication between the CSMC and the simulation GRID services. In addition, it enables the management of users and GRID nodes that can be used to host simulation GRID services. Finally the CSMC provides the means to extend the repertoire of the simulations it supports by enabling a flexible addition of simulation GRID services and configuration of the visualization mechanisms and of the simulation-specific parameters for these services.

In real-life contexts presented in this paper, the CSMC manages two different VSE simulators, Grid-based Sensasim [6] and WiFiVL[2]. In the sequel, more details on the deployment of Grid-based Sensasim are given.

Participants easily establish connection to the Flash-Meeting video-conferencing and communicate during the Virtual lab session; they login in to the Grid-based Sensasim Simulator for running the VSE.

The principal instructor gives a lecture using slides which are published as UoLs in IWT-GA. After the course lecture, student groups set up by the tutor modify the simulator parameters to view the real experiment, as shown in Figure 4. After this process, they run the simulation and view the results, as shown in Figure 5.

During the experiment, students-members of a team situated in front of different computers communicate and share their findings via Flash-Meeting and the SENSASIM instant messaging.

After the experiment is over, the team gathers and analyzes the data that have been the output of the VSE. In this act, they draw conclusions about the nature of the experiment (and they learn about it). Tutor or Student team members may gain control of the VSE execution and re-initiate the experiment having collaboratively set different parameters.

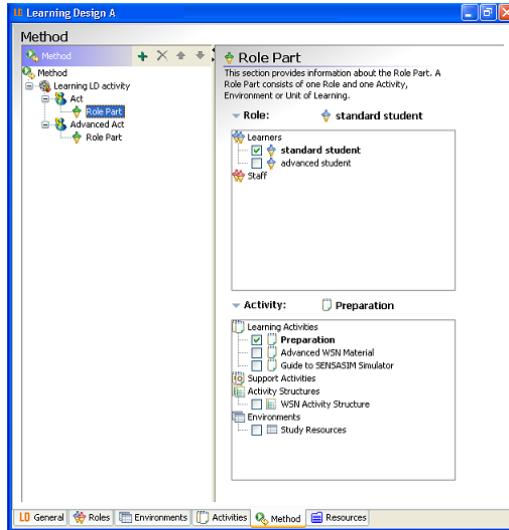


Fig. 6. Definition of different roles/levels of students, association with appropriate learning activities, thus introducing different learning paths per student level. Here the beginner student role and acts are shown.

3.2 Personalized Learner Access to Published LOs Realization

In order for learners to have access to the proper educational content before or after a synchronous Virtual Lab session, the tutor publishes properly designed Learning Objects and personalized UoLs for the participating students' benefits to aid them initially in understanding, on an individual basis, based on their skills and knowledge, and then re-execute experiments and verifying the acquired knowledge. This content management and configuring process, involving personalization and adaptation at student level issues, is performed by the tutor using core Grid-based learning platform services and tools [3].

For designing and creating the initial LOs to be published, the tutor mainly uses KRT and Reload authoring tools which are used for content creation, annotation and configuration purposes. These tools give the tutor ability to have different learning path designs and types of students, and thus allow a level of personalization; advanced and beginners, meaning that there are different learning paths for different types of learners based on their knowledge and skills. The tutor is able to define Roles and Activities relationships for those Roles (beginner and advanced student) in the Learning Objects design. The learning content types may be presentations (slides in PowerPoint or other format), text readings, or multimedia material (video or audio of a recorded lecture etc.). The author forms quizzes and practical training assignments for any material they wish.

Figure 6 shows an instantiation of such a process of content creation and configuration for a Role in the Learning Objects while designing different learning paths. This instantiation has already been performed in the context of use cases finalized deployments, and in preparation and configuration of educational content and learning paths for students having participated in Virtual



Fig. 7. The tutor uses the New Learning Experience wizard to publish the previously constructed LOs, for later access by his students.

Labs using the VSE simulators. The screenshots reflect thus deployment of developed tools and services to realize the targeted real-life learning scenarios.

For uploading and publishing LOs, the tutor uses the IWT-GA services [4], engineered within ELeGI [3]. Initially, the tutor or the content publisher logs in IWT-GA and selects the “Learning Experience Manager” services. From there onwards, he/she selects the “Create new

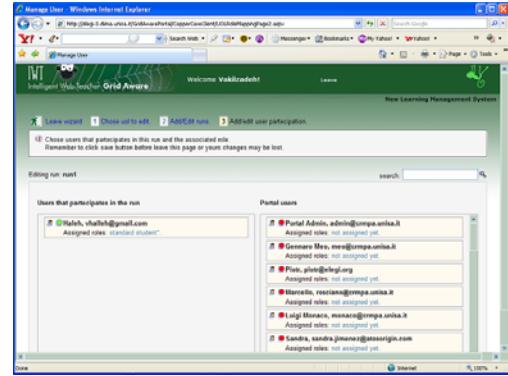


Fig. 8. Assigning roles to participants

learning experience wizard” and starts publishing the designed Learning Object (Figure 7)

After publishing the LOs in IWT-GA, which constitute Wireless Sensor Networks material in the specific VSE case, the tutor further proceeds to Add/Edit the users' participation and access to the published LOs; thus in this part of the process, it is defined which student will have access to the published LO, and with what specific Role, from the ones already defined during the learning path construction (in this case, Advanced or Standard (beginner)). Based on what the tutor specifies here, user participants have access to their predefined path, content and tests/quizzes. Thus, content is adapted to the students' skills and prior knowledge as assessed by their tutor. This process is instantiated in Figure 8.

The tutor then uploads tests or quizzes related to the constructed Learning Objects associated with different designed learning paths using the KRT tool. Based on assigned roles, participants have access to the proper content and quizzes when logging in to IWT-GA, as users

accessing the Virtual Lab topic and VSE related content.

After the content design, configuration and publishing during the content management process executed by the tutor or content publisher, learners that will participate in a scheduled Virtual Lab sessions and perform VSEs on specific topics described by the uploaded content, are able to access the educational portal (IWT-GA) with their issued student accounts, login in to IWT-GA and find the



Fig. 9. Students access to the configured learning material before a VSE session is run in a synchronous Virtual Lab.

proper LOs and adequate tests, associated with the VSE.

The medium of interaction is the Web. The learner logs in to the Web Server, where IWT-GA resides, providing configured learning material to adapt to the learner profile, and engages in a learning activity; he starts a presentation/lecture or he may immediately start with an exercise/practical training session.

Learners are able to consume static learning materials as well as dynamically run the dictated experiments by accessing the simulator through the educational portal. In

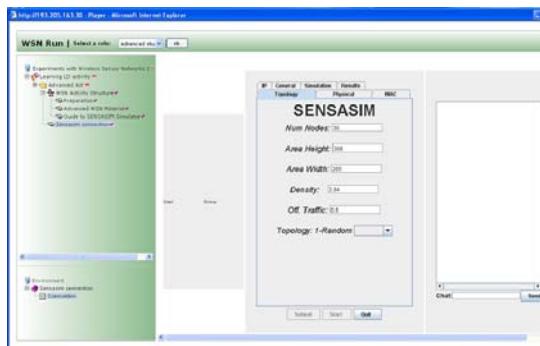


Fig. 10. Students access to the configured learning material – then, advanced students invoke SENSASIM to run experiments.

order to run the VSE using the provided simulator (here, the Grid-based SENSASIM), they follow the “Learning Experiment Delivery” option given to them and choose the proper Learning Experiment (here the Experiments with Wireless Sensor Networks) as shown in Figure 9.

Having configured the provided educational material based on student roles, learners are able to access and execute a VSE simulator (here, Grid-based SENSASIM), from within IWT-GA, after having passed through the appropriate preparation phase per student role. Grid-based

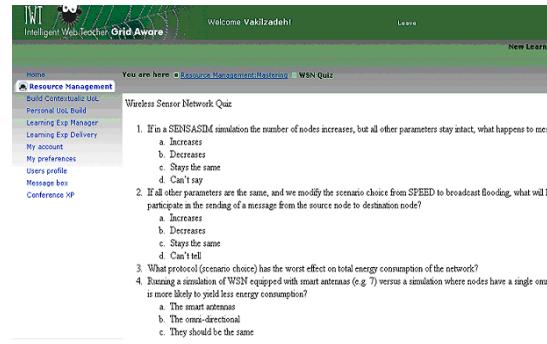


Fig. 11. Students taking a quiz on simulations and experiments already run using SENSASIM..

SENSASIM for executing virtual scientific experiments is integrated in and invoked from the configured learning material uploaded and published to IWT-GA, to enable students to practice before or after a synchronous Virtual Laboratory session, as shown in Figure 10.

After studying the published course material and running the experiments, tests and quizzes are made available for learners, who are able to easily locate them by using the IWT-GA content management capabilities. Fig. 11 shows an instance of a quiz related to a Wireless Sensor Networks simulation using SENSASIM.

4. System Evaluation

The SENSASIM Grid-based VSE simulator for Sensor Networks was deployed locally at Athens Information Technology (AIT), Athens, Greece in the context of the respective MSIN course and evaluated by groups of students located at AIT and the CyLab Japan site of the Information Networking Institute of Carnegie Mellon University in Kobe, Japan.

An iterative approach was adopted for the evaluation and assessment of the deployed solution, which involved two major iterations: (i) the deployment and evaluation of the first prototype and (ii) the deployment and evaluation of the second prototype. The results of each iteration cycle are presented below. Although further iterations are envisaged in future, the evaluation results of the second iteration already showcase increased acceptance of Collaborative Virtual Labs among students from remote collaborating institutions.

4.1 First prototype evaluation

The initial prototype evaluation involved a geographically distributed session between students at AIT in Athens, Greece and students at CyLab, Kobe, Japan. Following a virtual classroom session between the two sites, where a tutor at each site gave a half-hour lecture on sensor networks, students attended a virtual laboratory session that involved the use of the first prototype of the SENSASIM VSE together with communication facilities.

The evaluation results provided a rating of 2.71 for the collaboration process in a scale 1 (process worked very well) to 5 (process did not work at all). The rating for the interest of the VSE was 2.0 in a scale 1 (very interesting) to 5 (not interesting at all), while the rating for the communication tools was 2.28 in a scale 1 (appropriate) to 5 (not appropriate). The overall rating of the system was 2.4 as far as the integration of its components was concerned in a scale 1 (strongly agree) to 5 (strongly disagree).

In addition to the questions that were employed for the evaluation of the VSE session in terms of learning and collaboration, a properly structured questionnaire aimed to allow us to calculate the system usability score (SUS) of the SENSASIM VSE. Due to network congestion problems, communication and collaboration among the remote sites was bad, a fact that affected the evaluation result. The SUS score was almost 70% (in a scale 0-100). An analysis of the evaluation results indicated that the additional features enabling interactivity, turn-taking and real-time graphics would improve the performance of the VSE in terms of supporting collaboration processes, while the communication facilities could be improved, despite the fact that experienced Internet congestion may have been the prime cause for the low rating of the communication tools rather than the functionality of the tools themselves.

4.2 Second prototype evaluation

Taking into account the feedback of the evaluation of the first prototype, a second prototype was developed as detailed in the previous sections. The second prototype addressed the issues that were identified during the analysis of the evaluation of the first prototype. A group of five students who were attending an elective course on wireless sensor networks at AIT were asked to participate in an in-depth evaluation of the second prototype and to fill out questionnaires.

Based on the evaluation results, the SUS score of the second prototype was 80%, which was considered encouraging. The rating of the appropriateness of the communication tools was 2.00 in a scale 1 (appropriate) to 5 (inappropriate). The improvement of this rating can be explained by the better performance of the local network for voice and text based communication and certain improvements in the tools.

The evaluation group was asked to evaluate the appropriateness of media presentation of the VSE providing feedback on the new features enabling interactivity and real-time graphics. The responses provide a rating of media appropriateness of 1.00 in a scale 1 (appropriate) to 5 (inappropriate), which indicates that the improvements were well received.

In addition, students were asked to evaluate the collaboration process as implemented in the second prototype with increased interactivity and turn taking. The evaluation results provide a rating of 1.80 in a scale 1

(worked well) to 5 (did not work well at all), which is a clear improvement of the rating of the first prototype. The comprehensibility of the VSE was rated 1.40 in a scale 1 (easy to understand) to 5 (difficult to understand), while the clarity of the learning experience to the students was rated 1.60 in a scale 1 (strongly agree) to 5 (strongly disagree).

Since the evaluation of the second prototype, further improvements were applied on the SENSASIM VSE regarding text-based communication (improved chatting features, color-coding of the text of each participant) and media presentation (use of scalable vector graphics – SVG) to further improve the usability, performance and interoperability of the SENSASIM VSE with different browsers as well as the reuse of the collaborative parameter setup component with different VSEs.

5. Conclusion

The paper describes the specification, design, implementation, deployment and evaluation of fundamental rich-media e-learning services for realizing virtual campuses in real-life remote Universities collaboration. Such services complement existing distance learning services and focus on the offering of real-time synchronous shared and interactive virtual labs among remote communities as well as enabling learning management systems for personalized or role-based learning. As Virtual campuses are becoming a reality, advances in these areas are significant and pose additional requirements for reliable performance, fast execution and enhanced visualization, to attract the students' interest. Evaluation results have showcased that advancements in these aspects have made a significant increase in user acceptance.

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