Real-time Collaborative Virtual Interactive E-Learning Environment

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Abstract- The fusion of Virtual Reality, Collaborated Virtual Environments and e-learning provides a novel platform for both the teacher as well as students by creating a setting that is very close to the real educational environment. In this paper, we propose a framework based on the mapping between the real entities and the virtual entities in a typical educational environment. In particular, we emphasize on the design of key components like Virtual Classroom and Virtual Laboratory. As a case study, we describe how interactive 2D/3D animations can be used to better understand the laboratory experiments in a collaborative fashion while providing the teachers and the students with the ability to control these animations in real-time. We also stress the need for an educational Collaborated Virtual Environment to be both useful and fun, in order to enhance its usability and adaptability in various contexts. Last but not the least, we discuss the need for an educational body/network that manages the identities and roles of virtual actors, authenticates various parts of virtual environment and moderates communication happening within the Collaborated Virtual Environment.

Keywords- E-Learning; Collaboration; Interaction; Virtual Environment; Real-time collaboration; Virtual Interactive E-learning environment; ACE; A-VIEW.

I. INTRODUCTION

In this era of pervasive computing and global internet reach, advancements in modern day technology have tremendously expanded the reach as well as the scope of learning. In the last two decades, the world has witnessed a drastic improvement in the field of e-learning as we have transitioned from a computer based training (CBT) using a single computer to a Collaborated Virtual Environment (CVE) based training using large number of interconnected computers with varying degrees of Human-Computer Interaction (HCI) capabilities across the globe. A lot of researches along with numerous implementations have been made so far to take e-learning to the higher levels of sophistication. However, as the scope of collaboration and interaction goes far beyond the geographical borders, races, and ethnicities, various interesting concerns and issues can arise [1]. At the heart of an Interactive Collaborative Virtual E-learning Environment (ICVEE) that promotes higher order learning in the true sense, lies the ability of the virtual environment to provide an educational experience where knowledge creation and knowledge in action are the nexus of social, teaching and cognitive presence based on the community of the enquiry model [2]. The need to develop a learning environment which not only provides the users with the sense of realism [3], but also offers extended functionality that would otherwise not be possible, has been well stressed in the earlier works [4]. Moreover, ordinary CVEs cannot be used as they are for educational purposes [5]. An example of such a CVE is second life [6].

The use of Computer-Mediated Communication (CMC) in education falls under two main categories i.e. Computer Supported Collaborative Learning (CSCL) and Computer
Supported Cooperative Work (CSCW). Most of the commercial e-learning systems today enable synchronous co-operative learning e.g. sharing documents and online meetings [5], rather than asynchronous collaborative learning. Virtual multi user collaboration tools often fall into three categories as described in [7]. While co-operative learning is fairly structured and teacher-centered, collaborative learning is conversational, relatively unstructured, iterative and an active process well suited for tasks where students are required to jointly design, create or evaluate something [8]. In other words, collaboration is a must for socioconstructivist model of learning [9] and knowledge sharing that is more student-centered. The cooperative learning model is best suited for younger children where as collaborative models are well suited for adults. Multi User Virtual Environments (MUVEs) have emerged as a means of competence and confidence among the students [10]. Special care needs to be taken while designing an interactive e-learning CVE to employ the right model for the right kind of audience. Detailed comparison of CSCL’s and CSCW’s characteristics has been mentioned in [8]. It must be noted that learning techniques can have different impacts on the students with different learning styles as suggested in [11].

An ICVEE should allow for extending learning beyond the traditional classroom setting by allowing for social interactions and self paced learning. Moreover, an ICVEE must be sensitive to the variable factors such as different time zones, different geographical places, different cultures and different languages of its residents. Many at times, e-learning systems have failed due to complex user interfaces, less user friendliness, costly installations, lack of alternate means of communication, poor personalization capabilities and mismatch in interactions of the virtual educational environment and the real educational environment. As e-learning becomes more and more ubiquitous, the design of an ICVEE needs to allow for customization as well as extension. The very first requirement of an ICVEE is the degree of similarity between itself and the real world educational environment. This calls for a need to define a mapping between the real entities and the virtual entities present in a typical educational environment. Last but not the least, it is important to be aware of the limitations in technology that one may encounter while designing an ICVEE. These limitations can affect the scalability, adaptability, usability [12,13] and the security of the ICVEE.

II. RELATED WORK

In the arena of collaborated virtual environments for education, various systems with varying degrees of sophistication and complexity have been proposed and realized to some extent. However the e-learning community is still in nascent stages as far as realizing the framework and implementation of a real-time ICVEE that is adaptable across the e-learning community is concerned. [14] describes the fully immersive virtual reality environment based learning platform for chemistry education. However the limited scope as well as high cost involved in installation of such systems may be a limiting factor to its wide acceptance. [15] presents a framework for immersive virtual environment intended for remote collaboration and training of physical activities, but suffers from the same drawbacks, as of [14]. [16] describes visual and haptic collaboration in shared 3D spaces. The authors point out its limitation to be the lack of ability to set the collaborative shared scenes and its dependency on 3rd party software tools. [17] proposes a publish-subscribe model for multi-site 3D tele-immersion. Since the system uses shared resources, the management of forest creation becomes quite critical to the overall performance of the system. [18] describes a web-based collaborative e-learning environment with virtual reality. Unlike [4], there is no provision for asynchronous learning. [19] tries to narrow the gap between the teacher’s experience in Tele-education and that in the traditional classroom education, by means of integrating these two currently separated education environments together. However it suffers from the issues that are well known to researchers involved in indoor location tracking due to interference and multiple reflections. [21] uses synthetic characters called avatars for the virtual world. It is an interesting case study that calls for further research and practice in that area. Similar studies with promising results regarding the potential of CVEs like Second Life [6] have been made in different settings e.g. [21] and [22] in a university setting and [23] in medical/health arena. [24] has a similar study using Zora 3D virtual environment. [25] shows how augmented reality can be used in e-learning. [26] highlights the missing pieces like lack of teacher expression and lack of contextual understanding. These blanks need to be filled either fully or partially in order to mimic the real educational environment. Several other collaborative-object frameworks have been proposed, however much emphasis hasn’t been placed on teacher-student interaction. We employ shared, collaborative objects to implement this feature.

III. FRAMEWORK BASED ON OUR APPROACH

Prior to designing a framework for an ICVEE, a clear mapping between the real and virtual entities within an educational environment must be created as shown in Fig. 1. It must be noted that this list is not complete by any means, but rather serves as a pedagogical tool to create more comprehensive mapping based on the domain specific requirements of the users and regulations of the governing bodies. Answers to the six important questions (What, Which, Why, Where, When and Who) as mentioned in [27] need to be answered before for creating a valuable and meaningful mapping. Fig.1 shows a mapping of the categories alone. In practice each category will have certain entities under it. An example mapping1 for each category is shown in Table 1. These mappings serve as an input to create the design model for an ICVEE.

1 The exhaustive list of mappings is beyond the scope of this paper
Even though an ICVEE is not just a Massively Multiplayer Online Role Playing Game (MMORPG), it potentially allows for virtual interaction among large set of users. Moreover, it is important for ICVEE to be able to retain its users by catering to the customized needs of its users (which may change from one user to another) e.g. [28] depicts various connotations under which the word ‘fun’ can mean different to different people. An ICVEE must also allow for personalization, socialization and Human Computer Interaction along with their possible extensions using mixed reality, haptics, speech recognition and face recognition.

### Table I. Mapping between Real and Virtual Entities

<table>
<thead>
<tr>
<th>Environment</th>
<th>Real environment</th>
<th>Virtual environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>Real classroom</td>
<td>Virtual classroom</td>
</tr>
<tr>
<td>Educational</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussions</td>
<td>Synchronous</td>
<td>Synchronous/Async</td>
</tr>
<tr>
<td></td>
<td>discussions</td>
<td>discussions (verbal)</td>
</tr>
<tr>
<td>Roles/Identities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>Physically present</td>
<td>Avatar, audio, video</td>
</tr>
<tr>
<td>Collaborative objects</td>
<td>Writing board</td>
<td>Collaborative board</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multilingual</td>
<td>Rare, costs</td>
<td>Possible using voice</td>
</tr>
<tr>
<td></td>
<td>communication</td>
<td>modules and IVR</td>
</tr>
<tr>
<td>Corporation</td>
<td>Lecture recording</td>
<td>Rare, costs</td>
</tr>
<tr>
<td></td>
<td>recording</td>
<td>money</td>
</tr>
<tr>
<td>Surroundings</td>
<td>Actual</td>
<td>Synthetic (using</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chemistry)</td>
</tr>
<tr>
<td>Governance</td>
<td>Actual</td>
<td>Actual with virtual</td>
</tr>
</tbody>
</table>

To achieve real-time collaboration within an ICVEE, the communicating entities (collaborative objects) must be able to collaborate as well as interact in real-time. More realistic ICVEEs can support alternative ways of HCI that may be based on Interactive Voice Response (IVR), haptics and virtual/augmented reality. The ability of an ICVEE to go back and forth in time makes it a great tool to learn without getting penalized. It thus saves additional time, effort and money that would otherwise be unavoidable. As a case study, we implemented an avatar [29] based virtual chemistry laboratory prototype (explained in next section) where teacher and the student can collaboratively interact and perform various experiments. Unlike the non-collaborative nature of virtual laboratories like [30] our virtual laboratory allows the user to collaborate and interact with other users as well as the environment.

Our prototype is based on the principle of WYSIWIS (What You See Is What I See), where in any action or event on the working space or a 2D/3D object is reflected in real-time to all the collaborative participants. We have adopted an approach similar to the systems described in [31] and [32]. The labs within ICVEE may be extended by techniques similar to [33] and [34]. The interactions within a virtual lab can potentially trigger simulations [35] and even remotely control the devices as well as the outcome of the experiments. The teacher and the student can also share their applications using the desktop sharing capability. In the virtual laboratory, collaborative animations can be used to explain and try out various experiments, while the instructor can use collaborative graphics to demonstrate the working concepts and details.

In our Amrita Virtual Interactive E-Learning World (A-VIEW) prototype [36,37,38] the virtual classroom (as shown in Fig.2) allows a teacher and students to share the study material (documents) in real-time. Moreover, teachers as well as students can draw freehand drawings as well as geometric shapes on the shared whiteboard. As the teacher interacts with the collaborative objects, students also see the interactions in real-time and vice versa depending on whether a student is authorized to interact with the collaborative object or not. Our A-VIEW prototype represents a typical live e-learning environment. In this kind of an educational system, services such as teacher video, document, whiteboard, chat, desktop sharing, internet browser, 2D/3D animation, interaction window etc. are all powered by collaborative objects. Collaborative objects are usually classified into synchronous and asynchronous categories. Synchronous collaborative objects are used to achieve real-time interaction among users e.g. two way audio/video, and are widely used in e-learning whereas asynchronous objects are those in which interaction among users is not in real-time e.g. discussion forum.
educational environment. Moreover identity and role are mentioned in [39]. These identities must be managed and tracked by the governing bodies, just like a social security number would be managed and tracked by US government.

IV. PROTOTYPE IMPLEMENTATION OF A VIRTUAL LABORATORY WITHIN AN ICVEE

Our chemistry lab prototype uses the avatars for teachers as well as students. The collaborative objects for experimentation within the lab comprise of virtual instruments, virtual simulations and collaborative animations. This offers a hazard free environment for the students to get a basic learning before entering the real chemistry lab. Fig. 3 shows the snapshot of the virtual chemistry lab at four different points of time. In Fig.3(a), the teacher’s avatar welcomes the student to the lab and hands over the flask filled with a base that is needed for a titration experiment (the acid is already filled in burette). He then asks the student to try to perform the experiment. In Fig.3(b), the student’s avatar places the flask under the burette and discusses something with the teacher. As a next step the teacher asks the student to choose an indicator. In Fig.3(c) the student chooses the wrong indicator. In Fig. 3(d) the teacher helps the student to choose the right indicator. The indicator is put in the base solution. The student then proceeds with titration by slowly allowing the acid in the burette to drop into the flask. This is achieved by using collaborative 2D/3D animations. While a particular teacher/student is engaged in this act of learning, other students are also keenly watching their actions in real time. At any time the entire animation can be played back again, if need be. Thus both the teachers and the students can go back and forth in time and the entire experiment or a portion of the experiment can be repeated or modified without any additional risk or cost involved.

Students may also use the virtual chemistry laboratory to perform experiments by themselves; the clear advantage in this scenario is that students don’t have to worry about hazards/risks involved during real experiments. Universities can use this kind of tool to teach students at a much lower cost. Using our novel architecture called ACE (Architecture for Collaborative Environments) that is discussed in our previous work [40], or where users can collaborate in a real-time collaborative virtual environment. ACE is implemented based on a distributed client-server architecture, primarily consisting of two server clusters (active and passive servers), that communicate among each other.

V. CONCLUSION

To design a real-time collaborative virtual interactive e-learning environment based on a flexible framework, the entire environment must be modeled out using the mapping methodology described in Section III. Only by incorporating a robust and flexible model, would it be possible to design an ICVEE that can cater to the needs and the tastes of diverse group of people, spread across the globe. The ICVEEs can no more be treated as tools for asynchronous co-operative learning alone. Rather both the collaborative as well as co-operative modes of learning need to be supported. As ICVEEs begin to emerge as parallel social worlds with roles and identities associated with its residents/users, it poses security risks and privacy concerns also, which need to be well thought of, while designing the ICVEE.

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[10] Blake Peck, Charlynn Miller, “I think I can, I think I can, I think I can...I know I can Multi-user Virtual Environments (MUVEs) as a


