MERITS TRAINING SYSTEM
Using Virtual Worlds for Simulation-based Training

David Chodos, Eleni Stroulia, Pawel Kuras
Department of Computing Science, University of Alberta, Edmonton, Alberta, Canada

Michael Carbonaro, Sharla King
Department of Educational Psychology, University of Alberta, Edmonton, Alberta, Canada

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Abstract: Virtual worlds offer a new application development platform, and are particularly appealing for creating new types of educational training programs. However, in order to enable the adoption of this platform by instructors, special-purpose authoring tools are necessary to enable domain experts to create and maintain their lessons plans. In this paper, we propose a framework for virtual world-based training, which uses the BPEL workflow language to organize educational content. The framework uses a web services-based approach to connect the content, workflows, and virtual world, thus avoiding dependence on a particular virtual world. Finally, we present a case study, currently in progress, designed to assess the utility of the framework.

1 INTRODUCTION

Virtual worlds have emerged over the last several years as a means for users to experience immersive environments and interact with each other in new and exciting ways. While much of the activity in virtual worlds has been of a social, unstructured nature, there have been efforts to make effective use of virtual worlds for business and, of particular interest here, education. However, much of this effort has focused on re-creating existing educational settings (campuses, classrooms) in a virtual environment, and has not been broadly applicable across educational contexts or institutions.

Meanwhile, workflows have been used for decades to specify and drive business processes, and have recently seen increasing use in structuring composite online processes through the use of SOAP (www.w3.org/TR/soap/), a standard for enabling online service interoperability, and BPEL (www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsBPEL), an executable language for specifying workflows.

In our work, we combine the immersive, collaborative potential of virtual worlds with BPEL-based process specification to enable instructors to specify educational scenarios, and to allow students to experience those scenarios in a realistic, interactive manner.

The immediate use of our framework is in simulation-based training of health professional students. It is in these terms that we evaluate our framework in this paper. In the longer run, we are interested in developing a suite of methods for analyzing the modeled processes, identifying opportunities of improvement, and better managing them.

The rest of this paper is organized as follows. Section 2 describes the MERITS framework for modeling and simulating training scenarios. Section 3 reviews our on-going case studies with MERITS. Section 4 discusses related work. Finally, Section 5 concludes with a summary of our work to date and outlines plans for the future.

2 THE MERITS FRAMEWORK

The MixEd Reality Integrated Training System

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(MERITS) combines a workflow description component, SOAP-based web services, BPEL workflows, and virtual-world components to support instructors in creating simulation scenarios, through which students can experience situations similar to those that they will have to deal with in their future professional life. The major elements of the MERITS software architecture are shown in Figure 1.

The MERITS architecture mimics the three-tiered structure of traditional web-based applications, with a virtual world as the user interface, a BPEL orchestrated set of software services as the application logic (that is, the software implementing the automated activities of the service-delivery process), and a resource repository maintaining a record of the archival data of the organization and the transient data of each service-delivery process. For more about the workflow description process, see Section 2.2.

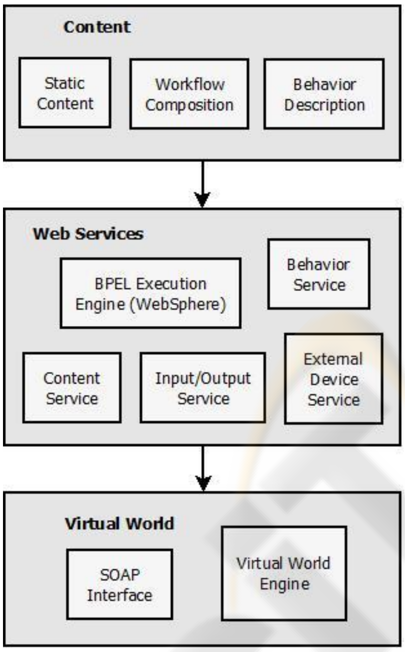


Figure 1: MERITS framework.

Instructors can specify relevant educational entities by updating the resource repository through web-based forms, accessing REST APIs of the repository. The BPEL-specified workflows that specify the behaviors of people and objects in the scenario may, in principle, be created using graphical, web-based tools. However, there are conceptual challenges involved in the specification of a BPEL workflow that make merely providing a graphical interface insufficient for removing implementation barriers for non-technical users. For more about this issue, see Section 3.2. At run time, the BPEL workflows are enacted through the interactions of people and objects in the virtual world and through the behaviors of underlying automated software systems. When a student performs an action through his or her avatar, a behavior script is executed in the virtual world. The execution of this script may (a) change the state of the virtual world and (b) change the state of the corresponding workflow, shown in the second tier in the diagram in Figure 1. In our implementation, the workflow server interprets the action in the context of the overall process workflow to determine how the scenario should proceed in response to the action. The BPEL workflow can also be connected to external devices, thus allowing the simulation to extend beyond the boundaries of a particular educational institution. For example, in a healthcare education context, the system may be connected to a web service that provides simulated patient data.

2.1 Workflow Integration

Workflows play an essential role in modeling any process. In the MERITS framework, we define four different types of workflows, each of which serves a specific purpose in the overall process:

1. The process workflow defines the various process paths that may be taken when executing the process.
2. An object workflow defines the behavior of an interactive object involved in the process, such as a piece of equipment.
3. A character workflow defines the behavior of automated characters that play some part in the process but are not simulated by students, such as non-responsive patients or bystanders.
4. Finally, normative workflows may be used to define the set of actions (and their control dependencies) that learners are supposed to follow, as they play their parts in the process.

While the process and normative learner workflows may seem similar, they serve very different purposes. The process workflow describes all possible paths – including those that are incorrect or sub-optimal – that may be taken in executing the process. A normative learner workflow, on the other hand, describes the sequence that should be followed by the learner. In this way the system is able to follow the state of the process even when it is not going in the prescribed manner, and provide feedback on the discrepancies between the learners' actual and desired behaviors.

For example, a student's execution of the emergency rescue process could be checked for the required actions – checking blood pressure, moving the patient into the ambulance – and might be invalidated if any erroneous actions – such as administering an improper medication – occur. However, there may be sequences of actions that are correct, according to the normative user process, but quite unconventional; for instance, the student might check the victim's pulse, go to the ambulance for a piece of equipment, and then return to the patient and assess the victim's level of consciousness.

2.2 BPEL Implementation

The workflows used in the MERITS system are specified in BPEL (WS-BPEL, 2009) and consists of three types of constructs: web service connections, program control constructs, and exception and error handling constructs. Using BPEL, while simpler than a programming language such as C++ or Java, is, most likely, too technically challenging for most content experts. While graphical tools for designing BPEL workflows – of which there are several – make some of the details easier to manage, these tools rely on the user understanding the underlying programming concepts. Thus, the workflow specification process currently works as follows.

First, one or more context experts describe the workflow using storyboard diagrams and descriptive sentences, and record this description on a wiki. Second, these descriptions are then analyzed by technical experts who elicit relevant entities and actions. Third, the results of this analysis and modeling decisions are recorded on the wiki, so that the elicited information can be validated by the content experts. Finally, based on the elicited, validated information, the technical experts create well-defined abstract workflows, which may also be shared and validated using the wiki. Thus, through this process, the responsibility for specifying the workflow in BPEL is delegated to technical users, although the content experts still retain control over the meaning of the workflow.

3 EMT TRAINING SCENARIO

To assess the utility of the MERITS system, we have undertaken several case studies. These case studies are drawn from a variety of contexts, and are qualitatively quite different from each other. This contextual diversity is intended to assess the flexibility and robustness of the system.

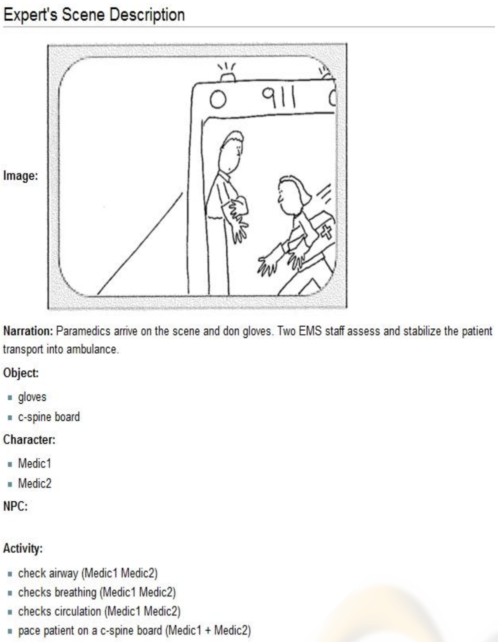
The first version of MERITS was evaluated in the context of modeling a simple interview process (Chodos, 2009). This version did not use a formal specification for the process workflows; we have since extended the framework with the BPEL specifications and the corresponding introduction of a BPEL execution engine to orchestrate the workflow instances at run time.

We are currently working with colleagues from the health sciences who want to use this framework to model complex processes in their field in order to develop simulation-based training scenarios for their students. The most mature process model to date is that of the handoff scenario between emergency medical technicians (EMT) and emergency room (ER) personnel when a victim is being transferred by ambulance from the scene of the accident to the hospital ER.

The EMT and ER personnel need to acquire and apply a diversity of basic and complex knowledge and skills to provide the best patient care. Medical and procedural knowledge is utilized to quickly transfer the patient safely to the ER. To coordinate activities with co-workers, hospital staff and victim's families, effective communication within and across disciplines is critical. The environment is unpredictable and highly stressful, thus emphasizing the need for the integration of medical knowledge, procedural and communication skills prior to entering clinical practice.

Basic skills and medical knowledge are typically conveyed in a classroom setting. Procedural skills are often gained through conducting training scenarios with students, who interact with professional actors playing the roles of accident victims, emergency workers, and hospital staff. While these training scenarios offer lifelike experiences for the students, there are a number of limitations: a) restrictions on the number of students who can participate at any one time; b) it is expensive to set up the scenarios because of the need for equipment, space, and people; c) distance education students are entirely excluded from this type of training. Furthermore, developing interprofessional communication skills across disciplines is often ignored and students are expected to gain these skills on the job.

Figure 2: Screenshot of EMT training scene.



Expert's Scene Description

Image:

Narration: Paramedics arrive on the scene and don gloves. Two EMS staff assess and stabilize the patient transport into ambulance.

Object:

- gloves
- c-spine board

Character:

- Medic1
- Medic2

NPC:

Activity:

- check airway (Medic1 Medic2)
- checks breathing (Medic1 Medic2)
- checks circulation (Medic1 Medic2)
- pace patient on a c-spine board (Medic1 + Medic2)

Figure 3: Wiki page - description and entities.

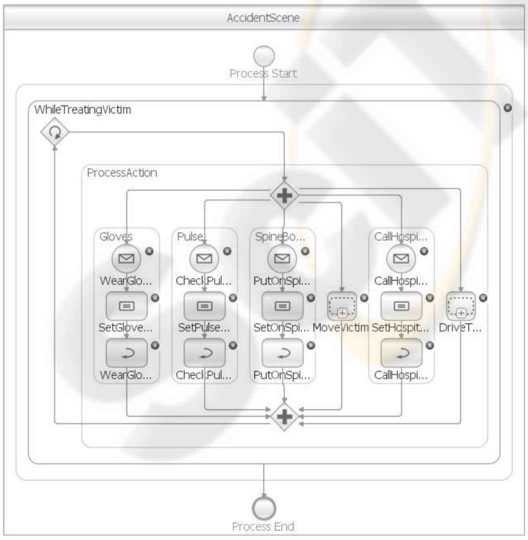


Figure 4: High-level workflow.

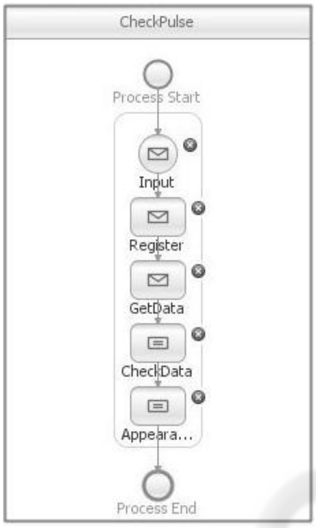


Figure 5: Check pulse workflow.

Figure 6: 3D model of ambulance.

Thus, given the shortcomings identified above, a MERITS-based training tool presents advantages over existing systems in several key areas. One is that a workflow-based system, with independent objects and characters, enables flexible scenarios. Thus, the student doesn't just learn a rigid sequence of steps; rather, the student can interact with active objects in any order, determine his or her path through the scenario (subject to constraints imposed by the context and the workflow), and thus engage in self-directed learning.

Another advantage of the proposed tool is that it offers a blend of character types – students, instructors and automated characters – which creates a variety of communication possibilities, and means that the system can offer several types of student-instructor involvement. First, students can interact with other students, either in the EMT field or in other, complementary disciplines. This allows students from many disciplines to not only get experience with the processes relevant to their own area, but also to get experience communicating with professionals from a variety of other areas. Second, students can interact with a mix of other students, instructors, and automated characters. Thus, a role in a scenario with minimal interactivity (such as an unconscious patient) can be simulated by a workflow-based automated character. More complex roles, meanwhile, can be played either by students or instructors (serving as “puppet masters” moving the scenario along). Finally, in cases where the behavior all of the external characters may be modeled, students can interact entirely with automated characters. This situation offers maximum accessibility for the student, who can train using the scenario whenever he or she chooses.

A prototype system for EMT training is currently under development, in collaboration with the Department of Computing Science, Faculty of Education, and the Interdisciplinary Health Education Partnership conducted by the Health Sciences Education and Research Commons. In this training program, EMT students encounter a victim at an accident scene, and must determine which actions to take in order to transport the victim to a hospital. A screenshot of this scene, implemented in a Second Life-based prototype system, is shown in Figure 2.

In creating a virtual world-based training scenario, we followed the process described in Section 2.2. First, experts in the field were asked to describe the scenes that make up the scenario. For each scene, the artifacts and actions were identified and transformed into workflow diagrams. A screenshot showing the wiki page for one such scene is shown in Figure 3.

The MERITS system stores and accesses content as needed, and coordinates user input with the various interrelated workflows. The actions taken by the student include using medical diagnostic equipment and interacting with the accident victim. These actions are interpreted by workflows, and the results are conveyed through a variety of artifacts. Most of the artifacts in this scenario are pieces of medical equipment – a spine board, for example, or the two-way radio in an ambulance – which are used in treating the victim, and provide immediate feedback. Other, larger scale, artifacts include the victim’s vehicle and the EMT ambulance. It should be noted that, in this case, the victim is also considered an artifact, since it helps convey the results of actions through its condition and location. The implementation of each of these components in the EMT training prototype will be briefly discussed in detail in the following paragraphs.

At the core of the MERITS system, we have workflows which specify a) the victim treatment process, and b) the actions associated with each artifact (gloves, spine board, radio, victim) in the scenario. The high-level workflow for the victim treatment process is shown in Figure 5, and described in the folllowing paragraph.

Many of the components of the victim treatment workflow – Gloves, Pulse, SpineBoard and CallHospital – are concerned with recognizing and recording simple actions. The MoveVictim component ensures that the victim is on the spine board before he can be moved to the ambulance. The DriveToHospital component analyzes the variables, which store previous actions, determines whether a prerequisite action (e.g., moving the patient into the ambulance) has been missed, and returns an appropriate message.

The workflows that define artifact-based actions in this process fall into two types: simple toggle (on/off) actions and information retrieval. The toggle actions, such as putting on gloves, register the action with the overall process workflow and instruct the virtual world to make the appropriate change in the object’s appearance. The second type of action adds information retrieval to the above tasks. This information may be retrieved either from a database or from an external web service. An example of this type of workflow (for the Check Pulse action) is shown in Figure 5.

It should be noted that, while the artifact-related components in the victim treatment workflow may seem quite similar to the artifact workflows just described, they are conceptually and functionally quite different. An artifact workflow describes the behavior of that artifact, independent of any processes. An artifact-related component within a process workflow, meanwhile, describes how that artifact's behavior – that is, the actions taken on the artifact – relate to the process as a whole. In this process, for example, the CheckPulse workflow describes the behavior of a pulse oximeter (or some other pulse-checking device). The Pulse component of the process workflow, on the other hand, describes the impact that checking the patient's pulse has on the process being modeled.

Representing an action in a virtual world can pose a variety of challenges, depending on the affordances and capabilities provided by the virtual world. For example, in Second Life, objects can only be *touched*, *worn*, *sat on*, *driven*, or *taken* by a player. Thus, an action such as carrying an object is difficult to represent, since to have an object follow an avatar, it must incrementally follow the avatar, be worn by the avatar, or be driven by the avatar, each of which have their limitations. It turns out that, while driving an object seems to be the least intuitive, it produces the most accurate results.

Finally, the artifacts relevant to the process must be modeled in the virtual world. For this process, the artifacts that were modeled included a spine board, the unconscious victim, a two-way radio, and the ambulance.

There are two distinct issues here: first, there is the representation of the artifact in the virtual world. Depending on the virtual world that is chosen, one may be able to create this representation using external 3D modeling software, import 3D models created by other users, or use in-world 3D modeling tools. For this process, we used 3D models created by other users for Second Life. Figure 6 shows a close-up of an ambulance, one such 3D model.

Second, this artifact must be able to exhibit the behavior implied by the associated actions. This, typically, involves the addition of native code to the virtual world representation of the artifact. See Section 3.1 for more about this issue. This code calls web services responsible for interpreting the result of the action, both in terms of any immediate changes to the artifact appearance, as well as the impact of the action on the process workflow. Finally, the artifact must be able to change its appearance in an appropriate manner.

At this point, we have just had some initial feedback with respect to the quality of our scenario representation by simulation experts from the EMT field but have not yet conducted any formal experiment. The first trial for empirically evaluating the effectiveness of our virtual-world simulation for training is scheduled for January 2010.

4 RELATED WORK

Using virtual worlds to create scenario-based training programs touches on several areas of related work. First, there is a growing body of work describing and analyzing the use of virtual worlds -- most prominently, Second Life - for post-secondary education and training. Second, there are several theories from educational psychology that support the effectiveness of scenario-based training programs. Each of these areas will be described in the following sections.

4.1 Virtual Worlds

The issue of using virtual worlds for education and training has received an increasing amount of attention from the academic community in recent years, as virtual worlds have become better established in both mainstream culture and in educational institutions. The following paragraphs present a sample of this work, which indicates both the steadily increasing interest in the topic, and the variety of approaches that are being taken.

Hong Cai, of IBM, has taken a broad view of the issue, examining the potential of virtual worlds for any kind of training program (Cai, 2008). He compared several virtual environments - Second Life, Active Worlds, OpenSim, and the Torque game engine - in terms of their fitness for educational activities, and analyzed various common learning activities with respect to their implementation in a virtual environment. He also presented a development lifecycle for creating virtual learning environments, and analyzed several virtual learning projects at IBM according to these analytical tools.

Edward Carpenter has developed a 3D crisis-communication training tool to provide communication students with opportunities to practice what are, in a standard classroom setting, largely theoretical approaches to dealing with crises (Carpenter, 2006). Through the immersive tool, students get hands-on training, and can experience events, rather than absorbing and interpreting them through written information. The tool uses a narrative, storyboard-based technique to deliver the educational content, where each student is offered a set of choices at key points in the story. Afterwards, the students are debriefed and the instructor analyzes and evaluates their choices. Because the system uses storyboards to structure the educational content, a student's interaction with the system is largely pre-determined, and quite rigid. As well, the system does not support collaborative learning, since it is intended for one student at a time.

Victor Vergara and colleagues at the University of New Mexico have developed a virtual environment-based tool to teach medical students about hematomas (Vergara, 2008). They have developed a 3D, multi-user virtual environment (MUVE) within which students can interact with a virtual character, nicknamed “Mr. Toma,” and other associated objects. Several rigorous studies of the system's effectiveness have demonstrated that it is equally effective as conventional, paper-and-pencil education methods. Furthermore, it offers additional advantages, including the chance to collaborate with geographically dispersed students, and an increased sense of immersion when using the MUVE system. A considerable amount of effort was put into ensuring that the content was presented accurately and effectively, including consulting with an interdisciplinary team of subject matter experts.

Finally, Forterra Systems has developed the On-LIine Virtual Environment (OLIVE) platform, which allows clients from government, healthcare and other contexts to create virtual world-based systems (Armentrout, 2008). One such system was developed to train first responders to car accidents on the Interstate 95 Corridor. A prototype system was developed at the University of Maryland, and tested with a small number of potential students.

While the preceding projects are quite varied in terms of the technology used and the context areas to which the projects were applied, there are several common characteristics that should be pointed out. First, each project found that the students' educational needs were met by the virtual world-based projects. This offers evidence that this type of system is effective in a wide range of contexts, and with a broad range of students. Second, with the exception of the project undertaken by Forterra Systems, most current projects are computing-science initiatives, for use in a single context area. This indicates that there is a need for a broadly applicable framework for virtual world-based training programs. This framework should enable the creation and maintenance of learning modules by non-technical content experts.

4.2 Educational Psychology

From an educational psychology standpoint, simulation-based training is supported by the situated cognition theory, proposed by Brown *et al* (Brown, 1989). According to this theory, knowledge is not a set of abstract concepts to be absorbed by the student; instead, it is dependent on the context and culture in which it is used. Adhering to situation-cognition principles, Collins *et al* developed the cognitive-apprenticeship model of educational practice, which incorporates the situated nature of the knowledge being conveyed to students (Collins, 1991). This model was later found to be effective within a technologically rich learning environment (Järvelä, 1995). Another related concept is constructivism (Duffy, 1992). This theory sees learning as an active process of constructing, rather than acquiring knowledge. Thus, instruction within a constructivist context focuses on supporting that construction, rather than conveying knowledge. These theories and studies support the value of simulation-based training. Students learn to integrate the knowledge and skills in order to apply them in a context similar to the real environment.

5 FUTURE WORK

There are several areas of future work that will be pursued over the coming months, to address existing issues, improve the specification process, explore diverse context areas, and provide empirical validation of the framework.

Implementing a process in Second Life (SL) poses platform-specific challenges. The limited interaction affordances provided by SL make it quite challenging, if not impossible, to implement some types of simple actions (such as picking up or pushing an object) in a natural, realistic way. Thus, we would like to either a) develop a consistent SL API which could be used to model processes in a natural way or b) migrate to another virtual world platform that provides better native support for the processes being modeled.

Another issue is the workflow definition process. Currently, processes are described by content experts and then converted into BPEL workflows by technical experts, supported by a wiki system. In the future, we would like to allow the content experts to create workflows using graphical tools. These tools would give content experts direct control over the process modeling workflows.

One of the key benefits of the MERITS system is its applicability to a wide variety of context areas. In addition to EMT training, we are also investigating training students in Occupational Therapy and the use of industrial equipment. By selecting a range of contexts, we can assess the utility of the MERITS system along dimensions such as social interaction and communication, artifact complexity and precision.

Finally, we are planning on conducting a series of empirical studies of the effectiveness of the MERITS system for modeling service delivery processes, beginning in November 2009. The initial study will take the form of a pilot of the EMT training scenario (described in Section 4) for the Interdisciplinary Health Education Partnership. The pilot study will followed by a larger-scale study beginning in January 2010.

6 CONCLUSIONS

In this paper, we discussed a software framework for specifying interactive educational scenarios, with BPEL and virtual-world elements for simulation-based training of students across health disciplines. We have illustrated our framework with the EMT training scenario, which highlights the complexity of such scenarios, in general. The EMT training scenario is realistic – it has been developed by EMT personnel and ER nurses – and its simulation will be used for training EMT and ER students in the near future.

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