ONLINE COLLABORATIVE SIMULATION CONCEPTUAL MODEL DEVELOPMENT

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ABSTRACT
Despite significant advancements in Web-based simulation research, its commercial applicability and adoption by users has not widened to the desired extent. We believe that by providing tools to support interaction, collaboration and formation of social networks, we may stimulate more interest in, and the wider adoption of Web-based simulation. This paper presents our work in developing an online collaborative simulation modeling tool that is aimed at supporting simulation conceptual model development, allowing users to form relationships and self-organize into virtual communities around common interests.

Keywords: simulation, web-based simulation, conceptual modelling, collaboration

1. INTRODUCTION
Web-based simulation is a term used to capture a cross-section of simulation methodologies and the World Wide Web (the Web, thereafter), specifically the utilization of the Web for supporting model design, model execution and analysis of generated simulation results. There are a number of potential benefits that can be reaped from harnessing the web infrastructure and technologies. First, it allows the sharing of simulation resources such as computers, software, storage and models. Second, it may improve the accessibility and availability of the model and the generated simulation results. Third, the Web may enable the reuse of existing simulation models by utilizing model repositories on the Web. Fourth, the Web can prove to be advantageous in enabling users on disparate sites to collaborate on model design and analysis of generated simulation results by leveraging the communication capability provided by the Internet. Finally, the Web provides an alternative platform for the use of simulation in education.

On searching papers using 'Web-based simulation' as the keyword from ACM, IEEE, and SAGE (include the SCS publications) digital libraries, we found that there was an explosive growth in the number of publications between 1996 and 2002. However, after the peak in 2002, the number of publications dropped very quickly. Kuljis and Paul (2003) argued that the problem with this stems from the fact that there was a mismatch evident between the main characteristics of the Web and the approach taken by the domain of Web-based simulation, which failed to take full advantage of the features of the Web including common standards, interoperability, ease of navigation and use, etc. In other words, the focus of many Web-based simulation endeavours was on the re-implementation of existing standalone and distributed simulation software, utilizing Web-related technologies.

In this paper, we emphasize on the importance of supporting collaborative activities in a simulation project. Pidd (2004, chapter 3) suggests that simulation projects require analysts to operate in two parallel domains: technical and organizational. In the technical domain, the team must abstract and simplify the systems of interest so as to develop and use a computer simulation model. In the organisational domain, the team must manage the project properly so as to gain the required insights in an appropriate timescale and within the budget. At each stage, the team members need to interact and collaborate with other team members and other stakeholders in the simulation project. A good interaction and collaboration may lead to good relationship between the people involved in the project and hence a social network could eventually be formed. Robinson and Pidd (1998) found out that good communication and relationship between the people involved in a simulation project is critical. Therefore, a tool to support the interactive and collaborative nature of conducting a simulation project may provide a strong incentive for users to adopt Web-based simulation more readily. In this paper, we present a tool that we have developed that supports collaboration at the early stage of a simulation project, i.e., conceptual model development.

The remainder of this paper is organized as follows. Section 2 provides the literature study of the research in web-based simulation. Section 3 discusses the importance of supporting interaction and collaboration in simulation projects especially at the conceptual model development. Section 4 explains the design and implementation of the tool. Finally, we present our conclusion and highlight some avenues for future work in Section 5.

2. LITERATURE STUDY

One of the objectives of computer networks (including the Internet) is to share resources. In the context of Web-based simulation, these resources include computing power, simulation software, data, models, simulation results and storage. It is fair to say that most, if not all, Web-based simulation endeavours have resource sharing as one of their objectives. Specific examples that emphasizes on resource sharing include project PUNCH (Purdue University Network-Computing Hubs) that allowed users from more than fifty universities to share simulation tools via the Web and the Web-based simulation project conducted by Wainer et al. (2008) that supported sharing of computing power, data, models and experiments on a global scale.

The Web could make simulation models and the information they generate more accessible than is the case with traditional simulation platform, owing to the distributed nature of the Web. Guru et al. (2000) developed a Web-based simulation system that utilized a database server for model storage and an application server running the simulation engine. The objective was to allow users to store the simulation model via the Web so that they can be easily located, retrieved, and updated using a web interface, and to execute the models using the same web interface. The simulation results were returned as HTML documents; hence they could be accessed easily using any web-browser. Another example is the construction process simulation project done by Halpin et al. (2003). In this project, a Web-based simulation was developed to provide an easy-to-access environment for studying and analyzing construction processes via the Web. General Motor (GM) Enterprise Systems Laboratory developed a Web-based simulation for Order-to-Delivery evaluation and prediction. The objective was to enable GM staff to conduct the simulation analysis anywhere at any time through the Internet.

The fact that simulation models can be shared and be accessible from the Internet leads to the concept of model reusability. In an ideal case, simulation analysts can search existing simulation models from various model repositories on the Web. Subsequently, these models can be re-used as is or they can be assembled to form a bigger model. The reuse of validated models aims at reducing the cost of simulation model development and the time required for model development while increasing the simulation's accuracy through more robust simulation programs. However, this turns out to be easier said than done.

The first issue is that providing a way to efficiently locate and organize simulation models is challenging. Most web search engines are not designed for this purpose. Even for a specialized search engine, brute-force techniques are not adequate and we need to rely on good heuristic techniques, for formal NP-completeness proof see Page and Opper (1999). The effectiveness of the specialized search engines can be improved through standardized model representation and/or the use of ontologies for simulation.

One of the standards for simulation model components is the Base Object Models (BOM) published by the Simulation Interoperability Standards Organization (SISO). BOM defines the syntax and the semantics needed to represent a simulation conceptual model and an interface of a simulation component (SISO 2006). The utilization of the repository of BOM-based components in the component-based simulation model development can be found in Moradi et al (2006).

Ontology is a formal descriptions used to describe and categorize concepts and the relationships among concepts within a particular knowledge domain (Gruber 1995). Web-based simulation can benefit from research in ontology for simulation, since it allows simulation models to be represented as a collection of ontology instances. Effective techniques to search for models based on a set of criteria can be done using specialized query languages. There have been a number of initiatives that explored the ontology-based model representation. Benjamin et al. (2006) outlined the architecture of the Ontology-driven Simulation Modeling Framework (OSMF), in which an ontology-based repository of simulation models was utilized. The University of Georgia's DeMO (Discrete-event Modeling Ontology) was developed to provide a comprehensive ontology for discrete-event simulation that covered the three world views: process interaction, activity scanning and event scheduling (Miller et al. 2004). PIMODES (Process Interaction Modeling Ontology for Discrete Event Simulations) used the same approach as DeMO but focused more on the process interaction world view (Silver et al. 2006).

The second issue is related to the concept of composability. Composability is the capability to select and assemble reusable simulation components in various combinations into simulation systems to meet user requirements (Weisel et al. 2003). Naturally, composability lends itself to a plethora of other issues such as: portability, interoperability (multiple resolution, communication protocols, etc.) and validity. Hence, composability, in itself is an important research topic both within the Web-based simulation research and the distributed simulation research in general. In general, we noticed at least three major approaches to composability: web-service (for example Chandrasekaran et al. 2002), BOM (for example, Gustavson and Chase 2004, Moradi et al. 2007) and ontology (for example, Silver et al. 2007).

The fact that simulation models can be shared might also be advantageous in enabling users on disparate sites to collaborate on model design by leveraging the communication capability provided by the Internet (Kuljis and Paul 2003). However, Henriksen et al. (2002) noticed that there was an apparent paucity of research into the collaboration aspect of web-based simulation. They developed a prototype that combined several existing software tools (such as: project management, animation and simulation) to support the collaborative aspect of a simulation project. Wang and Liao (2003) developed a Web-based simulation environment that provided facility for group communication and collaborative model design. The collaboration was achieved by providing a facility for team members to view the same model at the same time. Any proposal for changes had to be sent electronically to a coordinator. The coordinator would then edit the model so that the amended model could be viewed by the team members immediately. Araújo-Filho et al. (2004) developed a synchronous groupware environment that supported the conceptual modelling, computer implementation and experimentation processes of a simulation project. Unlike Wang and Liao (2003), the role of 'coordinator' was replaced by a software locking mechanism where at any point in time, only one member of the team could modify the model.

3. GROUP MODEL DEVELOPMENT

The area of Web-based simulation has witnessed some success in novel methods for executing models through both client and server-side applications, besides addressing the issue of model reuse. However, even with these advancements and the critical mass of research knowledge available, the applicability of Web-based simulation has not widened to the desired extent, and the potential benefits to be derived have remained unrealized from a commercial perspective (Miller et al 2001). On the basis of information gleaned from the literature, there seems to a disproportionate level of interest in the technology of Web-based simulation in the academic community and potential users who are likely to influence its commercial use; with the area of Web-based simulation remaining more of a scholarly endeavour, and thus principally academic in nature.

Fishwick (2002) noted that Web-based simulation can be an effective problem solving technique and decision support tool that has the potential of stimulating a paradigm shift in simulation; with the shift being one from a single simulation analyst running experiments and analyzing results on his computer to one of global proportions involving multiple interacting simulation analysts.

Simulation projects involve interactions and collaborations among different stakeholders (clients at different management levels, domain experts, simulation analysts, statisticians, etc.). Different stages in a simulation project involve different types of stakeholders and require different degrees of interactions and collaboration. For example, the conceptual model development stage may require heavy interactions between clients, domain experts and simulation analysts, while the computer implementation stage may require regular interactions between programmers and simulation analysts. Therefore, we believe that by providing facilities that support the interaction and collaboration in simulation modelling process, we may stimulate more interest in, and the wider adoption of Web-based simulation.

As far as we know, the formation of social networks through Web-based simulation has not been investigated. Engeström (cited in Breslin and Decker 2007) has argued that social networking sites' longevity is proportional to the degree to which people are connecting via items of interest related to their jobs, workplaces, hobbies, and so on. We believe that Web-based simulation should provide a facility that supports the formation of social network communities. We make a conjecture that this may further attract people to adopt Web-based simulation. People tend to form relationships and self-organize into communities around common interests. Therefore, people may form communities related to the simulation software they use, the type of domain they are involved in (such as: public sector, healthcare and manufacturing), the type of modelling paradigm they frequently use (such as: discrete event, system dynamics and agent-based), and so on. To a certain degree, different simulation communities exist in the physical world (such as: discrete event, system dynamics, agent-based simulation and simulation application in healthcare). Hence, it is plausible that the virtual social networks through the use of Web-based simulation may work. Further, the ontology-based Web based simulation may provide a facility for them not only for sharing their conceptual knowledge but also their simulation models (as long as it is legal to do so). Web-based simulation that supports the formation of social networks may also draw the attention of the new type of users who are referred to as the 'natural-born Webbers' in Kuljis and Paul (2003).

4. CSM WEB: A PROTOTYPE

To prove our concept, we have developed a Web-based simulation tool called Collaborative Simulation Modelling Web Application (CSM Web) that supports the interaction, collaboration and the formation of social networks among simulation enthusiasts either for specific simulation projects (professional), for leisure (perhaps in the form of 'Grab-and-Glue, run, reject, retry' approach as described in Kuljis and Paul (2003)) or for altruistic reasons (such as correcting errors in models posted by other people). At this stage, we focus on the conceptual model development because it is arguably the stage that requires high degree of interactions and collaborations (the same sentiment is also shared by Araújo-Filho et al. (2004)). Onggo (2009) used a number of diagrams to communicate different components in simulation conceptual models. One of the diagrams that can be used in simulation conceptual modeling is the Event Relationship Diagram (ERD) (Schruben 2008). ERD is independent of any software implementation and it can be converted into a target simulator automatically.

There are three types of user: model owner, collaborator, and visitor. A user can use all functionalities on her models (she is the owner of the models). A user cannot delete another user's models, even if she is a collaborator for the models (but as a collaborator, she can modify the models). A visitor has the least privilege. Figure 1 shows the Use Case diagram for the users and Figure 2 shows the Use Case diagram for invitation processing.

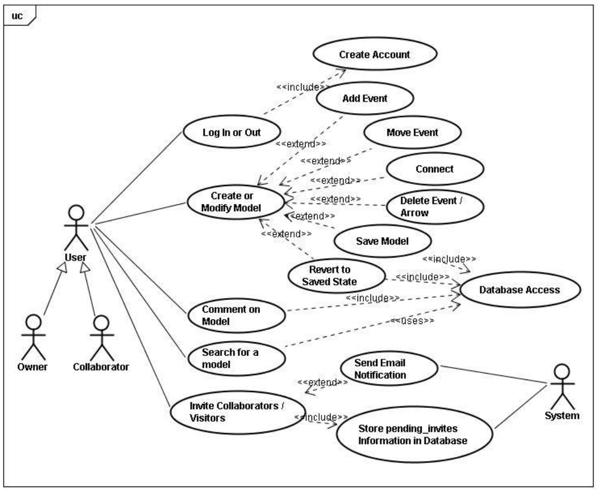

Figure 1: Use Case Diagram – Owner and Collaborator

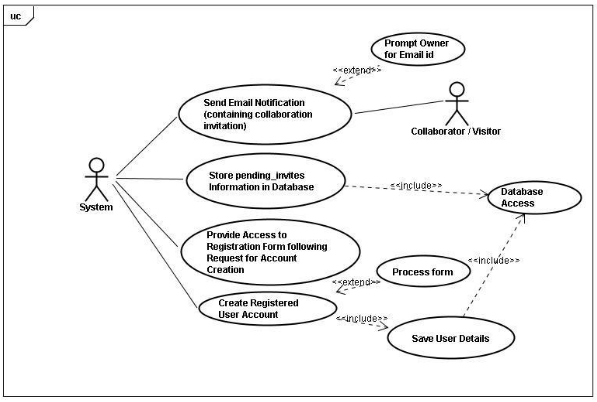

Figure 2: Use Case Diagram – Collaboration System

The CSM Web is implemented using in-browser VML/SVG for creation of models (drawing of events and arrows on canvas), and AJAX for the client-server communication. VML (Vector Markup Language), a standard proposed to the W3C by Microsoft (and others, including Visio Corporation, Macromedia, Inc., etc.) for Web vector graphics, is an application of XML 1.0 for supporting the markup of vector graphic information that is supported by Internet Explorer. SVG (Scalable Vector Graphics), on the other hand, is a W3C Recommendation open standard for describing two-dimensional graphics in XML, and supporting vector graphics in other standards-compliant browsers like Firefox, Opera, etc. We use a small JavaScript library called Raphaël which uses VML and the SVG W3C recommendation as a base for creating graphics, and provides an adapter to make drawing vector graphics for the Web cross-browser compatible and easy. As for the back end, the application utilizes PHP with a MySQL database to store model states and for the other features. PHP (Hypertext Preprocessor) is a commonly used server-side scripting language especially suited for creating dynamic Web applications (through access of data from databases and execution of back-end services in an intuitive manner). It is widely used with database management system such as MySQL and PostgreSQL. The combination of PHP and AJAX, is widely used to provide a powerful platform for the creation of Web-based applications. The architecture of the software is shown in Figure 3.

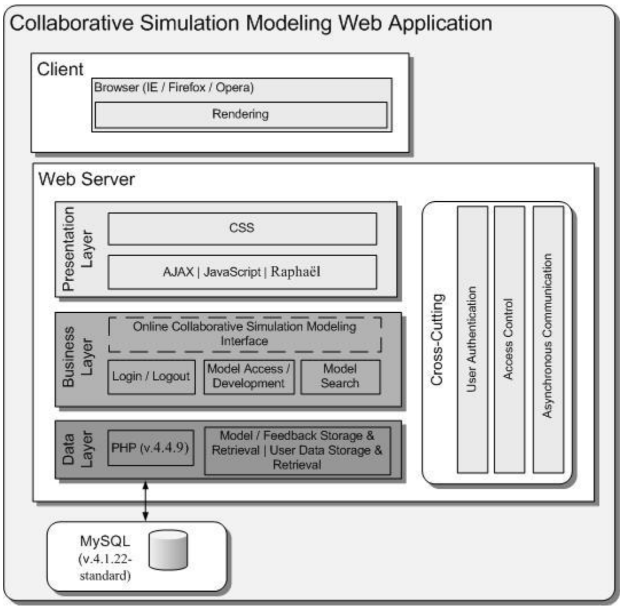

Figure 3: CSM Web – Architecture [Based on a template from the Application Architecture Guide 2.0 by Meier et al. (2009)]

The architecture is structured in three layers. The Data Layer creates a central point for data access (from the MySQL database) through storage, update and retrieval of necessary data. The Business Layer implements the business logic of the prototype, such as login and logout, search etc. While the Presentation Layer performs the task of interacting with the user, such as accepting username and password (for granting access to the system), search criteria (for performing a search on the relevant database), etc. At the client side, the Client Layer (which is the simplest one), composed of a Web browser in which the application is rendered, allows users to view the results of their requests for the available features, and that of the interactions with the features.

The CSM home page (Figure 4) allows a user to log-in or to search simulation models (without logging-in). Once a user has logged-in, the customized, main user interface is shown (Figure 5). The user interface comprises two parts: model creation frame and feedback frame. The model creation frame is used to create, modify, share, and delete models (Figure 6). The feedback frame is used to write comments on a model or to read comments from collaborators/visitors (Figure 7). Finally, Figure 8 shows how the same model is seen by the owner and a visitor. The new added event is shown in red in the owner screen. The new addition will be shown to the visitor once the screen is refreshed. CSM Web prevents entire page refreshes; thus ensuring that small, targeted traffic is passed between the client and server. In addition, the prototype breaks the traditional page update model by performing immediate, asynchronous part-page updates (by restricting updates to specific components) in response to changes made to a model, logging in of a user, or arrival of a new comment on a model; leading to significant reduction in wait time for screen updates.

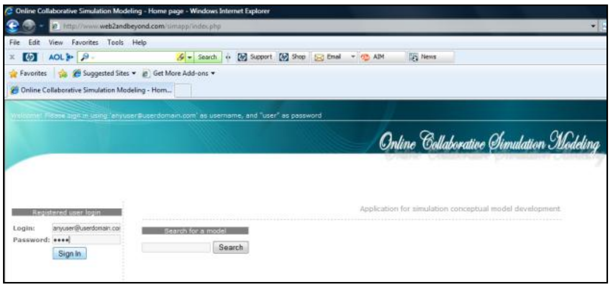

Figure 4: CSM Web – Home Page

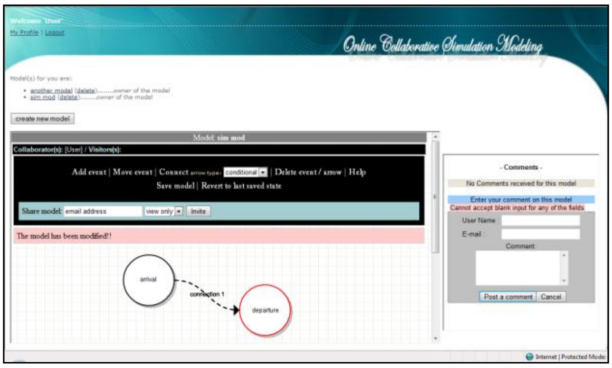

Figure 5: CSM Web – User Interface

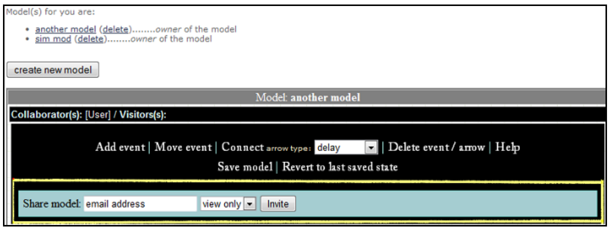

Figure 6: Model Creation Frame

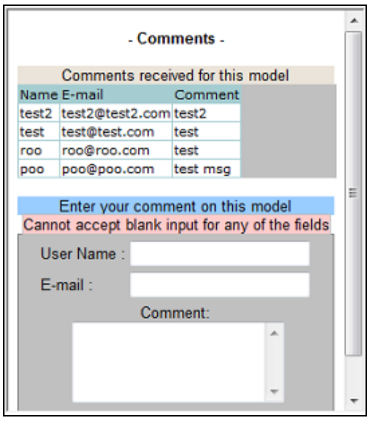

Figure 7: Feedback Frame

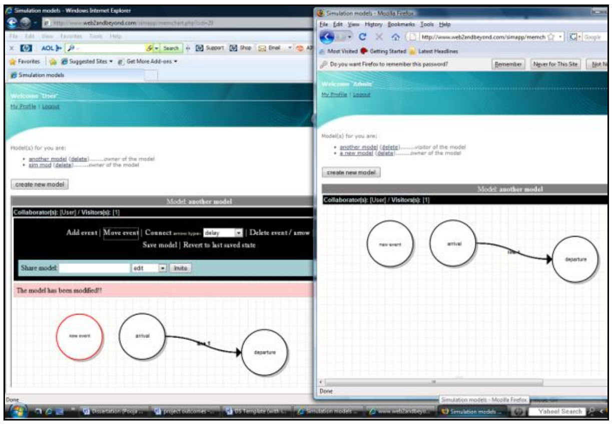
Figure 8: Collaboration View

5. CONCLUSIONS AND FUTURE WORK

We have shown from the literature that more efforts are needed for Web-based simulation to exploit the interactive and collaborative nature of simulation modelling process. We believe that by providing tools to support interaction, collaboration and formation of social networks, we may stimulate more interest in, and the wider adoption of Web-based simulation. We have shown through CSM Web that it is possible to build such Web-based simulation tool using the current Web technologies, such as: AJAX, Raphaël (JavaScript library), PHP and MySQL.

The CSM Web is able to demonstrate basic functionalities needed for our study. However, in order to conduct proper social experiments, we need to improve the functionalities and the user interface. This includes adding the functionality to run the simulation model and adding more social components such as friend list. We need to investigate whether open platforms such as: Drupal, Moodle, Wikis, etc. can be used as an effective collaboration platform for simulation modeling before investing valuable efforts in taking our prototype into a production version.

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