Integrating Cutting-edge Research into Learning through Web 2.0 and Virtual Environments

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ABSTRACT

In this paper, we report on the initial design and implementation of a project entitled *RE@L - Research Environments Associated with Learning through Social Networks*. Our goal is to examine how future science gateways that rely on immersive virtual environments and Web 2.0 technologies can bridge the gap between research and education. To this end, we strategically apply middleware technologies in such a way that it provides students at all levels with an unprecedented level of interactivity and access to cyberinfrastructure resources, educational tools, and social support structures. Our goal is to utilize middleware tools such that research and education are presented to students within the context of their daily lives, their technology choices, and their lifestyles – yet in pedagogically sound ways. This we implement by integrating current generation of middleware in the context of social networks and by applying middleware technologies for engineering the educational experience.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *collaborative learning, computer-assisted learning (CAI), computer-managed instruction (CMI).*

General Terms

Design, Experimentation, Theory

Keywords

Cyber-enabled education, future virtual organizations, informal science education, virtual worlds, beyond web 2.0

1. INTRODUCTION

There seems to be a significant divide behind what students today expect of interactive scientific resources for learning and what is provided to them through cyber-environments also known as science gateways. One of the biggest concerns that is raised by the current generation of science gateways is the minimal importance that they place on real-time social, behavioral functions that students as consumers are so used to on a daily basis. Given the exponentially increasing number of wireless, gaming, and interactive commodity services available to consumers and the rapid growth of socially-oriented virtual environments such as Second Life^{TM}, mySpace^{TM}, and Facebook^{TM}, the current generation of environments that attempt to bridge discovery and learning seem to lag significantly behind what the millennial students – and even scientists – are regularly comfortable with in their daily lives. The potential use of the current generation of middleware technologies within social networks has not been fully understood yet, mostly because middleware has so far been developed mostly from a high performance computing perspective.

In this paper, we present the foundation of the comprehensive application and extension of current middleware technologies within the context of social networks. We are creating a virtual organization for education called RE@L within the social network and virtual environment Second Life^{TM}. RE@L will serve as a prototype to study how compute, data, and other remote resources can be utilized to place learning within environments familiar to students. Cyberinfrastructure itself will be the subject matter of RE@L, students will learn CI using and building CI. Our design leverages existing middleware to build a service-oriented architecture to tie in not only compute resources offered by TeraGrid (TG), Open Science Grid (OSG), and the Clemson Campus Grid (running Condor) within the environment, but also link the assessment engine called Samigo, available through the open-source Sakai Collaboration and Learning Environment. Furthermore, Second Life^{TM} offers a robust set of APIs that enable us to expand tools and services easily within its virtual environment.

This work builds on the philosophy that teaching and learning environments need to leverage cyberinfrastructure more effectively to engineer educational experiences in ways that are more appropriate for the millennial generation. In addition to providing a framework for reaching a large audience, we feel that placing teaching and learning where students are already looking, increases the chances of enticing, inspiring, and keeping the students better engaged in science, engineering, technology, and mathematics. The work presented in this paper can be easily adapted to form the foundation of a cyberinfrastructure-enabled educational strategy that has all the critical ingredients of cutting-edge research at most US institutions of higher education. Upon

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completing development work, we intend to use the prototype that has been developed as part of this effort within classrooms, courses, and also for cyberinfrastructure training of scientists in order to study the performance and impact of this next-generation environment on student performance and also on its ability to foster learning and collaboration.

2. THEORETICAL FRAMEWORK

Discipline specific science gateways, such as the nanoHUB [Source: http://www.nanohub.org] and Network for Earthquake Engineering Simulation (NEES) [Source: http://www.nees.org], are the state-of-the-art in exposing cyberinfrastructure resources to a scientific community. Science gateways have also taken on the additional role of acting as the bridge between research and learning in a scientific domain. While there are definitely some positive moves to take better advantage of cyberinfrastructure in teaching and learning contexts, the bottom line remains that the rift between what students think of as advanced technology and our learning systems is slowly increasing. This growing gap between what students today perceive as cyber-resources for learning and their schools' view of the very same resources has lead to the genesis of the term "the Digital Disconnect" [14]. "Many schools and teachers have not yet recognized—much less responded to – the new ways students communicate and access information over the Internet" [14, p. iii]. This "digital disconnect" has made it extremely difficult to bridge the gap between real-world research and learning that occurs in formal and informal settings. As cyberinfrastructure efforts ramp-up with efforts such as petascale computing that usher in the next frontier in cyberinfrastructure, it is abundantly clear that now is the time to rethink how we structure cyber-learning and the environments that support such activities. Our thinking has to evolve beyond just the Powerpoint™ and web-page focused formats and the limited interactions they seem to offer. There is a big need to move cyber-environments for learning strategically forward into a realm where the virtually never-ending potential of cyberinfrastructure is brought to bare within these environments. This is the core of the argument that has led us to propose the set of deliverables discussed here.

The power of cyberinfrastructure lies in its ability to not only deliver resources, tools, and services to an extremely large set of users simultaneously, but also allowing them to interact and collaborate with each other in natural ways. Cyberinfrastructure has revolutionized the world of knowledge production and creation. It has allowed an increasingly large number of millennial students to participate in this process through extremely easy methods. Advances in cyberinfrastructure have introduced new set of services such as mySpace™, Facebook™, and Flickr™ that fall under the Web 2.0 genre. According to O'Reilly [O'Reilly2006], "Web 2.0 is the business revolution in the computer industry caused by the move to the Internet as platform, and an attempt to understand the rules for success on that new platform. Chief among those rules is this: Build applications that harness network effects to get better the more people use them." The most important reason for the success of these *social* networks is the fact that students can work and create knowledge within peer groups contributing to "harnessing collective intelligence" [15]. Figure 1 provides a 3-year snapshot of some of the common social networks that are based on the notion of allowing people to participate in the knowledge creation and dissemination process.

It is striking to note that in each of the six trends above in Figure 1 that - immaterial of the network and the services that are offered – all of them show a steep increase in the number of people participating in the network on a daily basis. Figure 2 provides the average daily reach of major efforts to bridge discovery and learning such as the National Science Digital Library (http://www.nsdl.org), MERLOT (http://www.merlot.org), Shodor Foundation (http://www.shodor.org), National Science Teachers Association (http://www.nsta.org), or even major cyberinfrastructure initiatives such as the nanoHUB (http://www.nanohub.org).

It is very clear from the above data that trends shown in Figure 2 do not show the increasing trend in daily impact that are so clear among social networks. We understand that the user groups for this comparison do not map one-on-one between social networks and educational environments. However, what is troubling is that we do not see an increasing trend in using educational environments even within the relevant user groups engaged in teaching and learning – maintaining a status quo that is

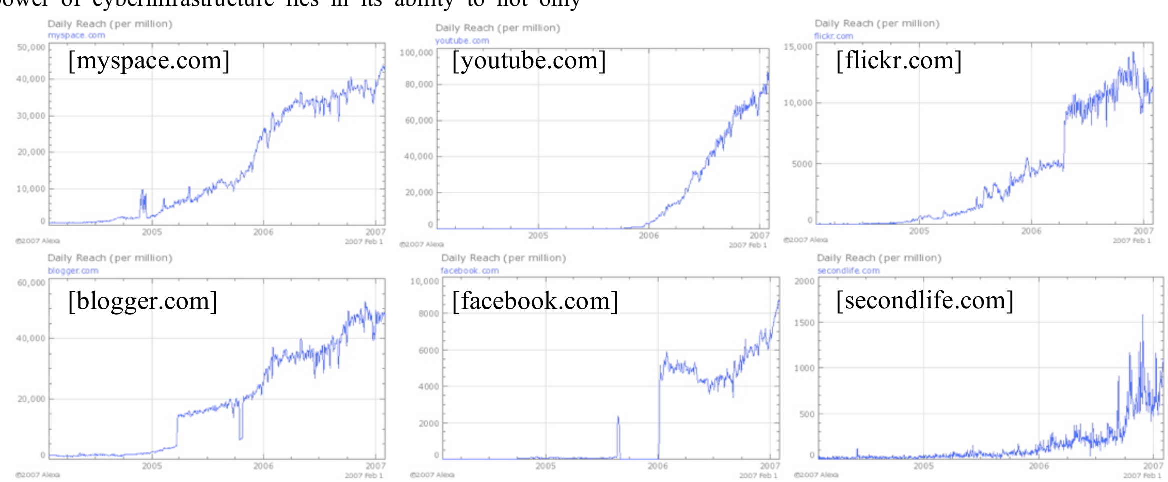

Figure 1. Daily reach (per million) of 6 popular social network sites based on Web 2.0 model (Source: [1])

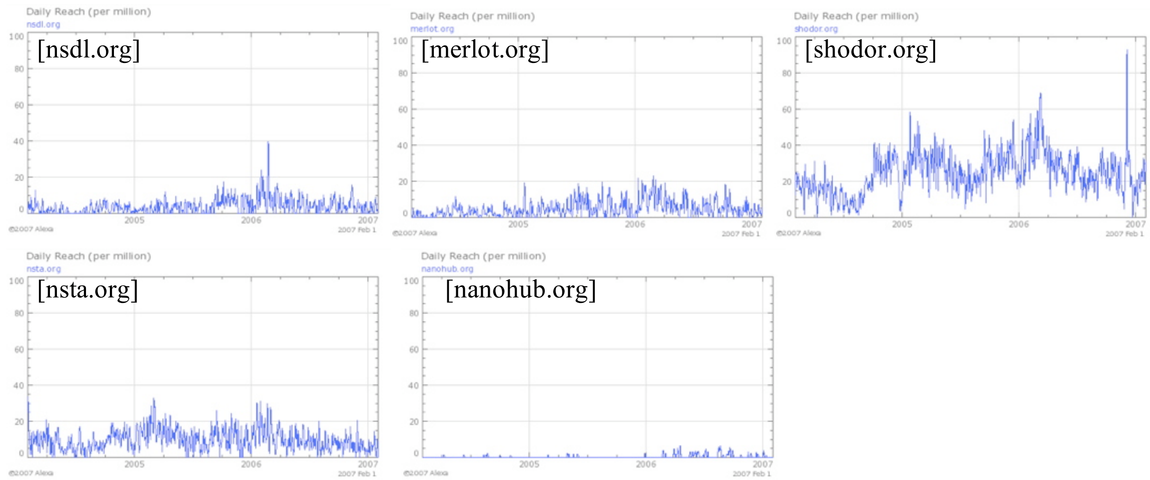

Figure 2. Daily reach (per million) of major educational environments (Source [1])

detrimental to competing in the global market. Also of significant interest is that students form a major demographic of all significant social networking efforts. In collecting this data and analyzing them, it was even more striking that the cyberinfrastructure-enabled educational outreach missions such as the CIChannel (run by San Diego Supercomputer Center) [Source: http://www.cichannel.org], Engaging People in Cyberinfrastructure (EPIC program) [Source: http://www.eotepic.org] did not figure in the top 100,000 sites used by the American public on a daily basis. Perhaps this is an indication that a new generation of cyberinfrastructure-enabled environments that draw on popular social networking paradigms holds the key to engaging students and indeed researchers.

The process of "harnessing collective intelligence" is enabled through cyberinfrastructure – which can, therefore, provide the added benefit of facilitating social and peer-group interactions that have been repeatedly shown as critical to student success. Lenhart et al. [13] suggest that use of modern IT technologies such as synchronous communication media enhances quality of teens' social life and academic work. While there are a number of sites online that cater to the day-to-day activities of students, there is a real void in how learning environments utilize cyberinfrastructure to blend active and inquiry-based learning activities with students' lifestyles. Even current generation of scientific environments that attempt to bridge discovery and learning utilizing Web 2.0 type environments are largely devoid of the "real-time" social interactions that seem to be a major factor in the way students utilize modern day IT tools and services. This call to create cyberinfrastructure-enabled learning environments that can have a transformative effect on how learning and research is situated in students' lives – while never has been attempted in the past – has very strong pedagogical and theoretical foundations.

There is well-established evidence in the field of education that learning is an extremely social, collaborative, and inquiry-based effort [5, 18]. Researchers working on issues of bridging discovery and learning have started pushing for new tools that utilize the notion of semantic web in higher education [2, 3, 12]. The goal behind this new branch of pedagogical research powered by cyberinfrastructure is the need to put learners within contexts and environments that they are most comfortable with and that allows them to explore as they learn. While there are significant differences between the core technical and philosophical implementation of Web 2.0-type environments and the type of environments purported by the semantic web approach [4, 7, 9] – the message from pedagogical researchers is that there is a need for a new generation of cyberinfrastructure-enabled applications that can better serve the learners. Dalsgaard states that "weblogs [*sic.* blogs], wikis and social bookmarking can be used to support e-learning activities. However, these tools are not developed for educational purposes, which means that a directed effort is necessary to develop educational social software tools to support learning activities" [6]. In the context of education, there is a need for a transformative effort that utilize cyberinfrastructure to bring aspects of both Web 2.0 and the semantic web such that we can leverage the commonalities of the two frameworks.

One other critical aspect of present day learning environments is that they do not engage significant computation power well within the application contexts. Students are most commonly reduced to handling toy problems without the benefit of the cutting-edge tools and services that are created as an off-shot of significant computational power. Commonly, students are taught beginning MATLAB™ or Microsoft Excel™ as tools for simulations and visualizing. While these are good entry points, the students commonly do not graduate beyond these tools – or for that matter to even utilize the more advanced libraries available for these tools. How can students who are never used to significant computational power be expected to be part of a workforce or scientific force that is based on cyberinfrastructure as a necessary ingredient for conducting business?

One of the simplest ways of exposing students to cutting-edge cyberinfrastructure is to make it an intrinsic part of their living environments. Condor and associated technologies offer an easy entry point to provide the compute power necessary for educational environments. Commodity clusters can be built easily and cycles of HPC clusters can be harvested with the Condor system. Clemson University has recently deployed Condor on its campus and a growing number of machines (~1,000) are joining a Condor pool. Before getting access to TG and OSG resources, we will use the Clemson Condor pool as a proof of concept that significant compute resources could be used from Second Life. As we harvest resources to build this prototype, we also have the added advantage of not interfering with the regular research activities that may need compute resources. Also, most educational environments cannot invest significant amounts into computing – which is one of the primary problems with teaching students about cyberinfrastructure using "hands-on" methodology.

In the next section, we discuss the architecture we are using for this work and also some preliminary integration results. Once again, we would like to point out that this is the initial phase of this work and we will have further results to report in subsequent papers.

3. ARCHITECTURE FOR RE@L

Our goal is to build a cyberinfrastructure-enabled learning environment that bridges discovery and learning in such a fashion that it blends in students lifestyles and technology choices. In order to accomplish this, we use a popular social network that has open-source viewers and APIs. The environment that we use in this project is called Second Life™ [Source: http://www.secondlife.com]. While there may be other environments in the future that may have similar and better capabilities, our project aims to demonstrate that we can indeed link advanced computational resources within educational environments seamlessly. "Second Life is a 3-D virtual world entirely built and owned by its residents. Since opening to the public in 2003, it has grown explosively and today is inhabited by a total of 3,297,492 people from around the globe" [SecondLife2007]. At the time of this submission, there are over 100 major educational institutions currently starting to develop learning environments within Second Life [InstitutionsList2007]. We must also point out that Second Life™ is a massively multiplayer online game (MMOG) – and the game being played blurs the boundary between the real-world and the game itself. According to BusinessWeek Magazine (May 1, 2006), "Virtual worlds may end up playing an even more sweeping role -- as far more intuitive portals into the vast resources of the entire Internet than today's World Wide Web. Some tech thinkers suggest Second Life could even challenge Microsoft Corp.'s (MSFT) Windows operating system as a way to more easily create entertainment and business software and services" [10].

The architecture for constructing such an environment is very similar to building any scientific gateway and is presented in Figure 3. The added advantage we get by using the Second Life™ engine is that if offers a fully immersive, 3D environment that is completely interactive. At the infrastructure level, we intend to utilize a Condor pool of 900 machines (and growing) that is being deployed at Clemson University with the added potential to access the TeraGrid and the Open Science Grid (OSG). The Condor pool will be linked into the Second Life™ environment by utilizing an initial set of APIs that are already available through an open-source effort. However, we must point out that not all services to complete this integration are already available. We will develop services that will allow users to monitor job status, submit jobs, and retrieve job output as part of the development effort we will undertake.

As we intend to develop this as an environment that bridges discovery and learning, we will develop a series of materials that will provide users with opportunities to learn about cyberinfrastructure and contribute towards the effort. The materials will be developed as learning object which are digits assets wrapped in XML-based metadata descriptors and contain a wide range of content, such as voiced presentations by experts, quizzes, and links to appropriate cyberinfrastructure resources.

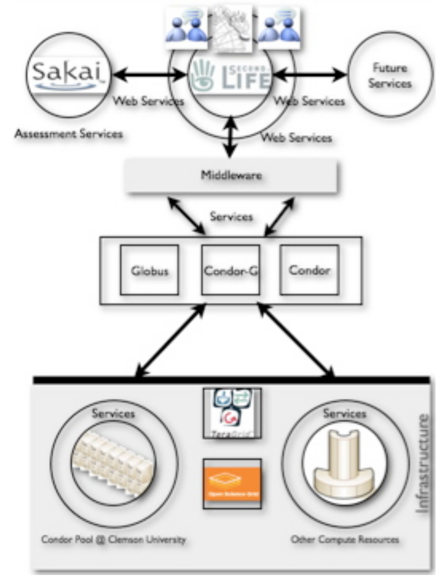

Figure 3. Architecture to be utilized in RE@L

The metadata descriptors are consistent with e-learning specifications such as IMS (not an abbreviation} [11] and Shareable Content Object Reference Model v1.2 (SCORM) [17]. Compliance with e-learning specifications ensures the interoperability and reusability of the content in other environments such as course management systems that are used on most university campuses. While this is an added feature that will slide easily within the environment, we believe that the framework we are developing is the key innovation we are making through this effort.

Over and above the link to compute resources, what makes this project very unique is its simultaneous focus on pedagogy. In order to achieve this goal, we need to use the virtual environment we build to collect data that can inform us about the learners's needs and learning patterns. At the same time, we need to build in the ability to be able to integrate this data into more formal evaluations and assessment efforts. We will leverage web services offered by the open-source Samigo assessment engine that is part of the Sakai Collaboration and Learning Environment [16]. Details on integrating the assessment and more details about underlying architecture of the assessment aspects of this work will be presented in future papers.

The next section discusses how RE@L will access remote resources such as compute and storage services on TeraGrid, Open Science Grid, and Clemson campus grid. Furthermore, we show specific preliminary data from a Condor pool at Clemson University displayed within Second Life™.

3.1 Remote Resources for RE@L

To date the national infrastructure has evolved from the supercomputing center program to become a distributed grid of supercomputing resources (TeraGrid), additionally the Open Science Grid (OSG) consortium is integrating compute resources at various research labs and campuses. The TeraGrid and OSG mode of operation has however seen a very strategic change in the way it supports its users.

OSG from the startup supported Virtual Organization (VO), while TeraGrid with its science gateway program has also now adopted the VO concept but with caution due to the accounting issue involved with letting a VO access resources as a group. This shift towards VO support can be traced back to [8] where the authors low level middleware but instead leverage the past NMI investments made in such middleware projects as Globus and Condor and focus our effort on using the Second Life APIs within application level middleware as a gateway to national resources.

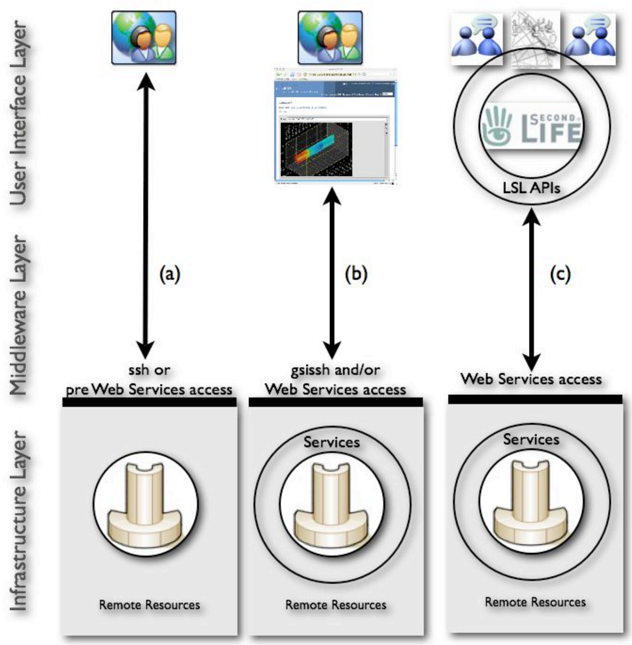

Figure 4. Science Gateway Evolution

stated that the VO concept had a profound impact in the management and provisioning of remote resources. Indeed linking research and education can be well understood when one thinks of a classroom as a VO. While scientific communities have embraced the VO concept and deployed various CI in support of their research, few CI have tried to address both research and education at the same time. Scientific CI has evolved from direct access to HPC resources to using web services for job submission and now to building their own infrastructures that delegate access to the compute resources. Figure 4 shows this evolution with our proposed next step of using a social network based 3D environment to replace the standard portal infrastructure. In case (a) users have traditionally access high performance computing resources through standard SSH access and account management, with the introduction of grid computing a layer of middleware create interfaces on these resources for remote job submission and data transfers. Now with the development of grid services (through for example the Globus toolkit), VO have started to access these resources as a group instead of as an individual. The user interface in case (b) being very often a web portal populated with grid portlets such as the one from the Open Grid Computing Environment (OGCE) effort. Our effort expands on current CI designs that build on a grid architecture and proposes a new environment for science gateway, one that uses a full 3D environment instead of standard web portals, this is presented in case (c) within Figure 4. While the concept is an evolution in terms of collaboration and interaction capability the core architecture is the same, one that is based on service oriented architecture and uses web services deployed by resource providers and other service providers. Therefore, we are not building new

The middleware integration of the 3D environment and the physical resources is based on the use of the Linden Scripting Language [Source: http://wiki.secondlife.com/wiki/LSL_Portal]. Any object within SL can be enhanced by stateful event driven code using LSL. A scripted object can contain variables, functions and a number of named states. Each state is determined by a description of how to react to events while the program is running. Movement of avatars, chat messages, emails can all change the state of an object. Objects can also communicate with other objects and agents as well as interact with external resources originally through XML-RPC and more recently through HTTP/HTTPS requests. The rich set of LSL API gives us the ability to animate any SL objects and to interact with outside resources through HTTP requests. While these capabilities might be limited right now, new enhancement to LSL would make possible the interaction with grid services such as job submission, data transfers and data replication through the Globus middleware or SOAP interfaces to remote resources such as the BirdBath SOAP interface to Condor [Source: http://www.cs.wisc.edu/condor/birdbath/]. As a starting point we experiment with connecting SL objects to the recently deployed Clemson Condor pool – a windows based pool of more than 900 machines and growing. The next stage of this work is the connection to TG and OSG will be worked on with the same underlying principle: use the web services deployed on these national infrastructures. This task will however require the creation of an official VO for this project and a strong identity management plan so that only known avatars can access these external resources.

The security aspect of accessing these national resources will be tackled even though at this time no clear answer is available. TG and OSG users are authenticated through X.509 certificates issued by trusted Certificate Authorities (CA). SL avatars in the RE@L environment will need to be tagged with attributes that link them to a CA or a shibboleth identity provider. Authentication and Authorization of users in national grids using attributes is the future path towards widening access to these resources. Clemson University has made great strides in that direction by joining the InCommon federation and deploying a shibboleth IdP as well as deploying the GridshibCA which allows Clemson users to get a grid proxy in their file system. To tackle TG and OSG access we envision building SL objects that will communicate with the GridshibCA and download a proxy outside of RE@L, the users would then be able to bind to this proxy from RE@L to perform remote tasks in TG and OSG.

At a high level every VO CI need to enable the following three objectives: Research, Educate, Collaborate. The research mission of VO will be supported by the access to remote resources as described above, it is to be noted that visualization capability could potentially be developed within SL itself. In addition to compute and storage resources, collaboration tools will complement the overall architecture. Collaboration will be handled by the environment itself and the use of instant messaging between avatars and the streaming of audio and video which is built in within SL. Any object can we tailored with a specific texture, each texture can tagged with a URL of a streaming media making it possible to stream audio and video in specific part of the SL environment. This technique will be used to potentially replace existing techniques used for collaboration such as Access Grid, CI Channel, webcasting, and Macromedia Breeze.

3.2 Preliminary results using Second Life – Full Condor Stats within Second Life

In order to test the above architecture, our approach, and also the Second Life environment, we undertook some simple exploratory integration activities. The first activity was to integrate the ability within Second Life to show condor-stats of the Clemson Condor Pool. In order achieve this we leverage the exact mechanisms that allow the web-based activity tracking of condor pools. The first step in the process of incorporating real-time Condor statistics within Second Life, involved the creation of a .NET HTTP interface that examines the Condor stats pages and parses all the required data. In its current form, the .NET interface we have developed is capable of providing all stats that are seen on a regular Condor page such as the one from Clemson – that is found at http://central.condor.clemson.edu/condor-stats/. Furthermore, some post processing is also performed using .NET charting services that creates charts of the appropriate datasets. Due to some well-documented format restrictions within Second Life, we need to convert the resulting chart data object into a Shockwave file (swf), which is the standard format for most viewers that utilize the Adobe Flash format. Therefore, the final process that is triggered by the web service is a sub-routine that converts XML chart views into Flash SWF format. This is the object that gets returned by the HTTP interface to the Second Life environment. The next step is to make these statistics available within the Second Life environment. This is done by creating a simple screen object within Second Life to display the stats and a menu list for users to request a specific type of statistic. Two scripts written in Second Life's Linden Scripting Language (LSL) are attached to the screen object and the menu list objects respectively.

The user selects an option from the menu list – for example, the stats for the entire month of September. This triggers the LSL script to make a call to the .NET statistics HTTP interface and pass appropriate parameters to the service. This in turn returns a Flash SWF object that is embedded into the screen object by the LSL script. Figure 5 below shows a snapshot of the Data for the month of September from the Clemson Condor pool. Here you see the avatar view as seen with Second Life and its corresponding web view. The reader will immediately notice that the views are exactly the same.

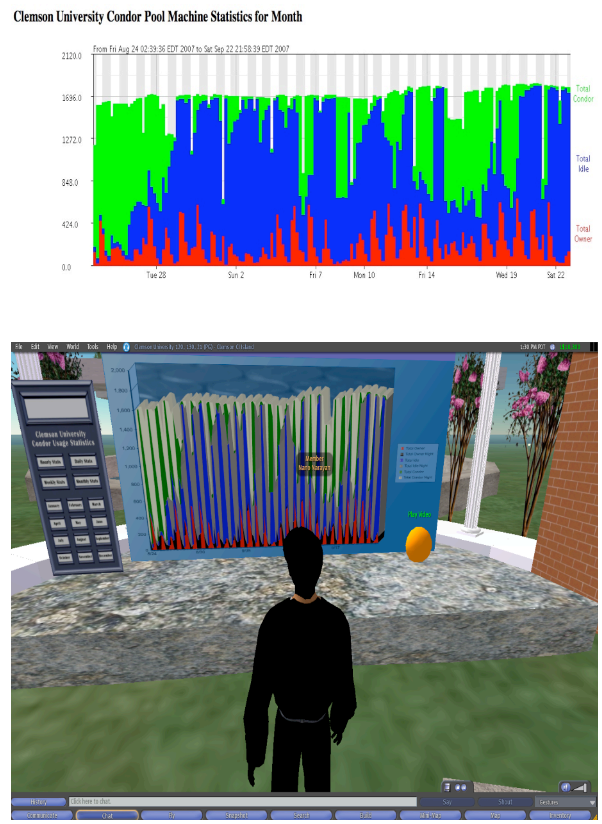

Figure 5. September Clemson Condor Statistics within Second Life and verification with the live website

In designing this service, we have already gained considerable experience with providing real-time data within a 3D virtual environment. Also, we have identified several of the strengths and weaknesses of the medium. One of the primary aspects of the design that poses problems is the possible limitation on the size of the data packets that can be transmitted in and out of the Second Life environment. Since this is a massively multi-user environment, these restrictions seem reasonable. However, there are some important scientific activities that may be hindered by such limitations. This is, perhaps, one of the first results we have derived from our experiments with Second Life. We are aware of the need to verify these results further through other confirmatory experiments.

We are also currently experimenting with the size of data transfers possible within Second Life when transferring search results using popular search APIs provided by Google, Yahoo, and others. We are experiencing similar data throttling as in the case of Condor stats service. On a related note, Second Life does not offer a search engine capability that can return results from web searches. In the process of experimenting with the size of data packets, we are also attempting to build a search service using Google and Yahoo within Second Life. This service will be made available through some basic prim objects that will be activated through a standard chat channel mechanism. A discussion about the search service is outside the scope of this paper. Furthermore, we are also experimenting with the processing and visualization of chemical structures within Second Life. Efforts are underway to search for a specific chemical structure using the search engine service and then visualizing this information real-time within Second Life. It is important to conclude this section by reiterating that the Second Life environment offers a great deal of possibilities. We are still in the process of understanding fully the capabilities and limitations of this environment. While this paper is our preliminary report on research with post web 2.0 virtual environments, the next anticipated outcome is an in-depth paper on these aspects of the virtual world.

4. CONCLUSION

In this paper, we are presenting a new and innovative direction for future science gateways. It is our hypothesis that the next generation of science gateways will go beyond Web 2.0 technologies and allow the inclusion of real-world social, behavioral characteristics of its users. We have presented some preliminary results by extending the service oriented architecture framework in the context of virtual environments. The next stage of this work will offer a variety of services to users within Second Life that will enable the bridging of cutting-edge research and education. Most importantly, we are exploring new directions for bringing scientific content into education in forms that students today are most comfortable and is already part of their everyday repertoire.

5. ACKNOWLEDGMENTS

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