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Service oriented support for heterogeneous software tools in environmental modelling and visualisation

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Abstract: Natural resources management policies often entail a complex environmental decision-making process. This process can be greatly enhanced if it is based on an exploratory-envisioning system such as the Spatial Information Exploration and Visualisation Environment (SIEVE). This system integrates Geographical Information Systems, collaborative virtual environments, and other Spatial Data Infrastructures with highly interactive game-engine software. By leveraging these technologies, the system increases the potential for every participant, regardless of his level of involvement to have a better understanding of the issues at hand and to make better informed decisions. In a like manner, current scientific research has taken advantage of e-science platforms that share resources and enhance distributed simulation, analysis and visualization. Many of these infrastructures use one or more collaborative software paradigms like Grid Computing, High Level Architecture (HLA) and Service Oriented Architecture (SOA), which together provide an optimal environment for heterogeneous and distant, real-time collaboration. While significant progress has been made using these collaborative platforms, frequently there is no particular software suite that fulfils all requirements for an entire organization or case study. In these cases, an end-user must cope manually with a collection of tools and its exporting/importing capabilities to obtain the output needed for a particular purpose. This paper proposes a modular, real-time collaborative framework based upon user and tool-wrapping interfaces that are compliant not only with the aforementioned exploratory virtual environment, but also with web service-based Grid and HLA technology guidelines. The framework architecture is divided as follows:

- *Visualization Layer Services*: composed of modules that offer the end visualization outcome, which depends on performance/quality of detail required to visualize the same data provided by the next layer. This layer includes Web Client services, Virtual Collaborative Environment interface services and high definition rendering services.
- *Management/Orchestration Layer Services*: process services that link and sequence services according to existing and potentially new visualization requirements. These automated services further delegate specialized functions such as management, security, batch processing and similar features. This layer includes a Workflow Manager, a Simulation Real Time Infrastructure Manager, a Render Manager and a Grid Middleware Manager.
- *Data Layer Services:* data sources that can be composited to feed spatial and non-spatial information requirements that the orchestration layer needs to fulfil its lifecycle.
- *Communication Services:* encapsulating CityGML information using Web Services protocols (Web Service Description Language -WSDL, Simple Object Access Protocol -SOAP, and Universal Description Discovery and Integration -UDDI), data is transferred from all layers through Wrappers/Interfaces that are implemented by standard contracts on each module.

In this manner, this framework orchestrates the use of heterogeneous software tools which collectively support distributed visual spatial analysis and complex environmental decision-making processes.

A proof-of-concept prototype will be presented to illustrate a combination of representative commercial and open source software used in the area of spatial visualization, distributed computing and complex environmental simulation.

Keywords: *Distributed Collaboration in Virtual Environments, Spatial Analysis; Grid Services; SOA; HLA; e-science.*

1. INTRODUCTION

Today's global environmental issues, including water shortage and climate change, demand our serious attention. To cope with these problems, raising public awareness is essential (Flanders et al., 2008; Warren et al., 2008). It has become increasingly evident that a multi-disciplinary effort is required to meet these challenges. This multifaceted approach entails a complex environmental decision-making process, and a cooperative and integrated platform can greatly enhance this process. Among the varied range of technologies that exist today to support such processes, Geographical Information Systems (GIS) technology is one of the most useful tools for efficient spatial analysis. Moreover, its power to convey concrete results can be augmented when its output is combined with visualization tools that render 3-D spatial information in computer-generated "Virtual Environments" (Ghadirian and Bishop, 2008; Zhang et al., 2007).

Taking this visualization approach further Stock et al. (2008) introduced the concept of an exploratory-envisioning system. This system, called Spatial Information Exploration and Visualisation Environment (SIEVE), provides rural communities with the possibility of a more "natural, real world" immersion to explore and judge possible future scenarios of landscape changes. This option also increases the potential for every participant, regardless of his level of involvement, to have a better understanding of the issues at hand. Such results were obtained thanks to a special type of Collaborative Virtual Environment (CVE) (Jefferey et al., 2005). These systems integrate GIS, virtual environments, and other Spatial Data Infrastructures with game-engine software[1], a technology designed to provide multiple users with a highly interactive and simultaneous experience. Indeed, many approaches that use game-engines to create CVE have been applied successfully (Cauchi, 2005; Pumpa and Wyeld, 2006). In a like manner, current scientific research has taken advantage of e-science platforms that share resources and enhance distributed simulation, analysis and visualization. Many of these infrastructures use one or more distributed software paradigms in order to support collaborative results (Hutanu et al., 2006).

Nonetheless, these systems are built upon platforms and programming languages which are tailor-made for a particular purpose, not easily extended to support a wider sharing of resources and collaborative work (Li et al., 2007). To overcome such problems, as well as to facilitate the sharing of heterogeneous geospatial data and support real-time collaborative tasks between geographically distributed members, many organizations leverage latest distributed computer technologies based on grid computing and web services (Riedel et al., 2008). Many organizations have sought to converge grid services with web services, which is the pillar of the Service Oriented Architecture (SOA) paradigm. The SOA paradigm is based on loosely-coupled modules that are orchestrated together by means of standard communication protocols, Web Service Description Language (WSDL), Simple Object Access Protocol (SOAP) and Universal Description Discovery and Integration (UDDI). This Web Services technology communicates its parties regardless of platform and language implementations, by using standard eXtensible Markup Language (XML) schemas, which provide well-formed data packages and conformity to consensus standards, thus allowing automatic information extraction and verification. When using this web services framework on a grid middleware platform, many computers, potentially thousands, share data, applications and computing capacity to achieve a desirable outcome, in a manner transparent to the end-user who only interacts with a single entity (Riedel et al., 2007).

In the area of landscape visualization the Open Geospatial Consortium (OGC) has extended the aforementioned XML schemas to specify Geography XML (GML) and CityGML (OGC, 2008). These schemas define a common semantic information model to represent 3d urban and geographical models, going beyond purely graphical or geometrical models, and adding semantic and topological aspects of it, and by the same token, enabling lossless information exchange between spatial systems and users (Wang et al., 2007).

Following the same line of thought, in order to integrate different simulations, the High Level Architecture (HLA) standard (IEEE 2007) enforces a similar collaboration paradigm upon simulations. HLA dictates the implementation of a Real Time Infrastructure to standardise communication and dataflow between engaging simulations. The integration of various simulations is essential to the whole process of landscape visualisation in support for environmental management. Among other reasons, simulations are the perfect tool for developing theories that deal with problems where direct empirical analysis is impractical or impossible (Lomi & Larsen, 1996). For instance, long term effects due to future climate change have stimulated the development of uncertainty models that strive to analyse the causes of regional and global change. These approaches have made substantial contributions to the analysis of climate change impact, and

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[1] Our SIEVE viewer is based on the Torque Game Engine (GarageGames, 2004). While we acknowledge that there are several game engines currently on the market, a discussion on our choice for this particular game engine lies outside the scope of this article. Please refer to the aforementioned study in Stock *et al*. (2008).

have been widely used in the exploration of predicted change in land and natural resource management (Lee et al. 2008; Ménard and Marceau, 2007. In the field of CVE: Ghadirian and Bishop, 2008; Kwartler, 2005).

2. BACKGROUND

A reusable framework to integrate distributed services for collaboration has been proposed by Luo et al. (2007). In this framework a web services "bus protocol" integrated self-made and third party collaborative tools, following a "mash-up approach" to meet specific platform needs, including security and management. Similar approaches using grid technologies have been successfully implemented (Foster, 2006; Riedel et al., 2006). For instance, The Earth system grid (Kendall et al. 2008), not only enables grid sharing of analysis and climate modelling, but also real time distributed visualization of simulation output. The Large Hadron Collider at CERN is engaging in one of the largest data-crouching experiments to date (Clery, 2006). In summary, grid services technology is poised to become the essential part for most e-science collaboration platforms (Riedel et al., 2008).

The same grid services technology has been widely applied in designing distributed virtual environments for geospatial data (Zhang et al., 2007). The CSIRO's Solid Earth and Environment Grid also aims to address the issue of transparent access to resources through OGC Web Services architecture (OGC, 2006), thus facilitating the management of Australia's natural and mineral resources (Wybon, 2006). Likewise, a 3d-GIS architecture platform based upon CityGML Web services standards was proposed by Wang and Bian (2007). This architecture implemented a similar three-tiered layered framework proposed here, emphasizing 3d geo-data applications and OGC's web features services. Analogous technology implementations were carried out by Wang et al. (2007), where a web-based framework was used to target specific urban data sharing dynamic planning.

In the area of HLA web based distributed simulation, Boukerche et al. (2008) and Möller and Dahlin (2006) proposed frameworks that used web services as its communication protocol to control HLA compliant simulations. These platforms successfully implemented flexible and extendible applications to interface with simulations in real-time. When simulation models are integrated in a distributed platform, it has the potential to create sound and relevant assessments of complex environmental impacts, as well as offering to a community of institutions the flexibility to assembly individual modules and modeling paradigms (Rivington et al., 2007; Warren et al., 2008). In fact, if a complex forecast like the ones produced by climate change models is comprehensible, the risks inherent with certain decisions will be more tangible. In addition, an uncertainty analysis for model outputs can better determine the quality of the information obtained (Chen et al., 2006).

Granted, most of this significant progress has been made using open source, easy to integrate collaborative platforms and software. On the other hand, most organizations depend on a collection of open and commercial tools, and there is no particular software suite that fulfils all requirements for the entire organization. This is particularly true for those that rely on landscape visualization to support management decisions. In these cases, an end-user must cope manually with their exporting/importing capabilities to obtain the output needed for a particular purpose. Nonetheless, the integration of commercial software with the collaborative paradigms just described remains a difficult task, although a highly desirable one, to overcome in the near future (Li et al., 2007). Consequently, we aim to define a modular, real-time collaborative framework based upon user and tool-wrapping interfaces that are compliant not only with our exploratory virtual environment (SIEVE), but also with commercial off-the-shelf tools, Grid Services and HLA standards guidelines.

3. FRAMEWORK ARCHITECTURE

The overall guiding principles for this framework architecture are the SOA design principles. They rely on modules that offer services through standard communication protocols between each other, while maintaining a layered architecture that organizes and orchestrates functionality among services. In this manner, our framework ensures both the sharing of spatial information and collaborative work upon it.

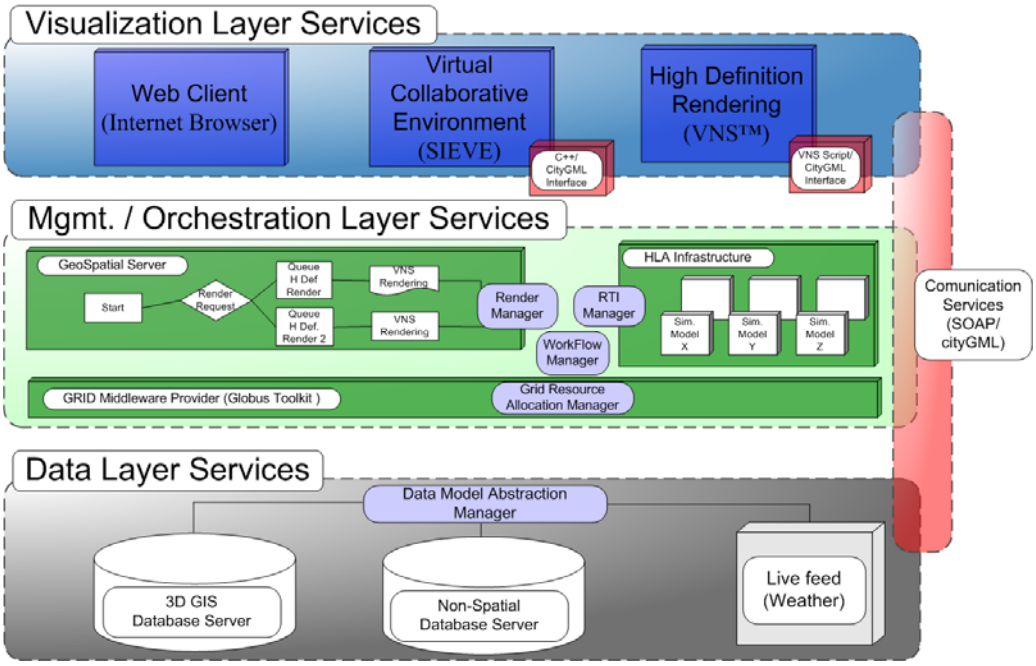

Figure 1. Architecture diagram with a modular SOA platform built upon aggregation of modules according to their services offered.

3.1. Visualization Layer Services

Composed of modules that offer the end visualization outcome, which depends on performance/ quality of detail required to visualize the same data provided by the next layer. This layer includes:

- *Web Client Services*: These are third party software that range from the common Internet browser to more sophisticated readers of web 2.0 content like mobile phones (e.g., Microsoft™ Virtual Earth, Google™ Maps mobile API).
- *Virtual Collaborative Environment Services*: Game Engine with real-time, immersive environment for virtual collaboration (e.g., SIEVE).
- *High Definition Rendering Services*: Third party tools for particular visualization needs (e.g., Visual Nature Studio ™ 3, 3D Nature, 2008).

3.2. Management/Orchestration Layer Services

This architecture depends on process services that link and sequence services according to existing and potentially new visualization requirements. These automated services further delegate specialized functions such as management, security, batch processing and similar features. This layer includes:

- *Workflow Manager*: Responsible for managing sequence of operations/processes to achieve a specific organizational goal (like rendering a sequence of images), orchestrating the interaction of both human and machine actors that may intervene in the process.
- *RTI Manager*: Responsible for managing the Real Time Infrastructure that implements HLA compliant API and rules. It enforces the standards that any engaging simulation should adhere to. Consequently, it will coordinate data feed/exchange and operations between simulation federates running on the framework's execution platform.
- *Render Manager*: Responsible for scheduling batch or simultaneous rendering tasks to available GPU machines (e.g., Rendering Farms).
- *Grid Middleware Manager*: Responsible for enabling grid technology, thus sharing resources across multiple machines, while masking this implementation to the other layers which only interact with a single "virtual" entity.

3.3. Data Layer Services

Data sources can be composited to feed spatial and non-spatial information requirements that the orchestration layer needs to fulfil its lifecycle, thus abstracting the need for a particular data source, whether this source is a GIS Database, a RSS live feed or other machine available sources such as anonymous ftp repositories.

3.4. Communication Services

Encapsulating CityGML information using Web Services protocols (Web Service Description Language - WSDL, Simple Object Access Protocol -SOAP, and Universal Description Discovery and Integration - UDDI), data is transferred from all layers through Wrappers/Interfaces that are implemented by standard contracts on each module.

As a proof-of-concept in leveraging on these collaborative software, we integrated our current platform of high definition rendering, using the commercial software VNS™ 3 (3D Nature, 2008), with the open source Geoserver (OGC 2006) and our Virtual Collaborative Environment (SIEVE). A typical flow of information through this architecture would be as follows (Figure 2):

Some stakeholders are navigating a SIEVE environment session [1]. They may want to obtain one or more high resolution images of the particular scenario they are currently discussing. Users' requests to render those views are dispatched asynchronously (without obstructing the natural workflow of the collaborative session) through the wrapper interface of SIEVE [2], as SOAP messages to the Orchestration layer. The WorkFlow Manager acknowledges this request and start a new process [3a], gathering available/optional data from other sources (for instance, the weather time stamp from the internet [1.3b], but it could be any HLA simulation layer output as well), also delegating best allocation of resources to another process service, in this case the Render Manager [4]. The requests are processed according to VNS rendering machines' availability, including ancillary info linking appropriate resources of view locations and bearings, Level of Detail, shape files, 3d Objects, etc. [5]. The Render manager then queues and/or dispatches render requests to the High Definition wrapper interface [6]. When the render process is completed [7], the Render manager will notify the Workflow Manager [8], which will in turn publish corresponding links on the Geoserver web page [9], also notifying users of the outcome of the task through email, RSS, etc. [10].

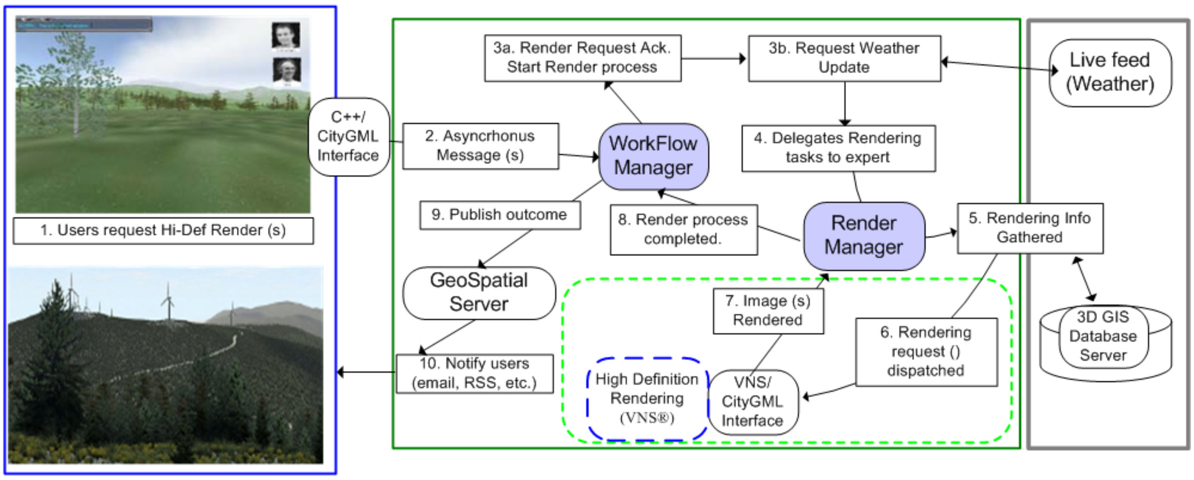

Figure 2. Framework's workflow example of a high-definition rendering request.

4. DISCUSSION

This framework orchestrates the use of heterogeneous software tools which collectively support distributed spatial analysis and complex environmental decision-making processes. It is also extensible by adhering to service contracts that are defined collectively by regulatory organization such as OGC and IEEE. For instance, due to the modularity of the architecture, it would be possible to add another high definition render of choice, or extending modular Render Farm's capabilities, without considerable overhead or software refactoring.

Equally important, we aim to reflect on the technical plane the ideal of managing environmental resources with a broad perspective, one that takes into account all, and often conflicting, interests in different spatial and temporal scales. At the same time, this framework attempts to mirror the following perception: systems dealing with complex environmental concerns should not be dependant on a specific software or economic/scientific paradigm (Pahl-Wostl, 2007). Moreover, when this loose-coupling architecture is enabled, it permits a better uncertainty analysis, where a holistic notion of the system can be obtained (Warren et al., 2008). This perception also offers the possibility of taking options against a particular setting caused by other decisions from the wider community involved. Likewise, if environmental-process-model outputs are visualized in this cohesive manner, complex data layers can be perceived or analysed simultaneously. Following this line of thought, visualization could allow more realistic complex decision environments, where different types of people and interests can be modelled, its decision visualized, more easily understood, and readjusted accordingly (Bishop, 2005).

5. CONCLUSION

While this particular research attempts to lay the foundation for a framework to orchestrate heterogeneous tools using state of the art collaboration technology, the final goal lies further afield. Computational simulation in a collaborative environment promotes the cross-fertilization of ideas between diverse fields of knowledge, and sometimes even raises questions that traditional empirical studies may not be able to explicitly answer in a precise manner. A process directly linked to the success of the envisioned CVE is the following: if scientists and the community both share and interact with models for agricultural and natural resource management, and do so through a highly collaborative environment, the understanding of large amounts of complex information will be enhanced. From the insight that the ultimate answer for a sustainable future lies in a more collaborative world, if for one part the power of IT is harnessed, and for the other we can achieve a proper understanding of the human context within which this system must evolve, Australian public and private agencies concerned with the environment will benefit. Proper user-feedback and reengineering can produce quality software, including grid services, collaboration tools, and real-time visualization systems. These latter systems can be dovetailed to foster the visualization of better environmental solutions, leveraging the human decision-making process to envision a sustainable future.

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