INTEGRATING VR IN AN ENGINEERING COLLABORATIVE PROBLEM SOLVING ENVIRONMENT

Ismael H. F. dos Santos
Petrobras Research Center, Ilha do Fundão, Rio de Janeiro, Brazil
ismaelh@petrobras.com.br

Alberto Raposo, Marcelo Gattass
Department of Informatics, PUC-Rio, Rio de Janeiro, Brazil
{abraposo, mgattass}@inf.puc-rio.br

Keywords: Collaborative problem solving environments, Scientific workflow management system, Virtual environments.

Abstract: We present an environment for executing engineering simulations and visualizing results in a Virtual Environment. The work is motivated by the necessity of finding effective solutions for collaboration of team workers during the execution of complex Petroleum Engineering projects. By means of a Scientific Workflow Management System users are able to orchestrate the execution of different simulations as workflow tasks that can be arranged in many ways according to project requirements. Within a workflow, as its last step, the most interesting cases can be selected for visualization in a distributed collaborative session.

1 INTRODUCTION

The present work is motivated by the necessity of finding effective solutions for collaboration of team workers during the execution of large and complex Petroleum Engineering (PE) projects. Those projects usually require the execution of a large number of engineering simulations, encapsulated as engineering services, combined in different orders and rearranged in different subsets according to each project requirement. By means of a Scientific Workflow Management System users are able to orchestrate the execution of engineering simulations as workflow tasks that can be arranged in many different ways. Within a workflow, as its last step, the most interesting cases can also be selected for visualization in an immersive distributed collaborative session.

A Problem Solving Environment (PSE) is a specialized software system that provides all the computational facilities needed to solve a target class of problems. These features include advanced solution methods, automatic and semiautomatic selection of solution methods, and ways to easily incorporate novel solution methods. Moreover, PSEs use the language of the target class of problems, so users can run them without specialized knowledge of the underlying computer hardware and software technology (Houstis et al., 1997).

In this work, the presented solution, called Collaborative Engineering Environment (CEE) is intended to create a useful collaborative PSE through the composition of different tools for distributed group work:

1. Virtual Reality Visualization tool (VRV) – EnViron, a custom VRV adapted for collaborative visualization of PE simulations in an immersive or desktop Virtual Environment;
2. Scientific Workflow Management System (ScWfMS) – an open-source BPEL-workflow implementation used as a process-oriented tool to control the execution of PE projects;
3. Videoconference System (VCS) – CSVTool, a custom VCS developed for supporting human communication, providing integrated audio and video channels, subject to defined control policies;

In the following sections we present some aspects of the developed CEE. In section 2 we present the main characteristics of PE projects discussing some problems addressed by CEE. Related works that inspired the development of the CEE are presented in section 3. In section 4, we describe the CEE architecture. A case study is presented in section 5 and conclusions in section 6 finish the paper.

2 PETROLEUM ENGINEERING PROJECTS

Usually PE projects involve not only geographically distributed teams but also teams of specialists in different areas using different software tools, both commercial and homemade. The interoperability of those tools is still an issue in the industry and is a mandatory requisite for any viable collaborative solution.

Due to their huge complexity, PE projects are divided into smaller interrelated subprojects where each one deals with an abstract representation of the others. Because decisions are interdependent the necessity for collaboration is a key issue in this area. Each team activity or new decision can affect other activities. For example, during the design of a floating production unit (FPSO - floating production storage and offloading) changing the position of large and heavy equipment in the process plant can compromise the stability of the production unit. In some cases there is also an intrinsic coupling among the solutions of the different subprojects, which requires a lot of interactions and discussions among the teams involved. This is the case of the mooring system and of the production risers' subsystems. On one hand if the mooring system allows great fluctuations of the production unit, it can simply damage the production risers; on the other hand the presence of the risers itself helps to weaken the movements of the production unit which contributes positively to the equilibrium of the system. In order to achieve collaboration and interoperability between those subprojects a software-based interface is required.

Another challenge present in PE projects is related to the visualization of large engineering simulations. During the conceptual design phase of an industrial plant, several simulations should be applied to assess the robustness and feasibility of the project. Some of these simulations may require huge computational efforts to be processed, even for powerful computer clusters. Visualization should be as precise as possible in order to provide the user a full understanding of the results of the simulation.

In principle, PSEs can solve simple or complex problems, support both rapid prototyping and detailed analysis, and can be used both in introductory education and at the frontiers of science and engineering. For PE projects a PSE should focus on the development and integration of scientific tools and technologies coupled with collaborative environments to support the modeling and simulation of complex scientific and engineering problems constituting a useful CPSE (Collaborative Problem Solving Environment). These capabilities enable engineers to easily setup computations in an integrated environment that supports the storage, retrieval, and analysis of the rapidly growing volumes of data produced by computational studies.

In conclusion, according to the above challenges presented for PE projects, the proposed CEE is conceived as a useful CPSE for better controlling and executing specialized engineering projects through the use of its collaboration and visualization capabilities.

3 RELATED WORK

Problem Solving Environments have been built for a number of scientific domains. For example, (Parker et al., 1998) describe SCIRun, a PSE that allows users to interactively compose, execute, and control a large-scale computer simulation by visually "steering" a dataflow network model. SCIRun supports parallel computing and output visualization, but originally has no mechanisms for experiment managing and archiving, optimization, real-time collaboration, or modifying the simulation models themselves.

Vistrails (Callahan et al., 2006) is a visualization management system that provides a Scientific Workflow infrastructure which can be combined with existing visualization systems and libraries. A key feature that sets Vistrails apart from previous Visualization Systems as well as Scientific Workflow Systems is the support for data exploration. It separates the notion of dataflow specification from its instances. A dataflow instance consists of a sequence of operations used to generate a specific visualization. Vistrails approach inspired our CEE strategy but some of the differences of the CEE are the use of a BPEL (Business Process Execution Language) ScWfMS and the focus on immersive and realistic visualization.

In the Geology field, (Kreylos et al., 2006) presented an approach for turning immersive visualization software into a scientific tool. They created immersive visualization software, with measurement and analysis tools that allow scientists to use their real-word skills and methods inside a VE. They emphasized that VR visualization alone is not sufficient to enable an effective work environment. This observation has also motivated us to create some additional tools for our VR visualization subsystem of the CEE.

The effective integration of "smart" graphical user interfaces, with some advisory support, Scientific Visualization, VR techniques, Engineering Analysis and Modeling Tools aid in the automation of modeling analysis and data management for large and complex PE projects. To enhance engineers ability to share information and resources with colleagues at remote locations, collaborative and real-time technologies integrated into a CPSE provide a unified approach to the scientific and engineering discovery and analysis process.

A combination of a CPSE and VR visualization, which is not addressed by the aforementioned visualization systems, constitutes a strategic enabler for a successful data exploration and knowledge dissemination among workers in engineering enterprises. VR visualization technologies enhance the content knowledge within the engineering disciplines. In conjunction with collaboration both provide valuable insights for better Decision Support with risk mitigation. (Dodd, 2004) has mentioned that the next big management push is the empowerment of interdisciplinary teams with collaboration tools that include remote and immersive visualization on the desktop. Sharing the same opinion as Dodd we emphasize that the combination of collaborative tools and VR visualization constitutes a powerful component to our CEE architecture.

4 CEE MODEL

The developed CEE, as a specialized CPSE, allows users to collaboratively solve their problems through the use of predefined workflows or assembling new ones. Each workflow comprises a sequence of simulations that usually ends with a collaborative visualization session supported by the VR Visualization tool. Based on a thoroughly analysis of the domain of PE projects used as our prototype scenario, we defined a set of collaborative and visualization features for dealing with the difficulties described above. In what follows we present the major CEE functionalities towards this direction.

4.1 Collaborative Work

The support for collaborative work is provided by the use of a Scientific Workflow Management System (ScWfMS), Videoconference System and a collaborative support for creating annotations about the engineering artifacts used in the projects.

An annotation, in our context, is any textual information that users want to add to their projects to enrich the content or just for documentation; it can have a private or public (shared) scope. Annotations can be associated to any engineering artifact manipulated in a PE during a collaborative visualization session that usually happens at the end of execution of any sequence of engineering simulations, as the last step of typical engineering workflow. It could, for example, be a kind of instructional information denoting a sequence of operations that should be undertaken during a maintenance intervention in a production unit, or some information used to highlight interesting or anomalous events observed on the results of the simulations.

4.2 CEE Videoconference System

Audio and video communications are fundamental components of collaborative systems (Isaacs and Tang, 1994). Audio is an essential channel for supporting synchronous work, and video is important to provide a sense of co-presence facilitating negotiation tasks.

Videoconferencing Systems contain no knowledge of the work processes, and therefore are not “organizationally aware”. These systems are best suited for unstructured group activities once that audiovisual connectivity and shared documents enable flexible group processes. The drawback is that coordination tasks are left to the conference participants.

We have developed a multiplatform videoconferencing tool, CSVTool (Pozzer et al., 2003). The use of a custom tool allows a tight integration of this service into the CEE, with no duplication of session-management functionalities, and the direct control of audio and video streams according to the coordination policies defined.

4.3 CEE Visualization Tool

EnViron (ENvironment for VIRtual Objects Navigation) (Raposo et al., 2006) is a tool developed to facilitate the use of CAD models in VR applications. It is a system composed of a 3D environment for real time model visualization, and exportation plugins, which import model data from other applications, allowing EnViron to visualize and interact with different kinds of 3D data.

The applicability of VR techniques for 3D geometric CAD models has been restricted to design review, virtual prototyping and marketing purposes, mainly in the automotive and aircraft industries. More recently, 3D CAD models are starting to show their potential in VR applications for diverse purposes, such as ergonomic studies, safety training for Health, Safety Environments (HSE), and visualization of physical simulations, project documentation and real-time operational data.

EnViron is integrated into CEE offering resources for real-time 3D visualization and interaction in CAD models with enough realism and performance to be used for collaborative virtual prototyping, design review, change management systems, training, and visualization of engineering simulations among other activities.

4.4 CEE Scientific Workflow

In recent years, several industries have improved their operations through Workflow Management Systems (WfMS) – improvement of data management and better coordination of activities through specific Business and Scientific and Engineering Process. However, there are remarkable differences between Business (BWfMS) and Scientific Workflows (ScWfMS). (Weske et al., 1998) identified that in a scientific environment scientists will typically specify their workflows themselves, while in a business environment; a system administrator is commonly responsible for this task. Another characteristic of ScWfMS pointed in their work is the need to trace workflow executions. An engineer may need to reuse a workflow in order to reproduce results. The operations a user performs on a given data must be recorded in order to provide engineers with the benefits of successful and unsuccessful workflows.

Scientific workflows often begin as research workflows and end up as production workflows. Early in the lifecycle, they require considerable human intervention and collaboration; later they begin to be executed increasingly automatically. Thus in the production mode, there is typically less room for collaboration at the scientific level and the computations are more long-lived. During the research phase, scientific workflows need to be enacted and animated (fake enactment) far more intensively than business workflows. In this phase, which is more extensive than the corresponding phase for business workflows, the emphasis is on execution with a view to design, and thus naturally includes iterative execution. The corresponding activity can be viewed as a “Business Process Engineering” (BPE). For this reason, the approaches for constructing, managing, and coordinating process models are useful also in scientific settings. In this way, Scientific Workflows are to PSEs what Business Workflows are to Enterprise Integration.

4.5 CEE Implementation

Service-Oriented Architecture (SOA) is a style of architecting software systems by packaging functionalities as services that can be invoked by any service requester (Ort, 2005). An SOA typically implies a loose coupling between modules. Wrapping a well-defined service invocation interface around a functional module hides details of the module implementation from other service requesters. This enables software reuse and also means that changes to a module’s implementation are localized and do not affect other modules as long as the service interface is unchanged.

The adoption of an SOA for CEE produced a reduction of technology development costs by leveraging functions already built into legacy systems. SOA architectures are becoming a popular and useful means of leveraging internet technologies to improve business processes in the oil & gas industry nowadays.

An Enterprise Service Bus (ESB) is a pattern of middleware that unifies and connects services, applications and resources within an enterprise. ESB is a platform built on the principles of SOA and other open standards to help applications integrate seamlessly. Put another way, it is the framework within which the capabilities of a business' application are made available for reuse by other applications throughout the organization and beyond. The ESB is not a new software product, it's just a new way of looking at how to integrate applications, coordinate distributed resources and manipulate information. Unlike previous approaches for connecting distributed applications, such as RPC or distributed objects, the ESB pattern enables the connection of software running in parallel on different platforms, written in different languages and using different programming models.

Our proposed CEE has component-based architecture in order to facilitate the reuse of elements. The architecture of the CEE uses a BPEL ScWfMS as its kernel while the CSVTool, Environ and the other components are seamlessly accessed through the ESB according to the collaborative necessities of the teamworkers.

When the service-oriented approach is adopted for designing the CEE, every component, regardless of its functionality, resource requirements, language of implementation, etc., provides a well-defined service interface that can be used by any other component in the environment. The service

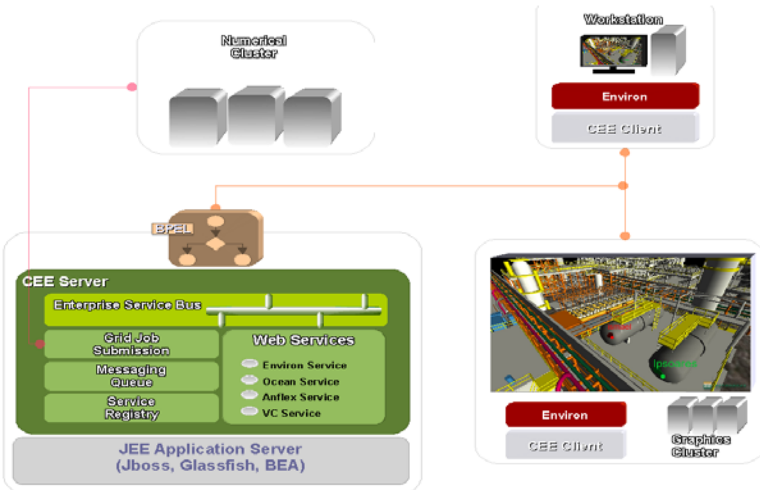

Figure 1: CEE architecture.

abstraction provides a uniform way to mask a variety of underlying data sources (real-time production data, historical data, model parameters, reports, etc.) and functionalities (simulators, optimizers, sensors, actuators, etc.). A Workflow, actually, in our context, a Scientific Workflow, is composed by coupling service interfaces in the desired order. These workflows specifications are created through a graphical front end, workflow designer, and the actual service calls are generated automatically and have their execution controlled by the workflow engine.

CEE has a client server architecture, where the CEE-server is deployed in a JEE (Java Enterprise Edition) Application Server (AppServer) which allows better scalability and automatic transaction control. The CEE principal services resides in the AppServer where a Service Registry is used to record all available services existent in the CEE-clients, for example the CEE-VRV tool, Environ, should be available on a CEE-client machine for allowing the user to participate in an Environ Collaborative Session, controlled by the CEE Service Coordinator (Figure 1).

The Environ Collaborative Session is implemented with the help of a Java Messaging Service (JMS) infrastructure available in the AppServer, providing a communication channel between peers participating in the Session. The channels are implemented as JMS topics (global channels) and queues, individual channels for each CEE-client (Figure 2). The Environ collaboration session is controlled by the CEE service coordinator and by each EvironProxy started on demand on a CEE-client machine by the Environ Service, which is a service demo registered at the Service Registry in CEE-server signaling the availability of Environ in the CEE-client.

5 DESIGN REVIEW WORKFLOW

Design review is the process of checking the correctness and consistency of an engineering project, and making the necessary corrections to it. CEE is very helpful in this process, for instance to assess the safeness of different emergency escape pathways in case of an emergency in the plant.

The Design Review workflow is a very simplified version of the previously workflow, where BPEL engine reads user input parameters and invokes CEE Service Coordinator to create an Environ Collaborative Session for users to collaborate, manipulating engineering artifacts and creating annotations in the model accordingly.

Object manipulation is an important resource in design review. The ability of moving, rotating and scaling objects is important for various purposes such as joining different models in a scene, viewing hidden portions of the model, planning the placement of a new piece of equipment on a plant, and simulating a maintenance or intervention operation in a process plant are also valuable tools.

As an example, the maintenance plan can be enriched with a detailed sequence of operations with annotations carefully chosen to be presented as an animation for the maintenance engineers during the operation (Figure 3). Moreover, integration with a database is useful to allow the user to create annotations on the model emphasizing critical parts. It is also possible to show comments attached to

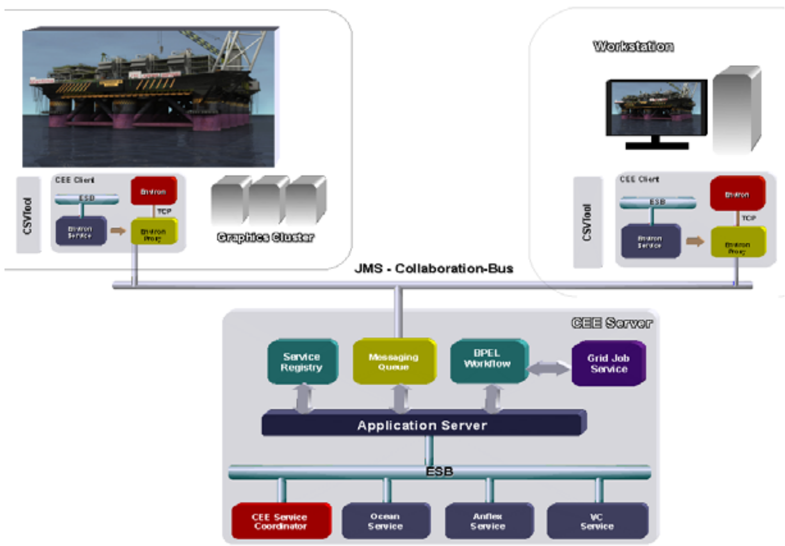

Figure 2: CEE JMS messaging architecture.

objects, which can be used, for example, as recommendations for project management.

Figure 3: Maintenance plan with annotations.

6 CONCLUSIONS

This paper presented an SOA of the CEE that we have developed. CEE is still in its infancy but is proving to be an effective Collaborative Problem Solving environment, allowing users to mitigate their problems during the execution of large and complex PE projects. Currently we are building more tools to improve the effectiveness of the use of VR technology by the team workers. Although this work is focused on a solution for Petroleum Engineering projects, we believe that the proposed CEE could also be used in other areas as well.

ACKNOWLEDGEMENTS

Alberto Raposo is partially sponsored by CNPq, project number 472967/2007-0.

REFERENCES

Callahan S. P., Freire J., et al., 2006. VisTrails: Visualization meets Data Management, *ACM SIGMOD International Conference on Management of Data*, 745-747.

Dodd, E. J., 2004. *Visualization and Collaboration for the On Demand Upstream Petroleum Enterprise*. IBM, Toronto, CA.

Houstis, E. N. Gallopoulos, et al., 1997. Problem-Solving Environments for Computational Science. *IEEE Comput. Science and Engineering*, 4, 3, 18-21.

Isaacs, E. A., Tang, J. C., 1994. What Video Can and Cannot Do for Collaboration: A Case Study. *Multimedia Systems*, 2, 63-73.

Kreylos, O., Bernardin, T. et al., 2006. Enabling Scientific Workflows in Virtual Reality. *ACM SIGGRAPH Conf. Virtual-Reality Continuum and its Applications in Industry, VRCIA*, 155-162.

Ort, E., 2005. *SOA Architecture and Web Services: Concepts, Technologies, and Tools*. Sun Developer Network, http://java.sun.com/developer/technical Articles/ WebServices/soa2/

Parker, S. G., Miller, M. Hansen, C. , Johnson, C. , 1998. An integrated problem solving environment: The SCIRun computational steering system. *31st Hawaii Int. Conf. System Sciences (HICSS-31)*, 147-156.

Raposo, A. B., Corseuil, E. T. L., et al., 2006. Towards the Use of CAD Models in VR Applications. *ACM SIGGRAPH Conf. VR- Continuum and its Applications in Industry, VRCIA*, 67-74.

Weske, M., Vossen, G., Medeiros, C. B., Pires, F., 1998. *Workflow Management in Geoprocessing Apps. Tech. Report No.04-98-I*, Univ.Muenster, Germany.