A Collaborative Environment for Offshore Engineering Simulations

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Abstract. The main objective of this article is to find effective solutions for collaboration of team workers during the execution of Large Scale Engineering Projects (LSEP). The research is based on actual operational needs of Petrobras, a large Brazilian governmental oil & gas company. For this article we have focused on Offshore Engineering Projects as our case study. We have implemented a Service Oriented Architecture aimed to create a collaborative environment, called CEE (Collaborative Engineering Environment), for visualizing engineering simulations considering important requirements identified for LSEPs, such as collaboration, workflow coordination, and immersive visualization. CEE allows team workers to concentrate in the task of solving a problem using seamlessly the computational resources available, from the execution of engineering simulations on a Grid to the collaborative visualization of results in an immersive or desktop environment.

Keywords: Scientific Workflow Management Systems; Collaborative Problem Solving Environments; Virtual Environments; Offshore Engineering.

1 Introduction

Contemporary Science and Engineering projects, specially the large scale ones, have common characteristics. They are highly data intensive and computational demanding, highly multidisciplinary and often involve large distributed teams of researchers working together on a single complex problem. Each team of specialists has its own model of the engineering artifacts to be designed, simulated or analyzed, and may use several different models or partial models for different purposes during the project life cycle. Specialists communicate using a shared vocabulary, but not necessarily shared technical knowledge. They also proceed by successive refinement of the models, which are coordinated and updated together, and negotiating design decisions among themselves.

Due to their huge complexity, LSEP are commonly divided into smaller interrelated subprojects where each one has a complementary representation of the models. LSEP also involve the interaction of people where information and data are distributed and knowledge is shared at request. Moreover, LSEP demand lengthy and complex processes involving multidisciplinary teams, usually geographically distributed with multiple information and storage systems and also using distributed and heterogeneous resources. Therefore, an integrated computer-supported solution to LSEP must include support for human collaboration and distributed resource management.

The concept of Problem Solving Environment (PSE) promises to provide LSEP with integrated environments for problem solving specialized in the application domain, increasing team members' productivity allowing them to focus on the problem at hand rather than on general computational issues. A PSE is a specialized software system that provides all the computational facilities needed to solve a target class of problems [1]. PSEs allow users to define and modify problems, choose solution strategies, interact with and manage appropriate hardware and software resources, visualize and analyze results, record and coordinate extended problem solving tasks.

Collaborative Problem Solving Environments (CPSE) focus on the development of a PSE coupled with collaborative environments to support the modeling and simulation of complex scientific and engineering problems. For LSEP, a CPSE should focus on the development and integration of scientific tools and technologies, coupled with visualization capabilities and collaborative environments to support the modeling and simulation of complex scientific and engineering problems in a collaborative way. Such 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.

Experience in dealing with LSEP design and analysis problems has indicated the critical needs for a CPSE with six distinguishing characteristics: interoperability facilities to integrate different applications; support for human collaboration; computing power for numerical simulations; visualization capabilities for 3D real-time rendering of massive models; transparency for the use of distributed resources; and advisory support to the user.

CEE (Collaborative Engineering Environment), our proposed solution, was conceived as a CPSE especially tailored for assisting the control and execution of shared engineering projects involving geographically distributed teams. It also allows an easy integration of different engineering applications providing team workers with means of information exchange, aiming to reduce the barriers imposed by applications with limited or no collaboration support.

In order to achieve its goals the CEE architecture is a composition of different CSCW technologies to create a useful collaborative engineering environment. CEE is composed of a Collaborative Visualization Environment based on a Virtual Reality Visualization tool [2] and a Videoconference System [3]; a Scientific Workflow Environment with a Grid Computing infrastructure support for executing large engineering simulations; and a Project Management Environment responsible for controlling the overall execution of the project and keeping track of all the information and different artifacts generated during the project entire life cycle.

The structure of the paper is a follows. Section 2 presents the related works that inspired the development of the CEE. The conceptual model of the CEE is presented in section 3 and the SOA Architecture in section 4. The application scenario of Offshore Engineering is presented in section 5 and conclusions follows in section 6.

2 Related Work

Dynamic data-driven approaches, such as the Data Driven Multiphysics Simulation Framework (DDMSF), are increasingly becoming more feasible because of the confluence of several technologies. First, advanced sensor technologies have improved the ability to capture data faster and at higher resolution. Second, Grid Computing infrastructure aims to dynamically and seamlessly link powerful and remote resources to support the execution of large scale and disparate processes characterizing a particular problem. Among all DDMSF components, the Discover Computational Collaboratory [4] strongly inspired our proposed solution. Its overall objective is to create a CPSE that enables geographically distributed scientists and engineers to collaboratively monitor, interact with, and control high performance applications in a truly pervasive manner, transforming high-performance simulations into modalities for research and instruction.

Paventhan et al. [5] proposed the creation of a Scientific Workflow for wind tunnel applications. They observed that scientific and engineering experiments often produce large volumes of data that should ideally be processed and visualized in near real-time. The difficulty to achieve this goal is that the overall turnaround time from data acquisition, data processing and visualization of results is frequently inhibited by factors such as manual data movement, system interoperability issues, manual resource discovery for job scheduling and disparate physical locality between the experiment and the scientist or engineer workstation. They argued that customized application specific workflows could reduce the time taken to accomplish a job by automating data flow driven activities, supplementing or replacing manual user-driven tasks.

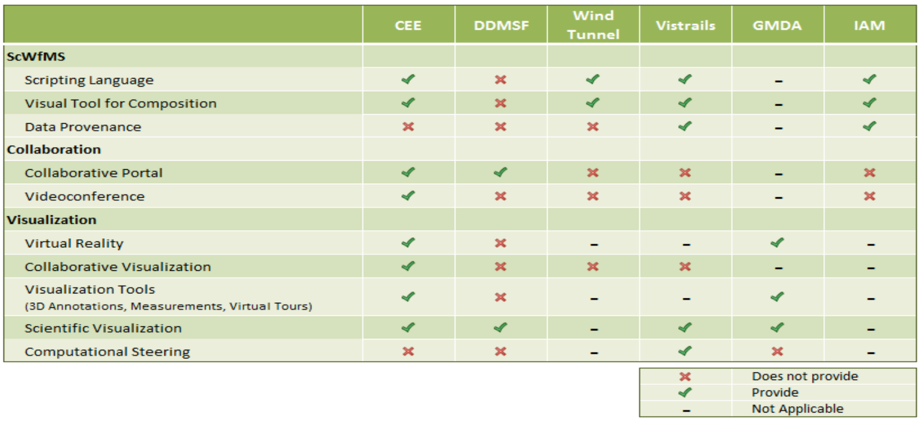
Vistrails [6] is a visualization management system that provides a Scientific Workflow infrastructure, which can be combined with existing visualization systems and libraries. A key feature that sets Vistrails apart from other Visualization Systems as well as Scientific Workflow Systems is the support 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. The Vistrails approach inspired our CEE strategy, but some of the differences of the CEE are the use of a BPEL (Business Process Execution Language) engine as our ScWfMS and the focus on immersive and realistic visualization.

Parker et al. [7] 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. Paraview [8] is a kind of PSE for visualization that allows the interactive creation and manipulation of complex visualizations. The success of SCIRun and Paraview demonstrates the importance of adding visualization to a PSE.

In the Geology field, Kreylos et al [9] presented an approach for turning immersive visualization software into scientific tool. They created immersive visualization measurement and analysis tools that allow scientists to use real word skills and methods inside Virtual Environments. They have also conducted some informal studies to determine the impact of using VR methods on some geosciences tasks such as Geological-Mapping and Displacement Analysis (GMDA). As shown by GMDA, the usage of a VR Visualization system to debug engineering simulations is a very powerful tool for LSEP. Although not being a quantitative study, due to the small numbers of participants, they observed that VR visualization enabled scientists to make more accurate observations in less time and with more confidence. This observation motivated us to include a VR Visualization system as an important component of the CEE architecture.

Service Oriented Architecture (SOA) [10] provides a platform for building application services with interesting characteristics such as: loose coupling, location transparency and protocol independence. An SOA application that influenced our research is the Integrated Asset Management framework (IAM). IAM provides to its users a front-end modeling environment for specifying and executing a variety of workflows from reservoir simulations to economic evaluation [11]. The IAM framework is intended to facilitate seamless interaction of diverse and independently developed applications that accomplish various sub-tasks in the overall workflow.

In Fig. 1 we present a comparison of the features provided by CEE and the features presented by the related solutions. It can be seen that CEE has a wider spectra addressing the most important requirements of LSEPs.



	CEE	DDMSF	Wind Tunnel	Vistrails	GMDA	IAM
ScWfMS						
Scripting Language	✓	✗	✓	✓	–	✓
Visual Tool for Composition	✓	✗	✓	✓	–	✓
Data Provenance	✗	✗	✗	✓	–	✓
Collaboration						
Collaborative Portal	✓	✓	✗	✗	–	✗
Videoconference	✓	✗	✗	✗	–	✗
Visualization						
Virtual Reality	✓	✗	–	–	✓	–
Collaborative Visualization	✓	✗	✗	✗	–	–
Visualization Tools (3D Annotations, Measurements, Virtual Tours)	✓	✗	–	–	✓	–
Scientific Visualization	✓	✓	–	✓	✓	–
Computational Steering	✗	✗	–	✓	✗	–

✗	Does not provide
✓	Provide
–	Not Applicable

Fig. 1. Feature comparisons between CEE and related solutions.

3 CEE Conceptual Model

CEE allows users to collaboratively solve their problems through the use of predefined scientific workflows or assembling new ones. Each workflow comprises a sequence of simulations, in the form of workflow tasks, usually finishing with a collaborative visualization task. This task is responsible to create a collaborative session supported by CEE. To achieve its goals CEE needs to be extensible, flexible and platform-independent, allowing a transparent flow of information among different teams, systems and their models. The challenges in building an effective CEE could be scrutinized in three domains.

Collaborative Visualization Environment – this domain encompasses different challenges from the areas of CSCW and VR. Regarding collaborative work, in this domain there is the necessity of providing effective human-to-human interaction and communication for solving conflicts and enhancing group productivity. Also there is the need of some support for coordinating the execution of tasks. Regarding virtual reality visualization, high performance and scalability are important aspects of virtual environment architectures intended to support execution of large shared virtual worlds over long periods of time. For this domain, we created the *Collaboration Manager Service* (Fig. 2), which is responsible for managing the user interaction with the CEE. The *Videoconference Service* and the *VR Visualization Service* work closely coupled with the *Collaboration Manager Service* to enable the creation of collaborative visualization sessions driven inside the CEE.

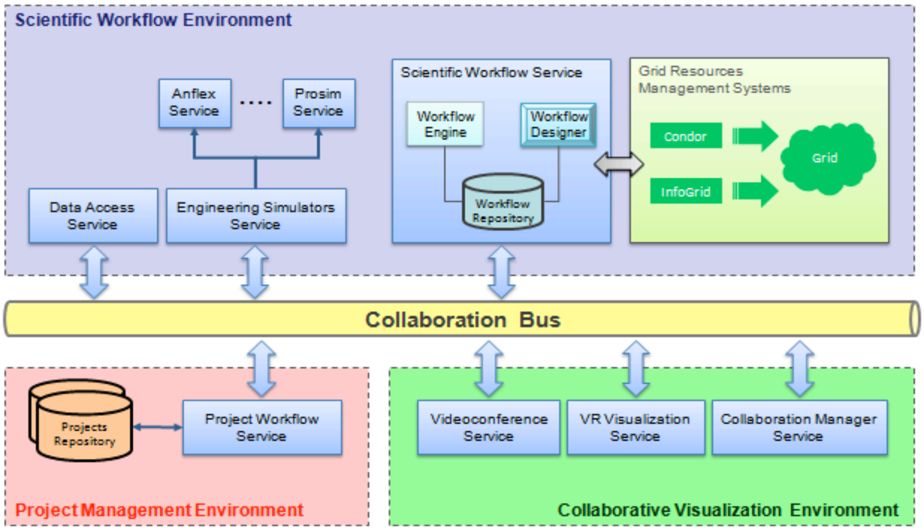


Fig. 2. CEE Conceptual Model.

Scientific Workflow Environment – this domain includes challenges related to the control of the execution of engineering simulations. Regarding interoperability and distributed execution, there is a myriad of software that specialists, potentially geographically distributed and using distributed resources, are forced to use in order to accomplish their tasks in a reasonable time. For this domain, we created the *Scientific Workflow Service* to help the users build engineering workflows and seamlessly execute them in a Grid Computing Infrastructure (GCI). More generally for *Distributed Execution*, we use the interoperability characteristics of the ScWfMS and the distributed execution support provided both by the GCI of the CEE and by the SOA backbone infrastructure. The *Engineering Simulations Service* provides a Webservices interface for remotely execute an engineering simulation program. In the Offshore Engineering, some of those simulators are, among others, Anflex [12] a Finite Element riser analysis software, and Prosim [13] a coupled analysis software for the design of floating production systems.

Project Management Environment - this domain points to the necessity of keeping track of all the documents and artifacts generated during project's life cycle. Multiple and different visions of the on-going project must be provided while users have different background and need different types of information to accomplish their duties. For this domain, the introduction of a *Project Management System* is a valuable resource, but is out of the scope of this article.

In the following sections we present the major CEE functionalities regarding visualization and collaboration.

3.1 Collaborative Visualization Environment

Collaborative systems should not only allow multiple users to interact with shared objects but also to communicate and to coordinate their actions. Collaboration may be seen as the combination of communication, coordination and cooperation [14]. Communication is related to the exchange of messages and information among people. Coordination is related to the management of people, their activities interdependencies and the used resources. Cooperation is the production of common artifacts taking place on a shared space through the operations available to the group.

The communication support is provided by a Video Conferencing System seamlessly integrated into CEE so that users can start a videoconference communication at anytime, while modeling their workflows or during visualization of results. There are different types of coordination and awareness support provided in CEE [15]. Workspace awareness in the virtual environment provides control of collaborative interaction and changing of the user location. Mutual awareness allows users see each other’s identity and observe each other’s actions. Group awareness facilitates the perception of groups of interest connecting people who need to collaborate more intensely. Informal communication enhances team awareness, even with no support to cooperation and with restricted coordination functionalities for controlling the simultaneous use of communication channels [16]. The cooperation occurs by the different types of model visualization available at the CEE, as well as data management infrastructure related to these models, real-time simulation and visualization of 3D models, possibilities of walkthroughs in the models, object interaction and manipulation, edition and planning and also access to organizational work history. Cooperation also occurs during the assembling of useful engineering workflows that will be used to orchestrate the execution of engineering applications.

The three services provided by Collaborative Visualization Environment (Fig. 2) are described below.

Video Conferencing System (VCS). The development of a custom videoconferencing system, CSVTool [3], allowed us to automatically establish videoconferencing channels among the participants of a conference, which greatly simplify and improve the communication. We can also tightly control the multiple audio and video streams among participants implementing different scenarios of usage. Besides the transmission of audio and video to multi-participants, with different operating systems platform, CSVTool provides extra interesting features for CEE: video stream from the image captured by the camera or the user screen, a textual chat tool and screen snapshots.

VR Visualization (VRV). Environ [2] is a tool designed to allow visualization of massive CAD models and engineering simulations in immersive environments (VR and Desktop). It is a system composed of a 3D environment for real-time visualization and plug-ins to import models from other applications, allowing users to view and interact with different types of 3D data, such as refineries, oil platforms, risers, pipelines and terrain data. In order to serve as the CEE's VRV, Environ was adapted to be transformed into a collaborative application with the support provided by the CEE collaborative infrastructure.

Collaboration Manager. The Collaboration Manager is responsible for managing the users' participation in a collaborative session and also integrates the resources of VRV and VCS.

There are three kinds of sessions available. In an *Informal* session each participant uses its individual telepointers all the time. There is no mediation of camera movements and the users are free to move around the scene propagating the camera movements to others. In this model, once a collaborative session is created, all users can use audio and video at any time. The only mediation mechanism supported is furnished by the social protocol available whenever a videoconference is started. In a *Classroom* session one specific participant, the instructor, acts as a coordinator of the session which means that all camera movements he performs are followed by other users, while the other participants have their telepointers disabled. The instructor also controls the audio and video channels of the participants, and he is also allowed to pass control of collaboration resources (telepointers, camera control, etc.) among participants. Users can also request the coordination role to the current coordinator who can accept or reject the request. The *Lecture* session has a speaker that acts as the coordinator of the session, with the same characteristics of a *Classroom* session. However, in this type of session there is no exchange control between the coordinator and participants and the participants can only receive audio and video stream from the coordinator. At any time a user can disconnect from the session, for doing some private work, and reconnect to session in later time, when its state is synchronized with the sate of the session, that is controlled by the *Collaboration Manager Service*.

Collaboration Bus (CBus). The CBus is a key component of the overall architecture and provides synchronous and asynchronous communication for the CEE components. The CBus is an infrastructure for communication based on the JMS Service Provider, the Message Oriented Middleware (MOM) used for giving the public/subscribe and point-to-point paradigms, and the Enterprise Service Bus (ESB). The integration of the VRV and the VCS with the other components is done in a seamless way through the Collaboration Bus, in a way that the user always interacts with the same interface independent of the application he/she is currently using. This is a very important aspect of the solution to keep the user conscious of what he/she is doing and what should be the next steps of the current task being executed.

3.2 Scientific Workflow Environment

In recent years, several industries have improved their operations through WfMS, improving data management and having a better coordination of activities through specific Business and Scientific Process. However, there are remarkable differences between Business (BWfs) and Scientific Workflows (ScWfs). In WASA project [17] the authors 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 ScWfs mentioned 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 describe series of structured activities and computations that arise in scientific problem-solving. In many science and engineering areas, the use of computation is not only heavily demanding, but also complex and structured with intricate dependencies. A Scientific Workflow is composed by coupling service interfaces in the desired order, created through a graphical or textual front end and the actual service calls are generated automatically and have their execution controlled by the workflow engine.

All the consistency, adequacy and compatibility of the shared data among its users should be done by the kernel of the CEE, in order to reduce non useful iterations during the project's life cycle. The ability of reusing partial workflows, which were previously stored in the system with some guidelines, provides an optimized usage of the available computational resources and also a better control of the costs and time scheduling.

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 "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 Problem Solving Environments what Business Workflows are to Enterprise Integration [18].

Scientific Workflow Management Systems (ScWfMS) are more data-flow oriented while Business Workflow Management Systems (BWfMS) are more control-flow oriented. BWfMS require the coordination of a number of small messages and document exchanges. In ScWfMS usually no documents undergo modifications. Instead, often a dataset is obtained via analysis and transformation of another dataset. BWfMS need complex control flow, but they are not data-intensive pipelines. On the other hand, ScWfMS must deal with the heterogeneity, complexity, volume, and physical distribution of scientific data. In addition to these data problems, ScWfMS often deal with legacy or third-party programs, which can also be heterogeneous, and possibly with no source code available.

In a typical scenario, data is usually passed from one program to another in order to complete several steps of the simulation. Once in the CEE, the sequence of operations to perform an engineering simulation are modeled as scientific workflows, there is an interoperability problem, since in most of the cases, data conversion steps are needed every time a different program needs to be run over the data. To solve the data interoperability problem, allowing applications to share engineering data in the context of such scientific workflows, a unified data format called GXML have been defined and developed [19].

4 CEE SOA Architecture

Service Oriented Architecture (SOA) is an architecture that allows independence between service providers and consumers. Enterprise Service Bus (ESB) represents the next generation of integration middleware, which establishes an enterprise-class messaging bus that combines a messaging infrastructure with message transformation and content-based routing in a layer of integration between service consumers and providers. The use of an ESB in the CEE architecture allows a seamlessly integration of distributed applications modeled as SOA services. For each external engineering application that will be invoked by the Scientific Workflow during the execution of a user job, we built a service interface (*Engineering Simulation Service*) that allows the application to be called from inside the workflow or any other application connected to the ESB. We distinguish three main layers in the overall architecture (Fig. 3).

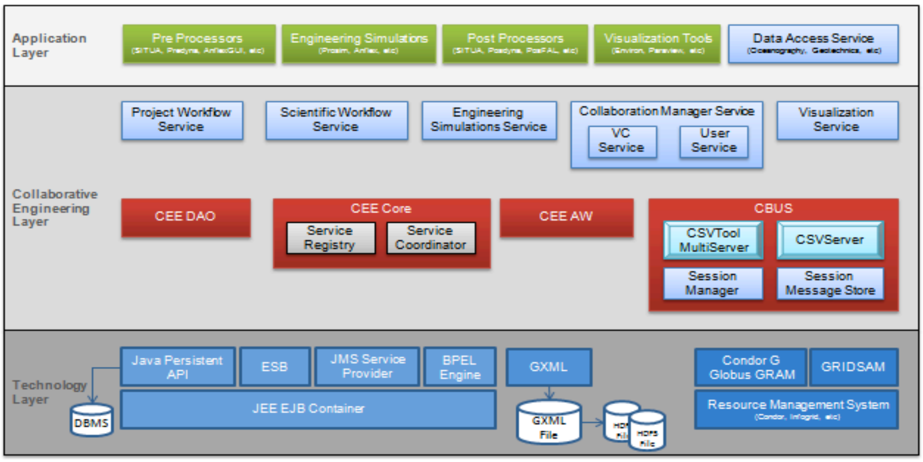


Fig. 3. CEE Architecture Layers.

Technology Layer. CEE requires a solid infrastructure to provide security, persistence, transactions support, scalability and performance. We have chosen the JEE (Java Enterprise Edition) standard as the technology infrastructure. The JEE middleware is responsible for the basic infrastructure such as security, performance, server federation, database persistence among others. As a Message Oriented Middleware, we have used ActiveMQ, an open source Java Messaging Service Provider. The overall architecture uses pervasively XML for data interchange among the Engineering Simulations, Pre and Post Processors and the VR Visualization Tool (Environ).

The Business Process Execution Language (BPEL) provides a standard-based way of orchestrating a business process composed of services [20]. As an execution language, BPEL defines how to represent the activities in a business process, along with flow control logic, data, message correlation, exception handling, and more. This capability is important for having a flexible environment for the execution of Scientific Workflows; therefore we chose the BPEL Engine as our Scientific Workflow.

For the Grid subsystem we have chosen Condor [21] and GridSAM [22]. GridSAM is a Grid Job Submission and Monitoring WebService for submitting and monitoring jobs managed by a variety of Distributed Resource Managers. GridSAM implements the Job Submission Description Language (JSDL) defined by the Global Grid Forum (GGF) [23]. Using GridSAM to execute jobs on a Grid (in our case, Condor) gives us transparency of the underlying Grid scheduler. Scientists only need to define the JSDL for their jobs once and not worry about which scheduler is used now or at any point in the future.

Collaborative Engineering Layer. This layer is the most important part of the overall system, and has been designed taking into account the CEE main components. The system is divided into several modules. CEE Core is composed by a collection of collaboration tools, providing services like shared spaces, access control, floor management, and integration for both synchronous and asynchronous communication through the use of a Collaboration Bus (CBUS). CBUS is an infrastructure for communication based on the Java Message Service (JMS) Provider and the Enterprise Service Bus (ESB) available on the technology layer.

The CEE Awareness Service (AWS) provides appropriate actuators for events received from the CBUS. It is responsible for signaling distributed events to the users participating in a collaborative session. In one side all components trigger events to this distributed bus, and in the other side awareness components listen to the bus for information about what is happening in the system. For example, when users leave a collaborative session or when there is a change in its state from offline to online and vice-versa, *"update user"* events are triggered to the CBUS and the CEE Awareness mechanism send messages to *VRV Service* and *VC Service* notifying the event. By their turn, those services signal those events in their user interfaces making the user conscious of what have happened.

There are a lot of services in this layer providing collaboration support to CEE applications. The *VR Visualization Service* and the *Collaboration Manager Service* are the most important components. They use the *CEE Core, CEE AWS* and *CEE CBUS* components to create a collaborative visualization tool to allow the users to visualize the results of an engineering simulation in an immersive or desktop environment.

Application Layer. The engineering applications supported by the CEE are in the Application Layer. It can be generically divided in four different components: Pre and Post Processors, Engineering Simulators (Anflex [12], Prosim [13]), Data Access Services and VR Visualization Tools.

5 CEE Application Scenario: Offshore Engineering

This section describes the Collaborative Riser Analysis Workflow project, an Offshore Engineering scenario where we applied the CEE.

Offshore Engineering projects share all the typical characteristics of LSEP already mentioned. Due to their huge complexity, these projects are divided into smaller interrelated subprojects where each one deals with an abstract representation of the others. Because decisions are interdependent, collaboration is a key point in this area. Each team activity or new decision can affect other activities. For example, during the design of a floating production and storage offloading, changing structural characteristics of the unit influences the mooring system, risers and can compromise the stability of the production unit. As a consequence, an inadequate mooring system design can possibly lead to an increase in the geologic and geotechnical risks.

Moreover, changes in environmental conditions, as the direction of wind and currents, as well as changes in the height and frequency of waves, induce movements in the mooring system, in the production risers and also in the ship, which generates second order movements that propagates to the whole system backwards. All those movements should be carefully analyzed to guarantee compatibility with the structural equilibrium of the production unit and the recommended operational conditions of the production risers.

To certificate the operation of the risers for their entire life cycle (30 years or so), simulations of the stress applied to the riser system are conducted based on meteo-oceanographic data about wind, tide and water currents. In order to avoid operational problems, simulations are made under extreme environment conditions to test against stress resistance. In our case we have used a riser analysis software called Anflex [12], an internally developed Finite-Element-based structural analysis package.

Fig. 4 shows the main components of the CEE interaction. Initially after the user is logged in the system, the CEE User Service on the client machine registers the user in the Collaboration Manager Service on the CEE server, all services that the user's machine is able to support (Environ Service, CSVTool Service, etc) is also registered on the CEE server Service Registry.

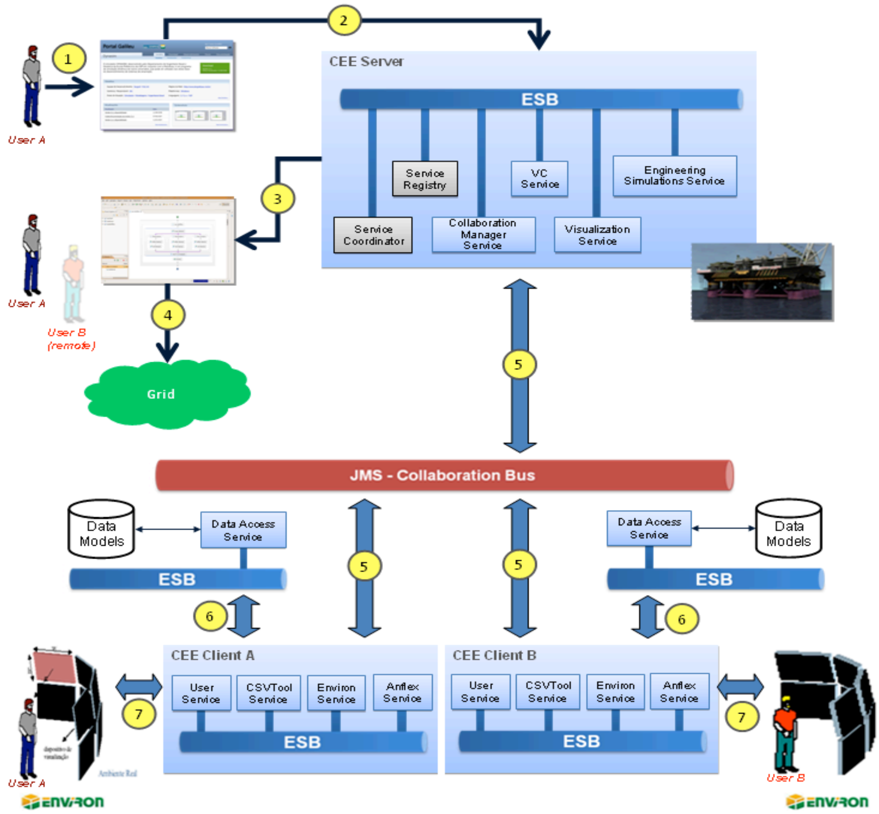


Fig. 4. Overview of the user interaction with CEE.

After registration of its services on the server, **User A** accesses the **CEE Portal** (**1**) through a web browser to request the execution services on the CEE server on his behalf (**2**). As an example, **User A** can model collaboratively with **User B** a *Concrete Scientific Workflow* (**3**). When the model is assembled and all input parameters of the concrete workflow are informed, **User A** can submit the workflow as a simulation on *a Grid* integrated into the CEE infrastructure (**4**). Examples of such simulations, in the context of Offshore Engineering, can be: design of a mooring system for a production unit or a fatigue analysis of a set of risers that bring the oil to an offshore production unit. Upon finishing its execution, the results of the concrete workflow may be visualized in a *Collaborative Visualization Session* with **User B** (**5**). During the collaborative visualization session, the users can require the execution of alternative simulations and have its results exhibited automatically (**6 and 7**).

BPEL Scientific Workflow - we have defined an Anflex-based riser analysis workflow controlled by the BPEL engine for automating the validation process and certification of riser analysis. The workflow integrates the execution of the following services: *Ocean Service, Anflex Service e Grid Job Service*. In Fig. 5 we show the final version of the Riser analysis workflow in a BPEL designer.

The workflow starts with an Anflex base-case, where the basic configuration of the experiment is defined such as a production unit, riser's geometry, soil bathymetry, etc. Anflex Service receives user input parameters from BPEL designer and is responsible for creating different loading cases according to the different meteo-oceanographic conditions provided by the OceanService. After that, BPEL instructs CEE GridJob Service to communicate with Condor to submit jobs for executing the Anflex simulation program on the available nodes of the Numerical Grid.

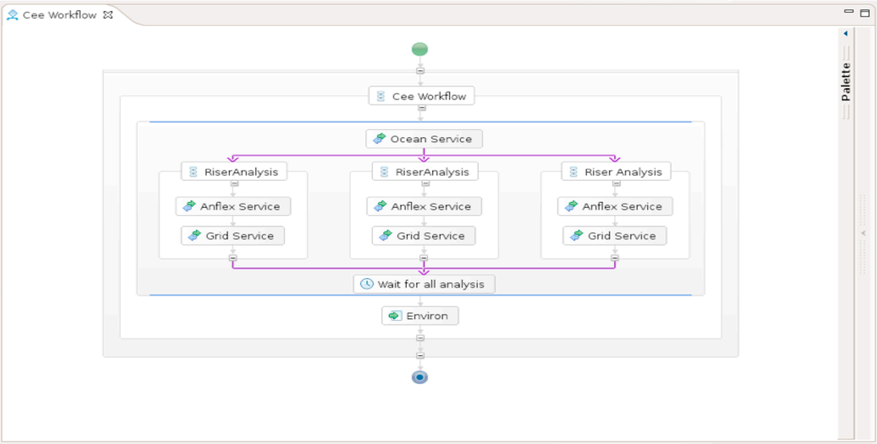


Fig. 5: Constructing the Riser Analysis workflow on BPEL Designer.

***Video Conferencing* –** Fig. 6 shows a collaborative visualization session with the presence of two users, represented by two distinct 3D-cursors, visualizing the simulation results in their desktop with the support of a Videoconference. The blue arrow represents the water currents that actuate over the riser, while the red arrow represents the direction of the movement of the riser.

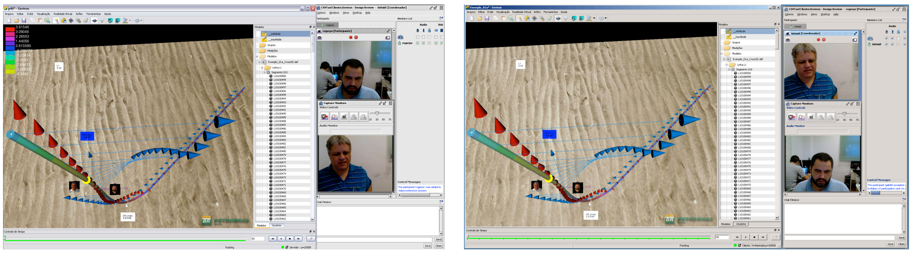
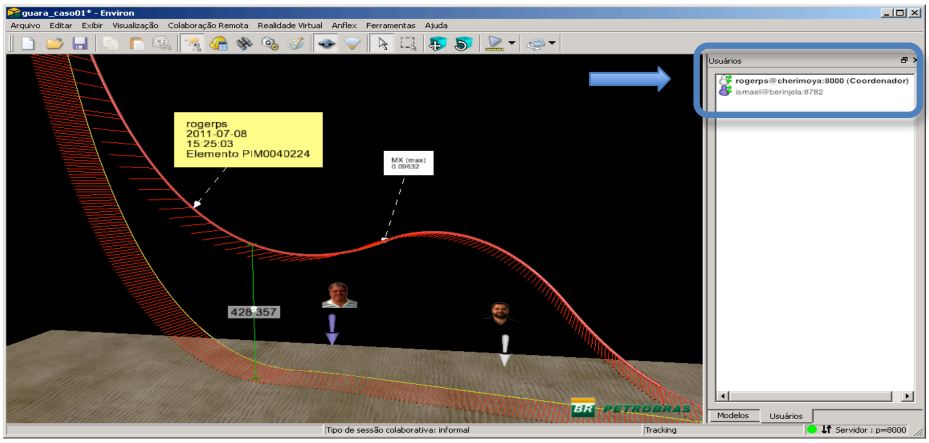


Fig. 6. Riser Analysis in CEE.

In the first screen the coordinator desktop is presented, while the second screen shows the participant. Both users receive a video stream from the other user, improving the efficiency of the collaboration due to the user awareness obtained by the use of the videoconferencing tool.

***3D Annotations and Measurements* -** Environ has special capabilities to show the extreme values and where are they located in the model, also allowing users to create

3D Annotations at any time. In Fig. 7 two annotations were created automatically by the Environ, showing the extreme points (maximum and minimum values) of a selected force or strength in the riser. The third 3D annotation was created by one of the users to register some important observation made in this collaborative session.



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Tipo de sessão colaborativa: informal

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Fig. 7. Two users in a CEE collaborative visualization session.

Among other resources, it is possible to playback the simulation, examine pipes, sea waves and ship movements, and track elements in the risers that are subjected to extreme conditions (e.g., high stress values). It is also possible to select any element in a riser and examine it carefully; especially those elements in places subjected to great stress, such as the joints connection and the Touch Down Point.

6 Conclusions

This article presented the conceptualization and implementation of a CPSE we devised for Offshore Engineering projects. As a proof of concept we have developed CEE, a collaborative environment to optimize the execution of Large Engineering Projects developed at Petrobras. Through the use of the CEE we have build an effective collaborative environment that allow users to mitigate problems that usually happen during the execution of large and complex engineering projects.

Upon the integration of VR technologies into the workflow of the team workers we expect to improve the use of VR in Offshore Engineering projects. It is clear that visualization resources improve the quality of engineering projects, but users do not want to spend their time preparing the content to be visualized in other system, like an immersive multi-projection environment. In this concern CEE is already showing its value, upon simplifying the daily job of the engineers, from running simulations on a Grid through visualizing its results on an immersive environment or on a desktop.

We believe that the main contribution of this research is the junction of approaches and technologies from different areas composing a CPSE suitable for LSEP (more specifically, Offshore Engineering projects), with distinguishable characteristics, when compared to similar systems. From Offshore Engineering point of view, the introduction of a Scientific Workflow in the project life cycle and the use of a CPSE are important contributions in the sense of providing a more structured way to solve the problems and the creation of tools more widely used.

From the VR and Visualization point of view, CEE approach treats them as first class tools, exploring their potential for facilitating information exchange and common understanding of complex problems. It was not possible to find any other approach complete as presented here in the academic literature or in any oil & gas company in the world.

The perspectives for the future is that many other organizations are going to start to use Scientific Workflows and this will become a common solution in high complex enterprises that have several areas that must be integrated and synchronized. Although this work is focused on a solution for Offshore Engineering projects, we believe that the proposed CEE could also be used in other areas.

We believe that CEE is a step towards a new frontier in CPSE, which is the use of a computation steering approach in tele-immersive CPSE. Computational steering is the practice of manually intervening with an otherwise autonomous computational process, to change its outcome. Abstractly, we can think of it as an API for interactive application control, furnishing interesting tools for data exploration visualization such as modify parameters while (long) running and "what if" explorations. The steering approach is a very valuable feature for any CPSE for science and engineering.

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