



**Ismael Humberto Ferreira dos Santos**

**A Collaborative Environment for Offshore Engineering  
Simulations based on Visualization and Workflow**

**TESE DE DOUTORADO**

Thesis presented to the Postgraduate Program in Informatics of the Departamento de Informática, PUC-Rio as partial fulfillment of the requirements for the degree of Doutor em Informática.

Advisor: Prof. Marcelo Gattass  
Co-advisor: Prof. Alberto Barbosa Raposo

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## Abstract

Santos, Ismael Humberto Ferreira dos; Gattass, Marcelo; Raposo, Alberto Barbosa. **A Collaborative Environment for Offshore Engineering Simulations based on Visualization and Workflow.** Rio de Janeiro, 2010. 145p. DSc. Thesis - Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

Deep-water production systems, including floating production units (platforms or ships) and all the equipments playing a part in the production process, are currently designed by means of complex computational modeling systems. Those systems involve the areas of structural calculus, meteo-oceanography (currents, waves and wind forces), hydrodynamics, risers (rigid or flexible steel pipes for carrying oil from the well in subsurface up to the production unit), mooring systems, submarine equipment, seabed foundations and Geologic/Geotechnical risk assessment. The project of a new production unit is a lengthy and expensive process, that can last many years and consume hundreds of million of dollars, depending on the complexity of the unit and how mature is the technology developed to make the project technically and economically feasible. Projects are conducted by diverse specialists, sometimes geographically distributed, yielding independent but highly interrelated artifacts and results. The need for collaboration is an inherent characteristic of deep-water floating production unit projects. The possibility to share information among users, control the execution of different modeling tools, visualize and manipulate virtual 3D models in immersive Virtual Reality (VR) environments is pushing the limits of teamwork activities in oil & gas industry especially in Offshore Engineering. The objective of this thesis is to establish the fundamental principles and address the main issues in the development of a Collaborative Environment for Engineering, named CEE (Collaborative Engineering Environment), in order to allow the collaborative visualization and interpretation of simulation results produced in engineering projects, which in general also involve different specialties. Due to the multi-disciplinary characteristic of those projects, collaborative visualization becomes a key component during the life cycle of engineering projects, especially those in Offshore Engineering, used in this work as case of study. We propose an

integrated collaborative environment to be used by project engineers' teams during the execution and control of complex engineering projects, as is the case of the projects of deep-water floating production units. The system requirements were carefully compiled aiming to enable an effective collaboration among the participants, creating a suitable environment for discussing, validating, interpreting and documenting the results of the simulations executed during the different phases of an engineering project. To further improve the interpretation capacity and a better comprehension of results the support for immersive 3D visualization is also available in the visualization tool, especially tailored for the Offshore Engineering domain. In order to meet these goals, we devise a Service-Oriented Architecture (SOA) for CEE. This architecture is composed of the integration of different technologies of Computer Supported Collaborative Work (CSCW), Virtual Reality (VR) and Grid Computing (GC). We use a Scientific Workflow Management System (ScWfMS), based on BPEL (Business Process Execution Language), a Grid-enabled software infrastructure for executing engineering simulations, and a Video Conferencing system (VCS) to furnish audio and video collaboration. For visualizing the results, a VR visualization tool, specialized for Offshore Engineering, ENVIRON, has also been developed in conjunction with the PUC-Rio/TecGraf team.

## **Keywords**

Computer-Supported Cooperative Work; Scientific Workflow Management Systems; Collaborative Problem Solving Environments; Collaborative Visualization; Collaborative Virtual Environments; Offshore Engineering; Oil & Gas.

## Resumo

Santos, Ismael Humberto Ferreira dos; Gattass, Marcelo; Raposo, Alberto Barbosa. **Um Ambiente Colaborativo para Simulações em Engenharia Offshore baseado em Visualização e Workflow.** Rio de Janeiro, 2010. 145p. Tese de Doutorado - Departamento de Informática, Pontifícia Universidade Católica do Rio de Janeiro.

Os sistemas de produção de petróleo em águas profundas, incluindo as unidades flutuantes de produção (plataformas ou navios) e todos os equipamentos que participam da produção são atualmente projetados por complexos sistemas de modelagem computacional. Tais sistemas envolvem as áreas de cálculo estrutural, meteo-oceanografia (forças de correntes, ondas e ventos), hidrodinâmica, risers (tubos de aço rígidos ou flexíveis para levar o óleo do poço em sub-superfície até a unidade de produção), sistemas de ancoragem, equipamentos submarinos, fundações e avaliação de risco geológico-geotécnico. O projeto de uma nova unidade de produção é um processo longo e custoso, podendo durar anos e consumir centenas de milhões de dólares, dependendo da complexidade da unidade e da maturidade da tecnologia desenvolvida para tornar o projeto econômica e tecnicamente viável. Os projetos são conduzidos por diversos especialistas, por vezes geograficamente dispersos, gerando artefatos e resultados independentes, porém altamente inter-relacionados. A necessidade de colaboração é uma característica inerente aos projetos de unidades flutuantes de produção para águas profundas. A possibilidade de compartilhar informações entre usuários, controlar a execução de diferentes ferramentas de modelagem, visualizar e manipular modelos 3D virtuais em ambientes imersivos de Realidade Virtual vem empurrando os limites das atividades dos times na indústria do petróleo especialmente em Engenharia de Petróleo. O objetivo desta tese é o de fundamentar os princípios e equacionar os principais problemas para o desenvolvimento de um Ambiente Colaborativo para Engenharia, denominado CEE (Collaborative Engineering Environment), de forma a permitir a visualização colaborativa e interpretação dos resultados de simulações criadas nos projetos de engenharia, que em geral envolvem também



diferentes especialidades. Devido à característica multidisciplinar dos projetos, a visualização colaborativa torna-se um componente de fundamental importância durante o ciclo de vida de projetos de engenharia, especialmente os da área de Engenharia Offshore, utilizada neste trabalho como caso de estudo. Propomos um ambiente integrado para visualização colaborativa a ser usado pelas equipes de engenheiros projetistas durante a execução e controle de projetos de engenharia complexos como é o caso dos projetos de unidades flutuantes de produção para águas profundas. Os requisitos do sistema foram levantados com o objetivo de permitir uma colaboração efetiva entre os participantes, criando um ambiente propício para discussão, validação, interpretação e documentação dos resultados das simulações executadas durante as fases de um projeto de engenharia. Para aumentar ainda mais a capacidade de interpretação e uma melhor compreensão dos resultados o suporte a visualização em ambientes imersivos 3D também está disponibilizado na ferramenta de visualização utilizada, que foi especialmente adaptada para a área de Engenharia Offshore.

Para atingir estes objetivos, propomos uma Arquitetura Orientada a Serviços para o CEE. Esta arquitetura é composta pela integração de diferentes tecnologias de Trabalho Colaborativo Auxiliado por Computador (CSCW), Realidade Virtual e Computação em Grade. Utiliza-se um sistema de Gerência de Workflows de Experimentos Científicos (ScWfMS), baseado em BPEL (Business Process Execution Language), para execução de simulações de engenharia em uma infra-estrutura de computação em grade subjacente e um sistema de Videoconferência (VCS) para suporte a colaboração de áudio e vídeo. Para a visualização dos resultados um sistema de visualização, especializado para Engenharia Offshore, ENVIRON, foi desenvolvido em conjunto com a equipe da PUC-Rio/TecGraf.

## **Palavras-chave**

Trabalho Colaborativo Auxiliado por Computador; Ambientes Colaborativos para a Solução de Problemas; Sistemas Gerenciadores de Experimentos Científicos (Workflows Científicos); Visualização Colaborativa; Ambientes Virtuais Colaborativos; Engenharia Offshore; Óleo & Gas.

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## Shortening

API – Application Program Interface  
AWT – Abstract Windowing Toolkit  
BPM – Business Process Management  
CEE – Collaborative Engineering Environment  
CFD – Computational Fluid Dynamics  
CFF – Component Framework Framework  
CLOS – Common Lisp Object System  
CLX – Component Library for Cross Platform  
CMS – Content Management System  
COCA – Collaborative Objects Coordination Architecture  
COM – Component Objetc Model  
COPSE – Collaborative Project Support Environment  
CORBA – Common Object Request Broker Architecture  
CoWfMS – Collaborative Workflow Management Systems  
CPSE – Collaborative Problem Solving Environment  
CRIWG – International Workshop on Groupware  
CSCA – Computer Supported Collaborative Argumentation  
CSCW – Computer Supported Cooperative Work  
CVEs – Collaborative Virtual Environments  
DACIA – Dynamic Adjustment of Component InterActions  
DISCIPLINE – DIstributed System for Collaborative Information Processing  
and LEarning  
DAO – Data Access Objects  
DTO – Data Transfer Object  
EJB – Enterprise Java Beans  
EBR – First Seminar on Advanced Research in Electronic Business  
ERP – Enterprise Resource Planning  
FAQ – Frequently Asked Question  
FPSO – Floating production, storage, and offloading production unit  
FSO – Floating, storage, and offloading production unit  
FTP – File Transfer Protocol  
GC – Grid Computing  
GPL – GNU General Public License



GRAM – GRID Resource Allocation Management  
HTML – Hyper Text Transfer Protocol  
HTC – High Throughput Computing  
IBIS – Issue Based Information Systems  
IDE – Integrated Development Environment  
IDL – Interface Definition Language  
IIOP – Internet Inter-ORB Protocol  
IJCIS – International Journal of Cooperative Information Systems  
JAAS - Java Authentication and Authorization Service  
JAMM – Java Applets Made Multiuser  
JCP – Java Community Process  
JMF – Java Media Framework  
JSF – Java Server Faces  
JSP – Java Server Pages  
LSEP – Large Scale Engineering Project  
MoCA – Mobile Collaboration Architecture  
MOM - Message-Oriented Middleware  
MVC – Model, View, Controller  
OEP – Offshore Engineering Project  
OLE – Object Linking and Embedding  
OMG – Object Management Group  
PDA – Personal Digital Assistant  
PME - Project Management Environment  
POJO – Plain Old Java Object  
RAD – Rapid Application Development  
RIA – Rich Internet Application  
RPCs – Remote Procedure Calls  
SAP - Business Management Software Solutions Applications and Services  
ScWfMS – Scientific Workflow Management Systems  
SBA – Space-Based Architecture  
SOA – Service-Oriented Architecture  
SDG – Single Display Groupware  
SDK – Software Development Kit  
SGBD – Sistema Gerenciador de Banco de Dados  
SOAP – Simple Object Access Protocol  
SWT – Standard Widget Toolkit  
UML – Unified Modeling Language

VC – Videoconference  
VCS – Videoconference System  
VNC – Virtual Networking Computing  
VE – Virtual Environments  
VR – Virtual Reality  
VRCs – Virtual Reality centers  
VRGeo – Virtual Reality for Geosciences  
VRML – Virtual Reality Modeling Language  
WYSIWIS – What You See Is What I See  
WfMC – Workflow Management Coalitio  
WfMS – Workflow Management Systems  
WYSIWYG – What You See Is What You Get  
XML – Extensible Markup Language  
XOOPS – eXtensible Object Oriented Portal System  
XSL – Extensible Style Language