



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

Rio de Janeiro

April 2010



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Bibliographic data

Santos, Ismael Humberto Ferreira dos

A Collaborative Environment for Offshore Engineering Simulations based on Visualization and Workflow / Ismael Humberto Ferreira dos Santos; advisor: Marcelo Gattass ; co-advisor: Alberto Barbosa Raposo. – 2010.

145 f. : il. (color.) ; 30 cm

Tese (doutorado)–Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Informática, 2010.

Inclui bibliografia

1. Informática – Teses. 2. Trabalho colaborativo auxiliado por computador. 3. Ambientes colaborativos para a solução de problemas. 4. Sistemas gerenciadores de experimentos científicos (workflows científicos). 5. Visualização colaborativa. 6. Ambientes virtuais colaborativos. 7. Engenharia offshore. 8. Óleo e gás. I. Gattass, Marcelo. II. Raposo, Alberto Barbosa. III. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Informática. IV. Título.

CDD: 004

Aos meus pais, Ubirajara e Dalva,
aos meus queridos filhos
João Guilherme e Pedro Henrique e a
minha amada esposa Yone.

Acknowledgments

A meus pais, Ubirajara e Dalva, por tudo que sou hoje.

A minha esposa, Yone, pelo seu amor e incentivo, e pela abnegação com que abdicou de muitas comodidades e assumiu tarefas que me cabiam.

Aos meus filhos, João Guilherme e Pedro Henrique, que são a razão da minha existência.

Aos meus orientadores Marcelo Gattass e Alberto Barbosa Raposo, pelo invulgar empenho que dedicaram a esta empreitada, pelos conselhos oportunos em momentos decisivos da consecução da pesquisa e pela confiança que depositaram em mim desde o início.

Ao meu ex-Gerente e amigo Álvaro Maia pela oportunidade que me deu confiando na minha capacidade de realização desse doutorado.

Ao meu Gerente e também amigo Augustu Petrus Levy por depositar uma confiança infindável no meu trabalho.

A Petróleo Brasileiro S. A. e ao CENPES, por todo o apoio e suporte financeiro que foram fundamentais por terem proporcionado a oportunidade e os meios para realizar esta pesquisa.

Aos amigos da Petrobrás, Heitor Araújo, Luciano Pereira dos Reis, Rodrigo Toledo pelo incentivo e motivação para continuar nessa jornada.

Aos meus amigos Rogério Pinheiro, Paulo Gallotti e a equipe do Environ, que tanto me ajudaram na implementação desta tese.

Aos amigos do TecGraf e da Puc-Rio, por terem proporcionado não só um ambiente propício para a pesquisa mas também um ambiente de extrema camaradagem e companheirismo.

Aos componentes da banca, por suas sugestões.

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