CONFIGURING A COLLABORATIVE VIRTUAL WORKSPACE FOR DISASTER MANAGEMENT OF OIL & GAS OFFSHORE STRUCTURES

Enio Emanuel Ramos Russo [1], Alberto Raposo [2], Terrence Fernando [3], Marcelo Gattass [4], and Börje Karlsson [5]

ABSTRACT

There are serious risks involved in running offshore units, with many reported disasters. These disasters can not only cause deaths and important environmental impacts, but also have a strong impact on business. Oil & gas companies are thus continuously seeking to employ processes and technologies to respond to such events in order to ensure safety. Such processes involve collaboration among a large number of groups and resources from different natures and geographically distributed, in order to make appropriate decisions within a short period of time. These groups are comprised of many technical experts and decision makers such as naval engineers, structural engineers, risers analysts and oceanographers, as well as managers. They need to be in constant communication with operators inside the unit, divers, security team, and, perhaps, with experts who are travelling to execute the rescue plan.

This work investigates how a distributed workspace environment can support disaster management, involving distributed collaborative technical teams. We first identify the requirements for the distributed workspace, from the stakeholders involved in a disaster, and analyse the commercial emergency systems available. We then elaborate a multi-perspective metamodel to support configuring this collaborative virtual workspace. Finally a prototype for oil & gas offshore structures disaster management based on our multi-perspective metamodel is derived and an HLA-compliant implementation for this prototype is developed as a proof-of-concept of the metamodel.

KEY WORDS

collaborative virtual workspaces, distributed environments, HLA, decision making, oil & gas

---

[1] Systems Analyst, Tecgraf, Dept. of Computer Science, PUC-Rio, Rua Marquês de São Vicente 225, Rio de Janeiro, RJ, 22453-900, Brasil, Phone 55-21-2512-5984, enio@tecgraf.puc-rio.br

[2] Professor, Tecgraf, Dept. of Computer Science, PUC-Rio, Rua Marquês de São Vicente 225, Rio de Janeiro, RJ, 22453-900, Brasil, Phone 55-21-2512-5984, abraposo@tecgraf.puc-rio.br

[3] Professor, School of Construction and Property Management, University of Salford, Maxwell Building, The Crescent, Salford, M5 4WT, U.K., Phone 44-161-295-2914, t.fernando@salford.ac.uk

[4] Professor, Tecgraf, Dept. of Computer Science, PUC-Rio, Rua Marquês de São Vicente 225, Rio de Janeiro, RJ, 22453-900, Brasil, Phone 55-21-2512-5984, mgattass@tecgraf.puc-rio.br

[5] Computer Science Researcher, Tecgraf, Dept. of Computer Science, PUC-Rio, Rua Marquês de São Vicente 225, Rio de Janeiro, RJ, 22453-900, Brasil, Phone 55-21-2512-5984, borje@tecgraf.puc-rio.br

INTRODUCTION

There are serious risks involved in running offshore units, with many reported disasters. Companies can lose billion of dollars by losing an offshore unit and further billions of dollars due to the cease of the oil production. As a direct result of these huge accidents, the oil & gas companies usually take actions in two main directions: *(i)* one that has the objective of correcting and improving the operational procedures; and *(ii)* a second one that has the aim of planning a set of projects to improve the technological level of the company in order to minimize the risk of future accidents (Costa 2004).

Considering the second aspect and the necessity of minimizing disaster impacts, we verify the need to develop a system architecture capable of bringing people together to work as a virtual team to explore various rescue plans and work towards consensus.

Many companies have been creating virtual teams that bring together geographically dispersed workers with complementary skills, increasing the demand for CSCW (Computer Supported Cooperative Work) applications. In order to make the development of a wide range of these collaborative applications more effective, we should offer a general architecture that is adaptable to different situations, tasks, and settings in a flexible way. The motivation for this work has been the necessity of developing a collaborative virtual workspace for disaster management of oil & gas offshore structures for a global company (Russo et al. 2004).

The main aim of this work is to investigate how a distributed workspace environment can support disaster management, involving distributed collaborative technical teams. Specifically, this research will focus on a distributed workspace for technical groups to work as a collaborative virtual team to explore various simulation options and to communicate their results to the decision makers. This aim will be achieved through the following objectives: *(i)* to conduct a survey to identify the requirements for the distributed workspace, from the stakeholders involved in a disaster scenario; *(ii)* to elaborate a metamodel to configure collaborative virtual workspaces; and *(iii)* to define a distributed workspace environment based on this metamodel for the technical team to engage in the rescue efforts.

REQUIREMENTS GATHERING

Petrobras, Brazilian Oil & Gas Company, faced two major accidents in the beginning of this decade. In 2001, the largest semi-submersible platform in the world P-36 sunk, killing 11 employees and ceasing a daily production of 84,000 barrels of oil and 1.3 million cubic meters of natural gas. In 2002, the FPSO (Floating Production, Storage and Offloading) unit P-34 with a daily production of 35,000 barrels and a storage capacity of 58,000 m^3 of oil had a stability problem and almost sunk, immediately ceasing its operation. At this time, Petrobras managed to rescue the unit without loss of lives.

The requirements gathering for the distributed workspace has been obtained through Petrobras case studies P-36 and P-34. These case studies have been used to identify the roles and attributes of people involved in a typical disaster management operation. Structured interviews have also been carried out to identify procedures and the users' expectations about the collaborative workspace. In this type of environment, it is important to model the users' relationships and to identify the main collaborative features that the users would like to have.

Once the users' requirement capture phase was completed, the next step was to define the technical requirements in terms of collaboration models, simulation steering, personalised and global workspaces, synchronised viewing, video-streaming, etc. We then conducted a survey on the main commercial emergency management systems available to gather their main characteristics and the main features still underdeveloped.

EVOLUTION OF DISASTER MANAGEMENT IN PETROBRAS

This section illustrates the complexity of the problem in terms of processes and groups of people involved in such disaster incidents. From this discussion, we show that Petrobras has been continuously active in improving its disaster management program.

During the P-36 disaster, there was a mechanical explosion and a chemical explosion with loss of lives, which caused difficulty in acting quickly to save the unit. During the P-34 disaster, there was no explosion, enabling the teams to react quickly, although the communication among them could still be improved. This research aims to make the next step change in terms of using ICT (Information and Communication Technology) to improve the collaboration between the stakeholders involved in disaster incidents.

In the case of the P-36 disaster, Petrobras identified the need for updated emergency procedures and for executing the actions within a short period of time in order to save the unit. This case aroused the need to investigate collaborative and decision-making models to help complex teams in avoiding disasters. In the case of P-34, there was already an updated model of the offshore unit and a form of distributed working that did help the rescue team to act quickly. There was also a static simulator that allowed the specialists to run different simulations. Nevertheless, the team still did not have an adequate environment to work as a virtual team to share knowledge, jointly discuss possible rescue plans, and to work quickly towards consensus.

As a result, it was necessary to bring people together into the same physical location with some delay in the process. Furthermore, some of the information was not directly available to the decision makers. This incident showed the necessity to strengthen the collaboration among the distributed teams providing better interaction, simulation and discussion during the whole rescue operation.

DISTRIBUTED NATURE OF THE TEAMS AND THE RESOURCES

In the case of Petrobras, when an accident occurs, the head office is immediately contacted and the General Manager of the operational unit is in charge of crisis management. All the work will be under his control in the decision workspace. The Security, Environmental and Health Dept. then starts emergency procedures and at the same time the technical specialists begin to act. In the technical workspace, there are naval engineers, structural engineers, risers analysts and oceanographers. When working together in a collaborative way there are usually the following main distributed groups: *(i)* the high-level decision team at the operational unit; *(ii)* a task force group leading the make-decision process; *(iii)* a technical support team at the company headquarters, at the Business Unit, and at the research center; and *(iv)* mobile experts, who sometimes are overseas or travelling and who must also be connected.

In addition to these groups, and working together with them, there are security teams in rescue units which are moved towards the region of the accident and give help during all the crisis period.

Not only the experts, but also the system resources are distributed in this scenario. For example, the computer intensive simulators may have to remotely run on a super computer or on a cluster of computers to get quick results. Also, the environment may need access to remote databases which maintain CAD models and simulation models of the unit.

In terms of configurations, each site participating in the crisis solution can have different ones, such as a Virtual Reality Centre, an intranet desktop and a laptop connected to the network. Moreover, experts who are travelling may have to be linked via mobile technologies and the connection between the unit and the people on earth may vary.

COMMERCIAL EMERGENCY MANAGEMENT SYSTEMS

After having determined the collaborative disaster management workspace requirements, we conducted a survey on the main commercial emergency management systems available. We identified the main characteristics of those systems, the main areas already covered, what is the state-of-the-art and what are the main features which are still underdeveloped.

While performing this survey, existent Emergency Management Systems from some vendors were investigated: L-3 CRISIS Command and Control System (MPRI Ship Analytics 2003); Oil Spill Crisis Management Simulator, also from Ship Analytics; and U.S. Automated Resource Management System (ARMS) Systems Requirements Document (Booz Allen Hamilton 2003). Crisis Intervention methods – the Crisis Intervention and Operability (CRIOP) Analysis (Johnsen et al. 2004) – being practiced in companies such as Statoil, Norsk Hydro, Elf and BP, were also investigated.

From this survey, we concluded that most of the Emergency Management Systems have some common characteristics, such as: serving as an incident management as well as a training and planning tool; having capability of integration, not only with internal databases and systems, but also with public emergency management systems; normally providing a Geographical Information System (GIS), which is responsible for displaying real-time data of the incident; and providing logging and tracking capabilities of resources and activities, as well as checklists as an efficient method to address the multiple simultaneous requirements.

In spite of all the features listed above, we identified two main drawbacks of current Emergency Management Systems: *(i)* lack of suitable integration of simulators with high performance visualisation systems; and *(ii)* inadequate security and access control features.

The survey demonstrated that, in spite of the integration of most of the Emergency Management Systems with simulators, there is the need to develop a system architecture capable of supporting distributed resources, mainly distributed simulators running on *high performance* visualisation systems. This architecture should also provide synchronous communication among different equipments with virtual co-location as one feature.

The integration of simulators using high performance visualisation systems in a synchronous distributed environment is the aspect of the emergency scenario on which we are going to focus. In order to support the definition of the architecture of this environment, a metamodel will be elaborated.

A METAMODEL TO CONFIGURE COLLABORATIVE VIRTUAL WORKSPACES

CSCW applications have largely focused on issues concerning differences between: *(i)* co-located work and working across distance; or *(ii)* work with people from the same culture, or common ground, and work with people from different cultures. The previous perspectives have been named, respectively: Place-Centered and People-Centered (Jones et al. 2004). We propose to adopt a different view on the problem based on the activities carried out by the teams participating in the collaborative work. We name it an *Activity-Centered* perspective, which may be seen as a multi-perspective concept since it not only encompasses the Place-Centered and the People-Centered perspectives, but also allows adopting each one or both of them in a hybrid way, and admits seamless change from one perspective to another.

Nodes are essential components of our metamodel, going from the top-most node representing the whole activity through many nodes of different levels representing groups and sub-groups until the leaf nodes representing a person or a software agent. Nodes also have an attribute called *artefacts* defined as "all objects on which users can operate" (Gross and Prinz 2004). Examples of artefacts are drawings, physical models, prototypes, and documents. Following the class concept, an artefact associated with a group node is shared by all members in the group, unless otherwise explicitly stated. In this case, a mechanism such as an access control list will determine who share access to the artefact.

Edges in our metamodel represent the interaction paths among nodes, which can be uni- or bi-directed. When an edge is represented by a thin arrow, this means that the nodes on its extremities are co-located. When the arrow is thick, the nodes are placed remotely to each other. Edges have one important element, *channel*, which represents the electronically mediated channel that allows communication between two nodes.

We take an overall picture of the disaster management collaborative application (Figure 1) to illustrate the metamodel components. The disaster management of an oil & gas offshore structure is a complex operation involving several groups, such as the oil & gas company, the rescue team, the health care centre, the press, among others. This is an inter-organizational complex activity led by the oil & gas company, whose node will be detailed.

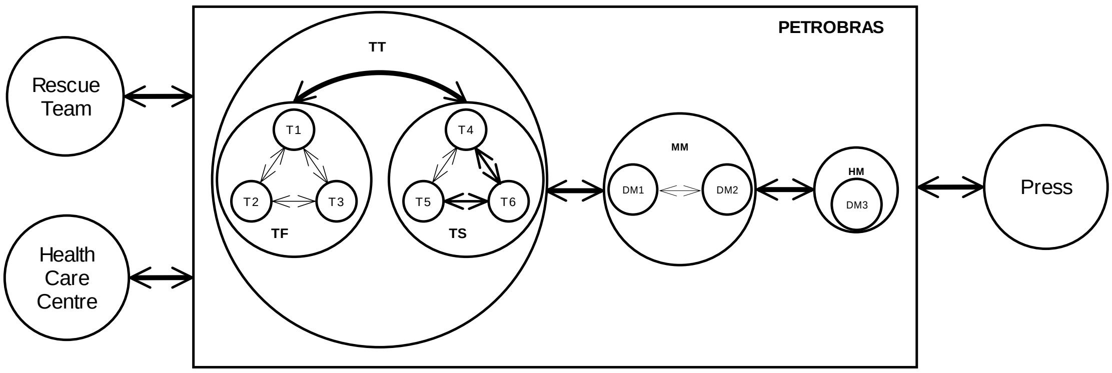

Figure 1: The disaster management collaborative application: overall picture

Within Petrobras node, we identify three main groups: the Technical Teams (TT), the Middle-level Managers (MM) and the High-level Managers (HM), each one remotely located to the other. TT is formed by two technical sub-groups: the Task Force (TF) team and the

Technical Support (TS) team, also remotely located.

TF plays the main role, leading the decision making process. It is constituted by three co-located technicians, such as naval engineers, structural engineers, risers analysts or oceanographers. TF runs different simulators to derive the best solution to save the offshore unit, permanently communicating with TS. They also maintain contact with MM informing about their work evolution and asking for approval for their derived solution. Once their solution is approved, they pass the sequence of commands to be executed to the unit operator (not represented in our picture).

TS team, with technicians working in the same fields as TF team, can be invoked by the latter to perform specialized simulations focusing on some particular issues that would not be possible to be done by TF, or to obtain another opinion about the problem.

MM is constituted by middle-level managers working co-located in a company office, with one of them usually being the responsible to make the final decision. They have an overall knowledge about the technical issues and work constantly interacting with the TT group. They also communicate with the HM group, informing about the work evolution and eventually when they need to make a more critical decision.

In our metamodel, we have also identified the need for additional *edge specialization elements*, namely *pre*- and *post-communication processing*, which are separated into two different classes. The first class is constituted by the ones directly associated with the leaf nodes. They represent the processing to be executed particularly onto a specific message being passed between two nodes. The second class is constituted by the ones associated with groups on different levels of the metamodel hierarchy, representing the policies of these groups when respectively sending (*out-policies*) and receiving (*in-policies*) messages. In Figure 2, we show possible pre- and post-communication processings that could be executed while sending a message from a Computer Science Researcher CR1 of the Computer Science Dept. CD1 of University U1 to Researcher CR2 of University U2.

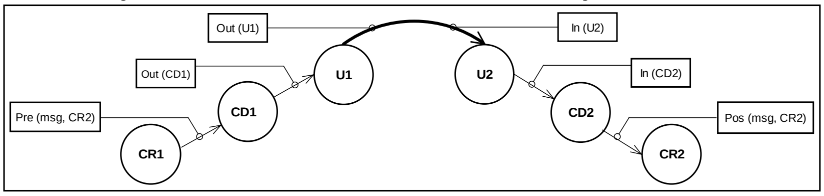

Figure 2: Activity-Centered metamodel: pre- and post-communication processings

According to the majority of CSCW studies (e.g., Cortés and Mishra 1996, Li and Muntz 1998), we adopted the strategy of separating the coordination structure and the computational program, using *role rules* with a logic-based specification language for specifying coordination policies. We also built a *message attributes table* to enhance the flexibility of the coordination program, separating coordination rules from data related specifically to each message. This table provides an indirection that enables dynamic reconfiguration.

PROTOTYPE

After investigating the activities involved in the disaster scenario and identifying their requirements in terms of ICT, we decided to concentrate on the Technical Teams group to develop a prototype of collaborative application implementing a particular model of our Activity-Centered metamodel. This prototype is particularly related to the work performed by the Task Force group (TF), including the simulators they run, their mutual communication and their interaction with the Middle-level Manager group.

During a crisis situation, the Task Force group typically uses three simulators. The first simulator to be run is SSTAB (Coelho et al. 2003), the Floating Units Stability system, used to analyse the static conditions of the floating unit (Figure 3a). SSTAB uses as its inputs the unit model obtained from a centralized system and updated data from the unit obtained through a monitoring system. It gives as outputs five files, including the inertia matrix.

The second simulator is called WAMIT and uses as inputs the output files generated by SSTAB. It works in the frequency domain, deriving the excitation forces of the unit and water forces reactions to lateral displacement. WAMIT is activated by a user interface program called WMG.

Finally the third simulator to be executed is DYNASIM (Coelho et al. 2001), for Dynamic Stability (Figure 3b). It uses as inputs the results obtained from WAMIT as well as the parameters representing the *height* and the *period* of the waves at the moment of the disaster. DYNASIM calculates the forces acting on the mooring lines and risers. When these forces are considered extreme, a retrofeedback process is started, performing all the simulations again, beginning with SSTAB, to find another stable condition of the unit.

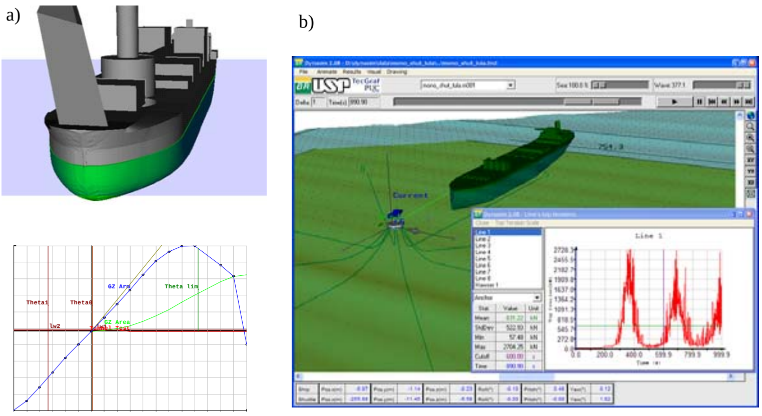

Figure 3: a) SSTAB; b) DYNASIM

The method used to save an offshore unit has the goal of defining a sequence of commands to be passed to the unit operators or to the rescue team so that they can move the unit in a step by step mode from its initial unstable condition until it reaches back its normal equilibrium state. It is based on the following workflow:

- We first use these three simulators to derive the initial conditions of the offshore unit.
- We then define a next step configuration of tanks (e.g., moving water from a ballast tank of one side to a ballast tank of the opposite side) and simulate the unit in this new condition using again the simulators. If we are not satisfied with the results, we define another configuration of tanks and continue this process, experiencing

iteractively configurations, until we are satisfied.

- From the configuration of the previous step, we now try to derive a new step configuration of tanks, using a process analogous to the one just described.
- We repeat this process of deriving step configurations of tanks using our three simulators until we reach back a normal equilibrium state.

At the end of this whole process, we have a sequence of commands in terms of tanks' valves operations, correspondent to the achievement of each of the step configurations described above, in a step by step mode, which was exactly our goal.

It is important to note that the executions of simulators SSTAB and DYNASIM are highly interactive visualisation processes, mainly in a crisis situation, when we need to rapidly experiment many alternatives to respond to the disaster. Also we have to consider that, in emergency situations, it is very important to be as fast as possible. Then, searching for points where we could save time, we found that, if WAMIT receives the results from SSTAB, it can be activated automatically on ending the SSTAB simulation.

An Activity-Centered model representing this crisis situation (Figure 4a) can be derived based on the participants' roles. We created two remote groups: Technical Teams (TT) and Decision Makers (DM). TT is constituted by the Task Force (TF) team with members T0, T1 and T3, and the software agent S2. DM is constituted by a single manager, a representative of all participants not directly involved with the technical part of the simulation activity such as operators and other managers, who only receive follow-up messages, commands to be executed or approval requests.

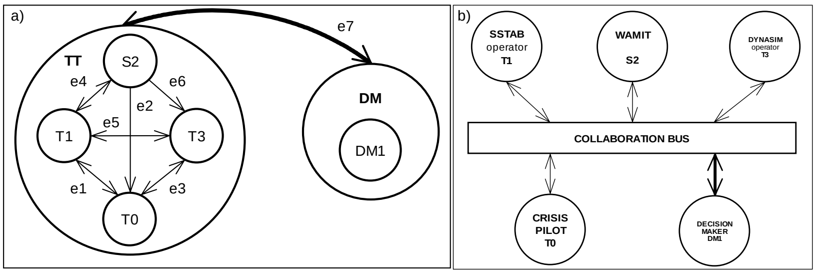

Figure 4: A first model of the disaster management application (a) and its prototype (b)

Other than the interaction network part of the model just described, we also define role rules and the message attributes table in order to represent the following workflow.

The Crisis Pilot T0 plays the main role in this disaster application, coordinating the collaborative session and leading the make-decision process. He asks for the SSTAB operator (T1) to begin his simulation. After receiving a message from agent S2 indicating the end of its simulation, he asks for the DYNASIM operator (T3) to begin his simulation. On receiving a simulation conclusion message from T3, he makes a decision based on the force values acting on mooring lines and risers. If he understands that these forces are extreme, he asks for T1 to begin the whole process again, in order to find a new stable condition of the unit, and this loop continues until he is satisfied with the force values obtained. In this case, he makes contact with DM1, asking for his approval to their solution. The basic conceptual level architecture of our collaborative application is shown in Figure 4b.

In order to map our model into an implementation-level architecture, we chose HLA – High Level Architecture (IEEE 2000), with real-time support and a flexible component-based architecture. The fundamental concepts in HLA are: *(i)* Federate – a simulation implemented as part of an HLA-compliant simulation; and *(ii)* Federation – a collection of federates working together. We use XRTI – The Extensible Run-Time Infrastructure (Kapolka 2003) as the HLA run-time infrastructure, an open-source and freely distributable implementation, written in Java and using XML object models. Among its basic characteristics we have: *(i)* a dynamic object model extension and composition support; *(ii)* a pure client-server topology in which federates only communicate with one another through the XRTI Executive, a server application; and *(iii)* Federates maintain two channels to the Executive: a TCP channel for reliable communication and a UDP channel for unreliable messaging.Observing the model of Figure 4a, we conclude that all participant members can constitute a single Federation. We then associate a Federate with each participant of this Federation. Each Federate code is a Java program built based on the workflow rules written in a logic-based program. To enhance flexibility, the main method of each Federate is the one named *process_role*, which receives as parameter the role to be played by the Federate, coded in a separate Java module. Using this strategy, we can code the workflow rules associated with a specific role directly into a separate module dedicated to this role.

CONCLUSIONS

This work was motivated by and was conducted in real-world settings, namely an oil & gas offshore structure disaster scenario. This seems to contribute to the CSCW field, since a review of CSCW evaluation studies concluded that less than half were conducted in real-world settings (Pinelle 2000). An adequate model to the disaster scenario was derived from our multi-perspective metamodel. We also implemented a first prototype as a proof-of-concept of our metamodel, using an HLA run-time infrastructure.

The metamodel allows flexibility in many dimensions. Separating high-level abstraction features from low-level implementation features allows the designer and the application developer to concentrate on their particular domain of expertise. Separating the computational program and the coordination program allows programmers to concentrate on coordination issues with high-level abstraction.

The metamodel is also customisable in the sense that it allows associating pre- and post-communication processings with each message sent. It allows parametric run-time changes such as changing names of pre- and post-communication processings in the message attributes table, or even changing the pre- and post-communication codes before they have been loaded during a collaborative session.

There is still a lot of work to do in order to make our metamodel a fully flexible and evolving collaborative architecture. Particularly to the situation of an emergency scenario being considered, it would be very important to include an Expertise Recommender system, such as the one proposed by McDonald and Ackerman (2000), since in a crisis situation it is fundamental to locate the expertise necessary to solve the problem in the lesser possible time. We should also investigate how to promote our metamodel from a customisable category to an adaptable category (Dourish 1998), upgrading from the capability of adjusting parametric controls to the capability of reconfiguring its behaviour according to immediate patterns of use. We could accomplish this using a learning mechanism to monitor the users' activities.

REFERENCES

Booz Allen Hamilton (2003). "Automated Resource Management System (ARMS), System Requirements Document (SRD)." *Contact No.: GS-35F-0306J, FEMA BPA # EMV-2001-BP-0147, Task Order 11*, Federal Emergency Management Agency, USA.

Coelho, L.C.G., Jordani, C.G., Oliveira, M.C., and I.Q. Masetti (2003). "Equilibrium, Ballast Control and Free-Surface Effect Computations Using The Sstab System." *8th Int. Conf. Stability of Ships and Ocean Vehicles - Stab*, 377-388.

Coelho, L.C.G., Nishimoto, K., and Masetti, I.Q. (2001). "Dynamic Simulation of Anchoring Systems Using Computer Graphics." *OMAE Conference*.

Cortés, M. and Mishra, P. (1996). "DCWPL: A Programming Language For Describing Collaborative Work." *Proceedings of CSCW´96*, 21-29.

Costa, T.V.M. (2004). *Modelos de Aprendizado Organizacional de Chris Argyris: Uma Investigação em Segurança Operacional e Conservação do Meio Ambiente (SCA) com Base em Acidentes da Indústria do Petróleo*. D.Sc. Thesis, Production Engineering, Federal University of Rio de Janeiro (UFRJ), 159 pp.

Dourish, P. (1998). "Using Metalevel Techniques in a Flexible Toolkit for CSCW Applications." *ACM Transactions on Computer-Human Interaction*, 5 (2) 109-155.

Gross, T. and Prinz, W. (2004). "Modelling Shared Contexts in Cooperative Environments: Concept, Implementation, and Evaluation." *Computer Supported Cooperative Work*, Kluwer Academic Publishers, 13 283-303.

IEEE – The Institute of Electrical and Electronic Engineers (2000). *IEEE Std 1516-2000, IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)-Framework and Rules*.

Johnsen, S.O., Bjørkli, C., Steiro, T., Fartum, H., Haukenes, H., and Skriver, J. (2004). "CRIOP®: A scenario method for Crisis Intervention and Operability analysis." *Report No. STF38 A03424*, SINTEF, Norway.

Jones, Q., Grandhi, S.A., Terveen, L., and Whittaker, S. (2004). "People-to-People-to-Geographical-Places: The P3 Framework for Location-Based Community Systems." *Computer Supported Cooperative Work*, Kluwer Academic Publishers, 13 249-282.

Kapolka, A. (2003). *The Extensible Run-Time Infrastructure (XRTI): An Experimental Implementation of Proposed Improvements to the High Level Architecture*. Master's thesis, Naval Postgraduate School, Monterey, CA, USA.

Li, D. and Muntz, R. (1998). "COCA: Collaboration Objects Coordination Architecture." *Proceedings of CSCW´98*, 179-188.

McDonald, D.W., and Ackerman, M.S. (2000). "Expertise Recommender: A Flexible Recommendation System and Architecture." *Proceedings of CSCW´00*, 231-240.

MPRI Ship Analytics (2003). *L-3 CRISIS Brochure*. North Stonington, Connecticut, USA.

Pinelle, D. (2000). "A Survey of Groupware Evaluations in CSCW Proceedings." *Technical Report HCI-TR-2000-01*, Computer Science Dept., University of Saskatchewan, Canada.

Russo, E.E.R., Raposo, A.B., Fernando, T., and Gattass, M. (2004). "Workspace Challenges for the Oil & Gas Exploration & Production Industry." *Proceedings of CONVR 2004 - 4th Conference of Construction Applications of Virtual Reality*, 145-150.