Workspace Challenges for the Oil & Gas Exploration & Production Industry

Enio Emanuel Ramos Russo
PUC-Rio
Rio de Janeiro - Brazil
enio@inf.puc-rio.br

Alberto B. Raposo
PUC-Rio
Rio de Janeiro – Brazil
abraposo@tecgraf.puc-rio.br

Terrence Fernando
The University of Salford
Salford – United Kingdom
t.fernando@salford.ac.uk

Marcelo Gattass
PUC-Rio
Rio de Janeiro - Brazil
mgattass@inf.puc-rio.br

Abstract

The objective of this paper is to present some of the key challenges faced when defining and building virtual workspaces for oil & gas Exploration & Production (E&P) activities. First, we present the main E&P processes that can benefit from the VR technology. Secondly, we classify and describe the different challenges.

Keywords

virtual environments, virtual workspaces, oil & gas, E&P processes.

1. INTRODUCTION

The oil & gas industry has been a leading player in exploiting the power of virtual reality technology to enhance its business processes. The motivation for deploying such advanced technology in this industry is due to the difficulties that the companies were facing in the late nineties, with the price of oil hovering near all-time lows. At that time, the pressure to reduce exploration and development costs of new reserves and existing fields were immense and the immersive virtual reality technology was identified, by the oil & gas industry, as one of the key tools which can meet these challenges. The Virtual Reality Centres (VRCs), large projection rooms with features such as 3D and stereoscopic images, soon became very popular in the oil & gas industry, since they gave specialists the ability to quickly and comprehensively interpret large volumes of data, thus significantly reducing cycle time for prospect generation [American98].

However, due to ever increasing business pressures, there are further demands on researchers to extend the capabilities of the VR technologies, so that it can be fully utilised in all the oil & gas exploration and production (E&P) phases. This paper presents various E&P processes of the oil and gas industry and discusses research challenges emerging from these processes.

The structure of this paper is as follows. Initially, Section 2 presents the key E&P processes and their application demands. Section 3 presents the classes of technology challenges emerging from these E&P processes for VR. The final conclusion of this paper is presented in Section 4.

2. TYPES OF E&P PROCESSES

This section discusses the main processes of the oil & gas E&P industry and the main challenges within each process. The work presented here is based on the authors' experience with oil & gas projects at Petrobras in Brazil.

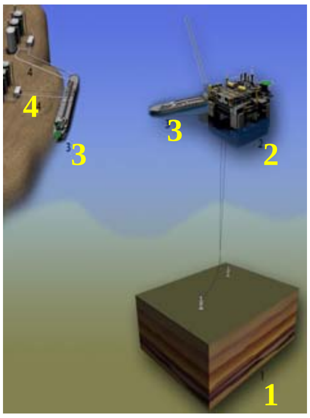

Figure 1: (1) reservoir; (2) offshore platform; (3) transportation ships; (4) oil pipelines.

Figure 1 shows the main resources involved in the production of oil & gas. The typical E&P processes in the oil & gas industry are: (i) reservoir exploration through 3D geomodelling and seismic interpretation; (ii) design and construction of the production facilities based on the results of the first phase; and (iii) production and transportation of the produced oil & gas.

The following subsections describe how virtual reality can enhance each of these E&P phases.

2.1 Reservoir Exploration Phase

During this exploration phase, the goal is to elaborate the subsurface model that best represents the reservoirs.

Whether it is a seismic cube or a stratigraphic geological model, what is important in this phase is to build an individual mental representation of the model. Therefore the key tasks in this phase are 3D geomodelling and 3D seismic interpretation.

Drilling wells for crude may consume up to 85% of the total exploratory funds. Thus, the decision to drill should be taken in a sensible way based on studies that provide detailed knowledge of the area's geologic conditions, both on the surface and in the subsurface. Of all such studies, the seismic method is more decisive to select the drilling spots. Seismography makes use of subsurface ultrasonography, generating seismic logs that provide an approximate image of the configuration of several subsurface strata.

3D geomodelling involves a large spectrum of skills, spread over different domains (geophysics, geology, reservoir and petroleum engineering). During its lifetime, a numerical earth model is shared by people with different types of specializations. The model evolves continuously over time, by absorbing various inputs from the team members [Reis01].

Seismic interpretation in the late seventies used to be made over a stack of paper maps, from which the interpreter would pinpoint areas of interest for drilling by creating a mental 3D image about thickness, constitution, depth and performance of rock beds. However, the advent of VRCs and stereoscopic images opened a door to a new world for seismic interpretation, allowing the users to visualise and explore in an interactive manner. The work became much more easier since specialists no longer need to use their knowledge and imagination to draw a mental picture of the area and to feel immersed in it. A mapping that used to take months began to be drawn in just a few hours [Petrobras99].

The viability to use 3D imaging fosters a more accurate and faster interpretation of the external geometry and internal architecture of reservoirs. With all the participants of a project having access to the same shared viewing, one can have a better interpretation of a large pile of data, achieving more reliable simulations of the oil output performance of that reservoir and analysis of its results. The team can calculate curves for future production, forecast the number of wells for drilling and devise the whole project for an oilfield development [Petrobras99].

The images can be studied until specialists are able to determine the best way to exploit the reservoir they represent. Well location, rock qualities and the distribution of well fluids (water, gas and oil) can be analysed more efficiently with the purpose of ascertaining the best distribution patterns for production and injection wells [Petrobras01].

One of the current key challenges in this area is the development of collaborative workspaces for supporting truly collaborative geomodelling and visualization for distributed users. Given the geographical dispersion of experts in the oil & gas E&P industry, remote collaboration offers great benefits, particularly in activities involving continuous model refinement and decision taking.

Another challenge is to develop better interaction facilities with real-time performance to explore the seismic data in a more interactive manner. This requires both heavy processing power and intuitive interfaces designed for team work. Two approaches could be explored in providing the computer power necessary for real-time seismic data exploration: PC cluster approach and computational steering from super-computers. Although both approaches are sensible from the research point of view, the PC cluster approach seems to be favoured by many due to the cost factor. The interfaces for controlling the simulation and visualisations, generated by these computers, need to be enhanced to provide natural interaction. The deployment of emerging technologies such as wireless tracking, PDAs, gesture-based interaction to develop natural interfaces for the team collaboration is still a challenging research problem.

Real-time follow-up and correction of the course of a deepwater horizontal well is one of the activities that can also take advantage of the VRCs' features. Although this technology may be used in any kind of well, its potential is clearly shown in horizontal drilling in the need to navigate the reservoir as it is drilled. Mostly in the early stages of the oil field's development, the reservoir may not always be found as forecast and as a result a well of about US$ 20 million may be lost. One of the challenges is to explore the use of optic fibre cables, connected to a VRC, to monitor the real-time drilling to make sure the rig will hit its target and will not skip the reservoir [Petrobras99]. This application obviously requires real-time features of the virtual reality system, as usually rig information is sent from the field at regular time intervals.

2.2 Design and Construction Phase

During the design phase, the oil & gas industry is interested in visualizing offshore structures, performing static and dynamic simulations of these structures to ensure its stability, examining the construction processes, analysing procedures for monitoring oil pipelines and emergency situations etc. The construction phase will only be executed, once these issues are fully analysed to the satisfaction of all the stakeholders.

2.2.1 Reviewing the construction process

Offshore structures, modelled using CAD systems, have every single component highly detailed, since the goal here is to analyse the construction process.

The engineers need not only to have access to every single part of the model and its characteristics, but also to review the model from different perspectives. Therefore the key challenge in this process is to develop a dynamic virtual environment to allow the designers to assess the construction of the offshore structures from their own perspectives. This will require a flexible software framework which can provide access to various simulations with personalised interfaces.

The installation of subsea equipments is a challenging task during the construction of offshore structures, requiring precise manipulation inside a complex environment. This requires highly skilled people to ensure the operations can be done efficiently without damaging the surrounding equipments. The challenge here is to enhance the current capabilities of the VR technology to allow engineers to rehearse such intricate operations in advance to avoid costly mistakes. The use of robots is also being investigated to conduct such operations remotely.

2.2.2 Stability analysis

Thorough analysis of stability of the offshore structures is an important aspect to be considered during the design phase, where thousands of barrels of oil are produced daily in the open sea. The stability analysis need to take into account the stress conditions, sea currents, waves and wind pressures on semi-submersible platforms and FPSOs (Floating Production, Storage and Offloading unit). Additionally, these production units may be floating in the sea, which is more than two thousand meters deep, and therefore requiring the deployment of complex mooring systems.

Most of the current simulators are still static [Coelho03], but the demand for dynamic simulations is growing in the oil & gas industry to conduct rich simulation of offshore structures to ensure safe operation. Examples of such dynamic simulators are Dynasim [Coelho01] and NOT (Numerical Offshore Tank) from Petrobras. The Dynasim system has been designed to compute the supervening forces and consequential movements on anchored structures, where as NOT has been designed to simulate waves, currents, the line dynamics and the damping of floating production and storage oil & gas systems. The key challenge which is being explored in this work is the deployment of massively parallel computing with PC clusters to support interactive visualisation and simulation. Another key challenge in this area is the deployment of such dynamic simulations to give designers and engineers the feeling of the movements suffered by the unit, using hardware simulators. Such a simulator could be used for assessing various issues in operation, maintenance and emergency scenarios.

2.3 Production Phase

The main aim of this phase is to support efficient and safe production of oil & gas. This requires putting in place a well trained work force for operation, plant monitoring, maintenance, emergency handling, etc. This section discusses how virtual reality technology could be used for supporting these key activities.

However, the application of VR in this phase requires an up to date virtual model of the plant. As a result, any changes to the plant need to be captured and be used to maintain a valid virtual representation of the real plant. This could be done by means of a 3D laser scanner that is capable of acquiring a cloud of points from the real structure. This section describes few examples to illustrate the use of VR in the production phase.

2.3.1 Monitoring

During the production phase, the virtual reality technology has the potential for supporting better monitoring of plants. Examples of such monitoring tasks include remote monitoring of oil pipelines to avoid oil spillages, stability of the offshore structures and off loading operations.

To better analyse oil pipeline deformations, it is possible to use post-videos over the structural analysis results. Also the manager or the specialist could be allowed to receive a visual representation of the oil pipeline directly from the field, in case of an accident or during a maintenance operation. However, in order to transmit data from the field to the expert’s virtual workspace, the equipments used by the field engineers must not be heavy and should be based on mobile technology to work on difficult terrain conditions.

2.3.2 Emergency scenario

The importance of rigorous procedures for handling emergency situation is now becoming extremely important due to ever growing environmental concerns. An oil spillage could have a devastating consequence on the environment costing millions of dollars to constrain the damage. Virtual reality can play a significant role in developing systems for training people for handling such situations and also for connecting experts during such a disaster situation to advise the workers, on the ground, to control the situation.

One such system, which has been developed to manage and control actions during a leakage of a pipeline is InfoPAE [Carvalho02]. It provides facilities to manage conventional and geographical data, associating them with the plans. The system has been developed to help and minimise the response time, to validate and optimise the emergency plan's logic and to train the teams responsible for the actions.

Another typical emergency scenario in the oil & gas area is a crisis situation in an offshore structure, when the structure becomes unstable. In this scenario, there are two main possibilities:

- If the unit is heavily damaged and has security problems, then the unit is abandoned and no person remains inside the offshore platform. In such a situation, divers are called to do possible rescue operations.
- If the unit has a minimal security condition, it usually remains with two or three operators. In such a situation, operators receive instructions from the experts on the ground to stabilise the offshore structure.

During such emergency situations, several expertise are brought together to provide advise. Typically the specialists involved are naval engineers, structural engineers, risers analysts and oceanographers. These specialists are geographically distributed and therefore in need of an efficient IT environment to support the collaborative decision making process.

3. CLASSES OF WORKSPACE CHALLENGES

In order to develop usable industrial solutions, it is important to first identify and analyse the industrial processes and the requirements and expectations from the specialists. Such an analysis for the oil & gas industry was presented in Section 2 in this paper.

From this analysis, it is apparent that the oil & gas industry needs a suit of virtual workspaces for supporting various tasks such as seismic exploration, design reviews including dynamic simulation of offshore structures, training environments for subsea offshore equipment installation and disaster management, monitoring of real-time follow-up and correction of the course of a deepwater horizontal well, decision making environment for emergency situations, monitoring environments for oil pipelines, offshore structures and off loading operations, etc. When constructing virtual workspaces for these applications, great care must be given to the user's expectations, appropriate collaboration operations, interaction metaphors, appropriate display environments and visualisation techniques to suit the tasks and the expert teams. Since most of these workspaces will be used by multi functional teams, it is important to deal with different levels of perception and perspectives that users are expecting to conduct their tasks. The VR technology used for building such workspaces should fit the user in terms of intuition, attention and productivity [Parkin99].

Although each application requires specific functionality and interfaces, the following generic classes of virtual workspaces, for the oil & gas industry, can be identified from the analysis given in Section 2:

- Distributed Design Review Workspaces.
- Co-located Design Review Workspaces.
- Field Activity Monitoring Workspaces.
- Disaster Management Workspaces.
- Training Workspaces.

The following subsections discuss the generic technology challenges faced when building these generic and specific workspaces.

3.1 Real-time Visualization and Interaction

A common characteristic of a typical virtual workspace, constructed for supporting an E&P process, is the enormous amount of data it has to deal with. The type of data could vary from seismic data for reservoir exploration to CAD and simulation data for the design and construction of offshore structures. For tasks such as monitoring of oil pipelines over a mountain, GIS, CAD and video data needs to be brought together to support the construction of the monitoring virtual workspaces. Such scenes could be out door environments or complex structures (offshore structures) with different spatial characteristics. Furthermore, the data produced for supporting certain design functionality may not have an efficient representation for achieving the best visualisation performance, requiring certain pre-processing techniques.

The challenge here is how to decide what part of the data to visualize at each time. This is not only because of performance and real-time constraints but also to avoid cluttering the scene with unnecessary data. Therefore model simplification algorithms which do not eliminate key features of the structures are important to provide usable real-time visualisation services for E&P processes. In addition, real-time performance for visualising such large data sets need to be gained by utilising the power of specialised hardware solutions or PC clusters.

In these virtual workspaces, the construction of interfaces for supporting specific activities for specific experts is extremely important to achieve user acceptance of the technology. Such interfaces need to be natural and simple without requiring any training. Although some advanced interaction technologies are now becoming available, it is important to research and build simple interfaces appropriate for a task. In [Froehlich99], Froehlich claims that the geoscientists found the Cubic Mouse, an input device specially tailored to geo-scientific data, is very natural and effective performs their tasks. Its interesting characteristics are the sensation it gives the user of having the whole model in his hand and the possibility of easily moving through 2D slices of the model by simply sliding small bars of the cube. It allows the users to focus on their exploration tasks rather than on operating the computer. Further research is required to identify interface devices and paradigms for supporting natural interaction within E&P virtual workspaces.

3.2 Collaboration

One of the most important challenges in constructing oil & gas E&P virtual workspaces is the development of efficient collaborative virtual environments (CVE). This is because most of the projects involve many professionals who are geographically dispersed over a country or even across different countries, who need to work together as a virtual team. These cross-functional team members need to collaborate effectively and make decisions quickly and accurately to support various stages of the E&P process.

3.2.1 Distribution support

For a virtual environment to be collaborative, it must be distributed between the participants who wish to share it. The choice between communication architectures is parameterized by the degree to which the data structures representing the virtual environment are replicated or cached between the computing nodes and the underlying transportation technology [West01].

However, whatever the technology, communication latencies are an important factor in building usable collaborative systems. If it is not possible to achieve the adequate synchrony, one solution is to at least focus resources upon those activities which are most sensitive to lag, i.e. those which produce the most pronounced discontinuities of perceptual experience when lag is present. For the moment, it is fair to say that there is no universal choice of distribution or communication architecture, but rather a range of trade-offs in performance and deployment issues [Singhal99].

It is impossible to predict the network requirements of CVEs in isolation; rather, we need a model of CVE operation which encompasses the application, user, software and hardware concerns. In this paper we follow the model proposed by Greenhalgh [Greenhalgh01], which has six layers:

1. Task/application/collaboration requirements: what do people want or try to do? For each virtual workspace, it is important to identify the exploration or design tasks that the user is expecting to perform.
2. User behaviour: what particular actions do people do and when? For example, if users speak only rarely, and never at the same time, then the network requirement for audio could be very limited. On the other hand, for some scenarios, there must be enough bandwidth for every user to speak at the same time. This could be the case of the emergency scenario, for example.
3. Process behaviour: how does the application respond? Once again, the emergency scenario could be a good example: while people heading the whole operation could execute any command, the other specialists could only execute the tasks they were asked to.
4. Distribution architecture: what communicates with what? The choice of distribution architecture determines which information must be communicated to which parts of the system. Typically, communication will be necessary between both people and simulators. Typically oil & gas applications nowadays are held in no more than a half dozen visualization rooms simultaneously, with no more than 20 specialists in each one. In the case of dynamic simulation of offshore structures, simulators performing various analyses need to communicate their data to each other and/or to a central controller to produce the final results of the simulation.
5. Communication protocols: how is information exchanged? Protocols can be either unicast or multicast or a combination to achieve both performance and reliability.
6. Network communication: what actually happens in the network? In the particular case of oil & gas applications, as presented in Section 2, it is not unusual to have one or more specialists out in the field who need to be somehow connected to the collaboration environment. This could be done by a mobile system. Therefore it is important to support both fixed and mobile communication support for E&P workspaces.

Due to the high commercial value of their data, oil & gas industry has imposed strict data base consistency and security requirements. As a result, the data is typically at various sources which need to be brought together to support innovative virtual workspace concepts discussed in this paper. The grid concept seems to match those requirements, since it is conceptually centralized with real data, distributed at various places transparently to the application.

3.2.2 Collaboration metaphors

While it is important to develop a flexible and open software platform for supporting collaboration, the human factors issues for supporting tighter interaction between the team members should not be ignored. Due to space limitations, only few interaction considerations important for supporting collaborative working within the E&P workspaces are summarised below:

- In some cases, experts would need the possibility of having a copy of the data model in their private workspaces to explore their ideas individually, and to take their views to the shared workspace for discussion. Such a facility is important for applications such as modelling or interpreting an oil reservoir or dealing with an emergency scenario.
- During collaborative discussions or training, it is important to control and share various viewing points to communicate ideas to each other. Some key viewing support necessary within collaborative working could be summarised as: (i) sharing of each other's viewing point (look over the other's shoulder) [Cheng98]; (ii) mirrored viewing point (the opposite side of the situation). Furthermore, in some emergency training situations, the trainees may want to observe the simulation result from various view points in parallel. For example, one might want to observe the simulation effect of a possible emergency operation using an exocentric point-of-view (outside in) and another may want to observe the simulation effect using an egocentric point-of-view (inside out). Such parallel observation could lead to better understanding of the emergency situation and to work learn to as a team.

The next generation of collaborative workspaces will provide much more realistic face-to-face tele-immersive environments, integrated with appropriate simulations and data bases [Johnson01]. Such mixed-reality workspaces, created by combining virtual workspaces and video avatars of users, have the potential for mimicking co-located meeting metaphors. However, the human factors issues, performance issues and business benefits of such environments will need to be addressed properly to ensure their acceptance by the oil & gas industry.

4. CONCLUSIONS

This paper discussed E&P processes of the oil & gas industry with the view to identifying how VR technology can be used to build better virtual workspaces for these processes. Several generic virtual workspaces were identified which are specific for the oil & gas industry. Finally the paper presented some of the generic technology challenges in building virtual workspaces for the oil & gas industry.

This paper emphasised the need for developing virtual workspaces with a thorough understanding of the processes and the user expectations to ensure their acceptance by the oil & gas industry. Furthermore, the paper argued that the interfaces of these virtual workspaces need to be mapped onto the roles and the tasks of the users.

However, the construction of virtual workspaces for every possible application and various users can be a tedious and expensive task. Therefore it is important that future research lays foundation for creating reconfigureable and dynamic software architectures to facilitate easy construction of various virtual workspaces on demand.

5. ACKNOWLEDGEMENTS

We would like to thank Petrobras and Tecgraf/PUC-Rio for their support, and, for their great contribution, Petrobras' engineers Álvaro Maia, Heitor Araújo and Isaias Masetti, and Prof. Markus Endler and engineer Luiz Cristovão Gomes Coelho from PUC-Rio.

6. REFERENCES

[American98] *The American Oil& Gas Reporter* (March 1998).

[Carvalho02] Carvalho, M.T., Casanova, M.A., Torres, F. and Santos, A.: INFOPAE – An Emergency Plan Deployment System. *Proceedings of the Int. Pipeline Conference* (2002).

[Cheng98] Cheng, D.Y.: Design of a Virtual Environment that Employs Attention-Driven Interaction and Priorization. *Proceedings of the 4th Eurographics Workshop on Virtual Environments* (1998), 114-123.

[Coelho01] Coelho, L.C.G., Nishimoto, K. and Masetti, I.Q.: Dynamic Simulation of Anchoring Systems Using Computer Graphics. *OMAE Conference* (2001).

[Coelho03] Coelho, L.C.G., Jordani C.G., Oliveira, M.C. and Masetti, I.Q.: Equilibrium, Ballast Control and Free-Surface Effect Computations Using The Sstab System. *8th Int. Conf. Stability of Ships and Ocean Vehicles - Stab* (2003), 377-388.

[Froehlich99] Froehlich, B., Barrass, S., Zehner, B., Plate, J. and Goebel, M.: Exploring GeoScience Data in Virtual Environments. *Proc. Visualization 99* (1999).

[Greenhalgh01] Greenhalgh, C.: Understanding the Network Requirements of Collaborative Virtual Environments. *Collaborative Virtual Environments*. London: Springer, 2001.

[Johnson01] Johnson, A. and Leigh, J.: Tele-immersive Collaboration in the CAVE Research Network. *Collaborative Virtual Environments*. London: Springer, 2001.

[Parkin99] Parkin, B.: The Human Sphere of Perception and Large-Scale Visualization Techniques. *Conference Guide of the 1999 High Performance Visualization and Computing Summit Oil & Gas*, Silicon Graphics, 15.

[Petrobras99] *Petrobras Magazine*, 7, 26 (1999), 20-23.

[Petrobras01] *Petrobras Magazine*, 7, 33 (2001), 14-17.

[Reis01] Reis, L.P., Bosquet, F. and Paul, J.C.: Toward collaborative geomodeling. *Proceedings of the 21st GOCAD Meeting* (2001).

[Singhal99] Singhal, S. and Zyda, M.: *Networked Virtual Environments: Design and Implementation*. New York: ACM Press, 1999.

[West01] West, A. and Hubbold, R.: System Challenges for Collaborative Virtual Environments. *Collaborative Virtual Environments*. London: Springer, 2001.