PUC

Workspaces' Challenges for the Oil & Gas Exploration & Production Industry

Enio Emanuel Ramos Russo
Alberto Barbosa Raposo
Terrence Fernando
Marcelo Gattass

Departamento de Informática

Workspaces' Challenges for the Oil & Gas Exploration & Production Industry *

Enio Emanuel Ramos Russo

Alberto Barbosa Raposo

Terrence Fernando

Marcelo Gattass

Workspaces' Challenges for the Oil & Gas Exploration & Production Industry

Enio Emanuel Ramos Russo[1]   **Alberto Barbosa Raposo[1]**
Terrence Fernando[2]   **Marcelo Gattass[1]**

[1]Laboratório de Computação Gráfica – TecGraf

Departamento de Informática

Pontifícia Universidade Católica do Rio de Janeiro – PUC-Rio

R. Marquês de São Vicente, 225, 22453-900. Rio de Janeiro, Brasil.

[enio, abraposo, mgattass]@tecgraf.puc-rio.br

[2] The University of Salford

RESUMO

O objetivo deste artigo é pesquisar e analisar os principais desafios encontrados na definição e construção de *workspaces* de realidade virtual para as atividades de exploração e produção na área de óleo&gás. Inicialmente, classificamos e descrevemos os diferentes desafios. Em seguida, apresentamos as principais atividades da indústria de óleo&gás que utilizam esta tecnologia.

Palavras-chaves: workspaces de realidade virtual, ambientes virtuais, colaboração, óleo & gás.

ABSTRACT

The objective of this paper is to prospect and analyse the main challenges faced when defining and building virtual reality workspaces for Exploration & Production oil & gas activities. Initially, we classify and describe the different challenges. Then, we present the main activities in the oil & gas industry that use this technology.

Keywords: virtual reality workspaces, virtual environments, collaboration, oil & gas.

1. INTRODUCTION

Computer graphics has always played an important role in many oil & gas Exploration & Production (E&P) industrial areas since the eighties. This is not difficult to understand as we analyse the main activities developed in these areas. For example, geophysicists, geologists and reservoir engineers have been using for many years 2D slices to represent oil reservoirs, the object of their studies. Similarly, platform engineers used 2D plants to execute the basic project of a platform. This was first made by hand and then using 2D computer graphics systems. A common challenge that all the E&P areas have to deal with is the huge amount of data involved in all of their processes.

The next step was to integrate all these 2D slices or plants to build 3D models. This began with the development of new systems and the availability of processors with higher performance. By the mid-eighties, specialists were already using graphic workstations with dedicated graphics processors, but still connected to a main host responsible for the application processing. This soon evolved to a different architecture, with the workstations having more and more capabilities, leaving only centralized tasks to the main servers, such as data base management systems. By the same time, considering the huge amount of data to be processed, parallel systems started to be used in order to reduce the total processing time.

Taking advantage of the technological evolution and trying to respond to the increasing demand of 3D systems, oil companies were among the first to make industrial use of the so-called virtual reality centres (VRCs). The motivation for this was not only driven by technological issues, but was also related with the difficult time companies were facing in the late nineties, with the price of oil hovering near all-time lows. The pressure to reduce finding and development costs for new reserves and existing fields was immense, so immersive technologies became one of the key tools to meet these challenges.

These VRCs, rooms with features such as 3D and stereoscopic images, are very helpful in oil E&P operations and in projects for oil facilities [Petrobras99], giving specialists the ability to quickly and comprehensively interpret large volumes of data, significantly reducing cycle time for prospect generation [American98].

After some time for the specialists to get used to this new technology, it rapidly became a useful and powerful tool, creating a demand for even more complex capabilities, such as real-time processing, interconnected VRCs, collaborative applications and many others.

Considering all those new issues, it is very important to generate an adequate workspace for each type of application. The objectives of this paper are to prospect and analyse the main challenges faced when defining and building workspaces for each of the oil & gas E&P activities and to propose an architecture suited for an emergency scenario engineering case. In order to achieve it, this paper is structured in the following sections: (2) classes of challenges; (3) types of E&P applications; and (4) conclusions.

2. CLASSES OF CHALLENGES

In this section, we classify and describe the different types of challenges faced when building workspaces for the oil & gas E&P industry.

2.1 Expectations and Perceptions

The level of expectations in computer graphics and virtual reality areas may be much higher than when dealing with simple desktop applications. The entertainment industry has created such realistic movies and videogames that technical users working in VRCs expect quality levels at least similar to those. For the users the complexity of the data involved does not matter; they simply want realism.

Accordingly to Johns [Johns00], the main factors involved in realism are: (i) scene realism; (ii) consistency of virtual environment data with real-world experience; and (iii) meaningfulness of experience.

That is why it is so important to first identify and designate who are the specialists that will use the system. We also have to find and understand which are the tasks and activities that each type of specialist will execute with or inside the system. Some studies have been carried out trying to develop methods and techniques to meet these requirements, like those of immersive modelling [Deisinger00], those of a geosciences VR toolkit [Bosquet99] and those present when interacting with simulation data in immersive environments [Knöpfle00]. Considering these studies, we are led to the conclusion that the virtual reality world is so broad and the possibilities opened with it are so many that we have to focus on developing a particular framework for each type of application instead of developing a more general one that could cover many types of applications.

Another challenge intimately associated with meeting the users' expectations is to deal with the different levels of perception the users experience when they move out of the workstations' screens and go to the multidimensional and multisensory worlds of the virtual workspaces. The challenge here is not only to deal with different perceptions of the virtual world from users and specialists in a common 3D visual experience, but also to define the technology – CAVEs, reality rooms, immersive workbenches, HMDs, stereo projection – that best fits a type of specialist or even a single user in terms of intuition, attention and productivity [Parkin99].

2.2 What to Visualize

The second class of challenges considers those involved in defining what to visualize in a virtual workspace for a specific application. If we consider that usually oil & gas applications deal with a huge amount of data, that becomes a complex task. Also we have to consider performance and hardware architecture issues, as well as

1

real-time requirements in order to define a possible and satisfying visualization condition.

2.2.1 Huge amount of data versus performance

A common characteristic of a typical oil & gas E&P application is the enormous amount of data it has to deal with. This occurs not only with the geoscientists working to interpret and visualize multidisciplinary data in order to arrive at a consistent model of the subsurface, but also with the engineers planning and implementing improved methods for drilling and conducting plant walk-throughs and fly-overs in a virtual world before the real-world object exists [Johnson99].

The difficult task here is how to decide what part of the data to visualize at each time. This happens not only because of performance and real-time constraints but also because in many cases we do not need to visualize the entire model in all its details. For example, while interpreting a reservoir model, it may be necessary to be aware of every single detail, since hard-to-find faults can be the keys to the whole interpretation. On the other hand, it may be unnecessary to show all the components of a CAD model, while executing a walk-through or a fly-over in its VR correspondent model, especially in real time conditions. That results in the necessity of building a visually simplified representation, without eliminating key structures.

Thus, oil & gas workspaces' developers need to elaborate optimisation algorithms as well as to build efficient hardware architectures to deal with these complex models.

2.2.2 Real-time requirements

Most of the E&P applications do not have specific real-time requirements. This happens because, when specialists perform tasks such as interpreting or modelling an oil reservoir, design review, change management systems or training, they may need accurate models, but not changing so fast that the real-time requirement would be the most important.

Even so, as virtual workspaces became more common in the oil & gas industry and users got more used to them, new applications and real-time requirements began to arise. Some of these, that we will cover in more details in section 3, are: (i) real-time follow-up and correction of the course of a deepwater horizontal well; (ii) subsea offshore equipment installation; (iii) dynamic simulation of offshore structures; and (iv) applications that deal with emergency scenarios.

2.3 Collaboration

One of the most important challenges to be addressed by an oil & gas E&P virtual workspace is to provide an efficient collaborative virtual environment (CVE). This is easy to understand if we consider that most of the oil & gas E&P projects involve many professionals, in many cases spread over a country or even in different continents, working together and being integrated. The objective here is that cross-functional team members collaborate more effectively and make decisions more quickly and accurately. To satisfy all these requirements,

we need to guarantee distribution support, an efficient network with a large bandwidth, adequate communication and data storage models, as well as to define what are the collaborative operations and metaphors the system is going to provide.

2.3.1 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 ultimately insurmountable. Real-time shared interaction is particularly sensitive to lag, especially in the case of immersive interfaces. The application's sensitivity to such lag depends on the degree of genuinely shared interaction desired. For example, in a passive walk-through of a model, small temporal discrepancies between the participants' experience of the world may well go unnoticed. At the opposite extreme, the two people operating a stretcher through the confines of an oil rig will find coordination difficult or impossible with any appreciable lag.

If it is not possible to achieve the adequate synchrony, we should 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. This involves determining a metric of significance and prioritising urgency within the communication infrastructure accordingly [West01]. Ultimately, as the components of a CVE system interact in complex ways, the designer must regard the application as a unified system. Invariably, trying to optimise one element of a CVE can adversely impact the behaviour of other components. In effect, CVE development is a difficult balancing act of engineering tradeoffs [Singhal99].

2.3.2 Network requirements

We cannot understand the network requirements of CVEs in isolation; rather, we need a model of CVE operation which encompasses 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 (section 2.1).

2. User behaviour: what particular actions do people do and when. It is important to consider user behaviour when trying to understand the network requirements of CVEs because almost all of those requirements derive from what the users choose to do and when they choose to do it. 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 of use there must be enough bandwidth for every user to speak at the same time.

3. Process behaviour: how does the application respond. Every CVE system has its own set of capabilities and its own ways of representing users and virtual worlds. For example, each system supports a different subset of possible user actions.

4. Distribution architecture: what communicates with what. The choice of distribution architecture determines which information must be communicated to which parts of the system. The distribution architecture will therefore determine how virtual worlds are organized and divided, which users can communicate with each other, and whether or not there are any central coordinating processes or servers. The distribution architectures can basically be divided into four models: client/server, peer-to-peer, object-oriented distributed computing and hybrid [Rodello01].

5. Communication protocols: how is information exchanged. Protocols can be either unicast or multicast. The developer has to choose the best distribution architecture/communication protocol combination that fits the particular application being elaborated.

6. Network communication: what actually happens in the network. There are some network requirements that depend on exactly where in the network each application is running and how the network is connected (e.g. LAN or WAN), since the actual bandwidth in different parts of the network will vary. We have also to consider that, in the particular case of oil & gas applications, 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 is usually done by a mobile system and is especially important when we are dealing with emergency scenarios.

The choice of distribution architecture is the main factor determining much of the multi-user "feel" of a CVE. For example, the distribution architecture will typically determine:

The possible structure of a virtual world, e.g. whether it copes well with large outdoor spaces or with complex building interiors. In the oil & gas industry we have to deal with both situations, as for example when building a complex offshore structure in a project room (indoor space) or monitoring oil pipelines disposed over a mountain (outdoor space). The challenge becomes even more complex when we have to deal simultaneously with the outdoor and the indoor spaces as it happens in some emergency scenarios, for example making decisions in a meeting room (indoor space) while dealing with a crisis in an offshore structure (outdoor space).

How many users may share a single virtual world. Typical 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 some cases, specialists spread over the outdoor space may have the need to enter the virtual world using a mobile system.

The dynamics of the virtual world, including the ways in which behaviours may be realized and what things may and may not be changed. For example, it is extremely hard to dynamically change basic geometries in some systems, whereas it is relatively easy in others. This is a very important issue of oil & gas applications considering the complexity of the data involved. What usually is done is the replication of the data model among the sites before the collaboration session begins. To avoid network overload, normally during a session the users are only allowed to do some incremental updates, transmitting only small data and/or action messages.

For the moment, we can say that there is no universal choice of distribution or communication architecture, but rather a range of trade-offs in performance and deployment issues.

We will also add another important requirement, intimately related to the ones above: the data storage model. Accordingly to Macedonia and Zyda [Macedonia97], the data storage models can be classified in: (i) centralized and shared data base; (ii) homogeneous worlds replicated data base; (iii) distributed and shared data base with peer-to-peer modifications; and (iv) distributed and shared client/server data base.

Due to many aspects, such as consistency and security of the data base, the oil & gas applications should use the centralized and shared data base model. The problem again is that the data base involved in those applications is huge and complex, limiting its centralized use. What we then observe is that almost all the practical applications use the replicated model, some of them allowing the users to make what we call incremental updates.

2.3.3 Collaboration operations and metaphors

All the generic operations made by a single user can be extended to allow collaborative operations. In a common integrated work done by the oil & gas industry, it will sometimes be interesting for one type of specialist to have his own view of the data model, working on it asynchronously and then going back to the synchronized session, passing his own conclusions to the other participants.

Metaphors specify the different paradigms that can be used to interact with data sets and to collaborate in virtual environments.

In terms of collaborative metaphors used in a visualization system, those that express the sharing of the participants' points of view are the most important. These metaphors include: (i) sharing of each other's point of view (look over the other's shoulder) – third person metaphor [Cheng98]; (ii) the same point of view (look through the person's eyes) – first person metaphor; and (iii) reflect the point of view (the opposite side of the situation) – second person metaphor.

2.4 Workspaces

In order to meet the users' expectations, we not only have to define what to visualize and fulfil the collaboration requirements, but also to build an adequate workspace for the specific application being considered. We do this by choosing the most appropriate interaction techniques and defining what kind of visual immersion or tele-immersion will be provided.

2.4.1 Interaction techniques

In contrast with the metaphors, the interaction techniques determine how to support and implement the different types of operations [Junior01]. Because of the nature of an immersive visualization environment, user interface and interaction modalities are critical to the success of the application and the environment.

Particularly in the case of geosciences applications, we have observed that users found the Cubic Mouse [Froehlich99], an input device specially tailored to geo-scientific data, very useful to 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.

2.4.2 Visual immersion and tele-immersion

One of the main concepts of 3D visualization is the concept of immersion. Immersion allows a better understanding of the depth and the spatial relationships among the objects in a 3D scene. 3D conventional visualization techniques allow the simulation of four physical properties of the real world capable of providing an immersion sensation: perspective projection, object occlusion, illumination and atmospheric attenuation. Virtual reality may increase this immersion level by adding three other properties: stereoscopy, ocular convergence and parallax [Romeu00].

In general, we define visual immersion by at least three characteristics [Pajon00]: (i) almost all or actually all the vision fields receive a visual information flow; (ii) the visualization of the 3D scene is stereoscopic; and (iii) the point of view over the 3D scene is set in real-time accordingly to the observer's position by capturing his head movement (head-tracking).

Nevertheless, applications really adapted to these environments are still rare. In general, standard desktop applications are used, and collaboration is improved mainly due to the fact that people share the same physical space, with their attention dedicated to a large-size visual representation of their data. Effective interaction techniques for either individual or collaborative activities are still underdeveloped [Reis01].

For ultimate collaboration – tele-immersion, which truly integrates distributed virtual reality with audio and video conferencing – very strict and unusually broad networking requirements are posed. The goal of tele-immersion is not to reproduce a face-to-face meeting in every detail, but to provide next-generation interface for collaborators worldwide to work together in a virtual environment that is seamlessly enhanced by computation and access to large data bases. While the goal of audio and video teleconferencing is to allow distributed participants to interact as though they were in the same physical location, tele-immersion allows them to interact as though they were in the same immersive virtual environment. This way, they can interact with each one another and the objects in their shared environment [Johnson01].

3. TYPES OF E&P APPLICATIONS

Having described the classes of challenges developers have to face when building adequate workspaces for the oil & gas industry, we are now going to see what the main applications of this sector are, focusing on the main challenges of each type of application. This section is mainly based on the authors' experience working in Petrobras projects.

The typical E&P sequence of activities, with the components illustrated in Figure 1, is comprised of: (i) reservoir characterization using 3D geomodelling and seismic interpretation; (ii) building and installation of the production facilities based on the results of the first phase; and (iii) transportation of the produced oil & gas.
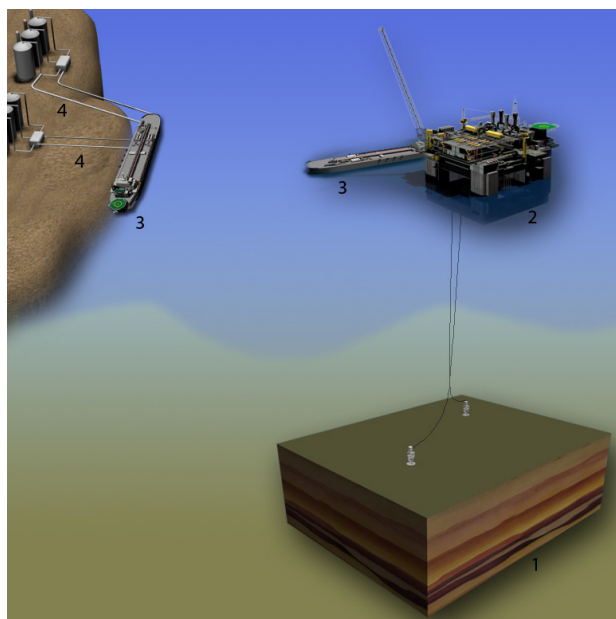
Figure 1: (1) reservoir; (2) offshore platform; (3) transportation ships; (4) oil pipelines.

In the next subsections, we are going to describe how virtual reality can enhance each of the E&P phases.

3.1 Geosciences Applications

Geosciences applications were probably the first ones of the oil & gas industry to make use of 3D visualization. This is not difficult to understand if we consider the type of activities the specialists involved in this area execute. The goal is to elaborate the subsurface model that best represents the reservoirs. It does not matter if it is a seismic cube or a stratigraphic geological model – what is important is to build an individual mental representation of the model. It became clear that 3D visualization could

help a lot in building this mental representation as well as in integrating different specialists in a team effort. From initial seismic quality control, horizon interpretation and fault validation to reservoir framework construction and multivolume co-rendering, visualization has reduced the interpretation's life cycle and its associated risks [Evans99].

3.1.1 3D geomodelling

This type of application 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 and evolves continuously, in a team effort [Reis01].

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. We 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 are 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) are analysed with the purpose of ascertaining the best distribution patterns for production and injection wells [Petrobras01].

In order to make this available to the specialists, Petrobras built the first Latin America VRC in its R&D centre (CENPES) in 1998, with the main purpose of proving the benefits of this new technology. Petrobras now has ten VRCs being used all over Brazil, including a holo-space recently installed in its head office.

The main software that has been used in 3D geomodelling until now includes GOCAD and Earth Vision, from Dynamic Graphics. The latter has played an important role, since it was the first one to allow users to have synchronized view of the earth model.

The next step for truly collaborative geomodelling and visualization is the extension of collaboration to distributed users. Given the usual geographical dispersion of expert professionals in the oil & gas E&P industry, remote collaboration offers great potential benefits, particularly in activities involving continuous model refinement and decision-taking, such as reservoir management.

3.1.2 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 a sort of subsurface

ultrasonography, generating seismic logs that provide an approximate image of the configuration of several subsurface strata.

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.

The advent of VRCs and stereoscopic images opened a door to a new world for seismic interpretation, allowing the users to watch the same seismic data on paper, but in much more detail due to perspective. The work became easier nowadays because specialists no longer use their knowledge and imagination alone 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].

In terms of software, several geophysical visualization programs have been developed, namely, in-depth Reverse Time Migration, 2D and 3D acoustic and elastic seismic modelling, and seismic volume visualization [Silva03]. Figure 2 shows different seismic volume-visualization methods: the image on the right uses the traditional illumination method; the image on the left uses the method proposed by Silva [Silva04].

This kind of tool requires heavy processing capabilities. The technological solution to this problem was to cut down on hardware costs by deploying PC-based computer clusters. Many geophysical problems may be thoroughly solved through parallel processing performed by clusters because seismic curves display an intrinsic sort of parallelism [Petrobras01].
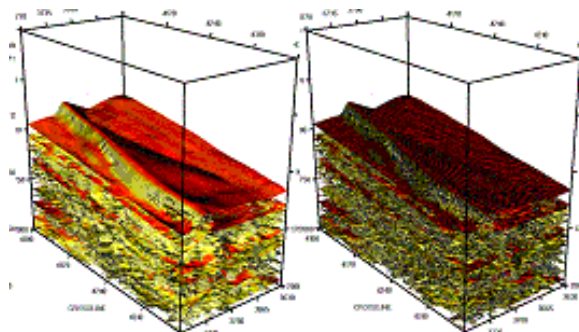
Figure 2: Seismic volume visualization with different methods.

The next step for seismic interpretation is to begin to use new interaction techniques such as gloves with sensors to move images, viewers to control a sequence of images, and substituting head movements for the mouse. Petrobras has already begun to use these techniques in a prospective way and is deciding when it will be the appropriate time to use them in production.

3.1.3 Real-time follow-up and correction of the course of a deepwater horizontal well

This is one of the activities that 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 wake of typical difficulties in this kind of job and 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 a well of about US$ 20 million may be lost. Hooked up by optic fibre cables to the offshore platforms, the VRCs allow the survey of real-time drilling, making 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, but this demand is not so high. Usually rig information is sent from the field at regular time intervals, so that it is possible to rebuild the model with the new information. The system must then be able to receive new information and rebuild the model in what we should better call a quasi-real-time condition instead of a true real-time condition. One solution currently used for this purpose is the gWLog [Campos02].

3.2 Engineering Applications

The second main class of activities developed by the oil & gas industry that make use of 3D visualization is that of engineering applications. In this case, we are interested in building and visualizing oil platforms and offshore structures, performing static and dynamic simulations of these structures, monitoring oil pipelines and dealing with emergency scenarios, among others.

The engineering area was one of the first to make intensive use of computer graphics resources. This was achieved with the use of CAD systems and models. Other applications demanding computer graphics began to be developed, mainly for post-processing numerical simulations. The engineers soon realized that with an adequate video they could display a structure deformation or reproduce a walk-through in an offshore facility, with both technical and managerial purposes. This was first done using desktop screens. Later, with VRCs being introduced in the oil & gas industry, the use of this type of resource was greatly increased.

In order to meet this growing demand, the Petrobras R&D centre decided to build a second VRC, this time specific for the engineering area.

3.2.1 Building, walking through and flying over offshore facilities

Offshore structures modelled using CAD systems have every single piece highly detailed, since the goal here is their building process.

That is not always the case when dealing with virtual reality applications over these types of data, because in this case our focus is in visualizing and walking through the facility with good performance and sufficient realism. It is necessary to treat the data before visualizing them. Also the functional way in which the data is organized in these models is not the best to visualization tasks. Sometimes, especially in training activities, we need precision and cannot discard some details that would normally be discarded when visualizing the model.

For this purpose, many recent works have been developed searching for efficient solutions to the

conversion of CAD models to VR models. An example is the ENVIRON tool, shown in Figure 3 [Corseuil04].
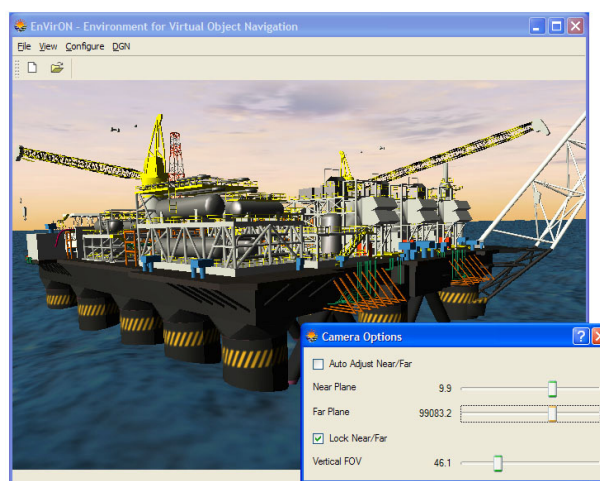

Figure 3: ENVIRON screenshot.

The installation of subsea equipments is another E&P activity than can be greatly benefited by the use of virtual reality. This enhancement is obtained considering that: (i) the work in these deep areas is normally done by remote-operated equipments; and (ii) as the number of equipments increase, it becomes more critical to install a new one, requiring good precision.

3.2.2 Capture of 3D as-built models

A relatively recent engineering application that also uses computer graphics resources is the capture of 3D as-built models. This is usually done by means of a 3D laser scanner that is capable of acquiring a cloud of points from the real structure. This is only the first step of the process, the most difficult task being the reconstruction of the 3D model based on this cloud of points. In order to achieve this, developers use specialized algorithms and heuristics, knowing that it is almost impossible to reconstruct the model in a totally automated way.

The motivation for the growing demand for this type of application was the necessity to have the original structures' plants updated according to their real state. In the case of an accident, this is even more critical because usually specialists will not have access to the real structure, having to work with its model to make rescuing decisions. It would be very interesting to have a virtual workspace to monitor and evaluate this process.

3.2.3 Static and dynamic simulations

This a very important engineering application used in many situations: to validate models being constructed, to analyse specific stress conditions, to deal with emergency scenarios, etc.

Most of the simulators are still static, but the demand for dynamic simulations is growing rapidly. In the oil & gas industry, the upkeep of complex structures where thousands of barrels of oil are produced daily in the open sea also requires calculating the action of sea currents, waves and winds on semi-submersible platforms and Floating Production, Storage and Offshore Loading

(FPSOs). Additionally, these production units may be afloat in regions two thousand meters deep or more, therefore requiring the deployment of complex mooring systems. To deal with such problems, Petrobras developed software such as Dynasim [Coelho01], to compute the supervening forces and consequential movements on anchored structures, and MG [Coelho00], designed to generate mesh-shaped graphic representations of surfaces in order to make their modelling easier for the numeric simulators as well as to make it possible to visualize the stresses that act on them.

Two other important simulators developed by Petrobras that make use of visualization systems are:

The Numerical Offshore Tank (NOT), a computer-intensive applied hydrodynamics lab whose main goal is to simulate and analyse floating production and storage oil & gas systems. The strong points in the NOT are the hydrodynamic numerical & empirical models, considering the interaction between waves and currents, the line dynamics and the damping, a strong graphical interface and full 3D visualization of the results of simulations. NOT has incorporated several innovations, such as massive parallel computing through a high-performance parallel PC computers cluster and an immersive visualization system that presents the simulation results in true 3D stereoscopic graphic as the virtual reality world.

The Floating Units Stability System (Sstab), which is used to project and analyse static conditions of floating units such as semi-submersible oil platforms [Coelho03]. This system had been successfully used not only by certifying companies but also in emergency scenarios under extreme conditions. It also works integrated with the Dynasim system (Figure 4). For the moment, it is being mainly used in desktop computers, but it is planned to be enhanced to a virtual reality system for both training and emergency handling purposes.
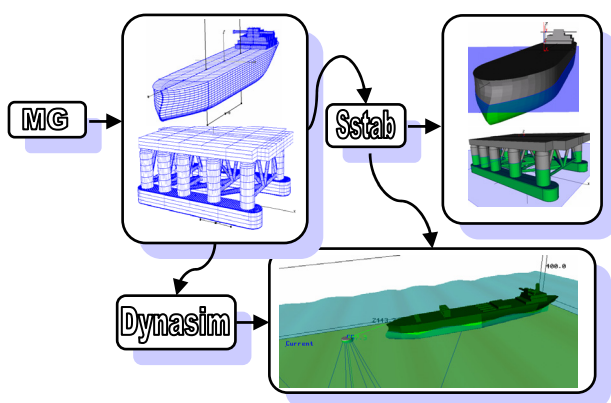
Figure 4: Integration among simulation tools.

Sstab has a very intuitive interface, with menus, data spreadsheets, buttons and a big feedback canvas area (Figure 5). When you feed Sstab with a new load case, it computes it and then suddenly moves to the new equilibrium state.
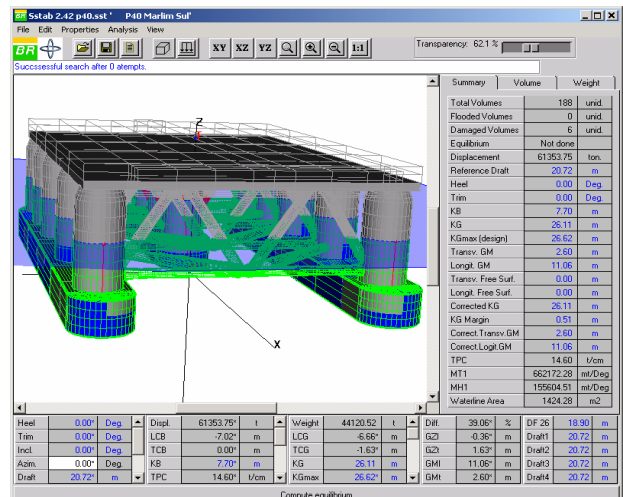
Figure 5: Sstab's interface.

Virtual reality may be an important enhancement for Sstab. In terms of training, for example, the following goals can be achieved:

To make the movement between states smooth, so that the users can feel what is happening with the unit.

To integrate it with a hardware simulator, so that the users not only have a stereoscopic view of what is happening but can actually feel the movements suffered by the unit.

Having defined the main objectives of a virtual reality training version of Sstab, we still have another important point to consider: the point of view to be used when doing the training. The most intuitive point of view is that of the first person, in which the user feels as if he were inside the unit, feeling all its movements. This can be interesting because some people feel sick with the sea movement and, with this training, they can evaluate this and be better prepared to face reality.

The third-person point of view can also be very interesting, and it can be more comfortable for the user to observe the unit's reactions as if he were watching a movie. Also, for those who do not feel very well with the sea movements, it can be more pleasant to be outside the unit

3.2.4 Oil pipeline allocation and monitoring

3D visualization techniques are used for pipeline allocation, which is made accordingly to environmental information. SAAAP (Figure 6) is a system for the calculation of the best pipeline trajectory and for its environmental evaluation based on the terrain's characteristics.

To better analyse oil pipeline deformations, we may use post-videos over the structural analysis results. Moreover, it would also be very interesting to have a virtual reality system capable of acquiring and transmitting visual data directly from the oil pipeline in the field. The main reasons for this are:
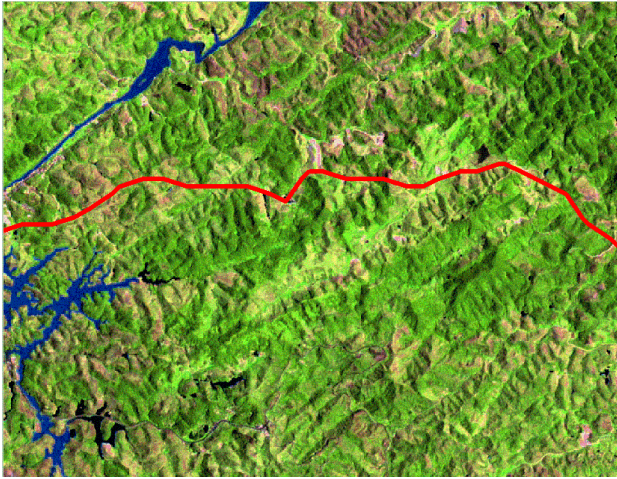
Figure 6: Virtual pipeline trajectory over a satellite image.

Normally the access to these pipelines is not easy, so not many specialists go directly there.

The manager or the specialist can be called and visualize the oil pipeline directly from the field in case of an accident or when a part in need of repairs is found.

The main requirements of this type of application are:

Capture quality has to be good enough for people in the office to have a precise idea of what is the pipeline's state.

The equipment being carried by the specialist in the field must not be heavy, since he usually has to move to points of difficult access.

The equipment has to use long-life batteries, considering that usually the specialist can walk for hours without energy points.

The system needs mobile capacity with the feature of occasionally connecting to a satellite considering that sometimes it has to work at points of difficult access.

The flexibility of the system displaying the captured video is also desirable: it can be interesting to show it on the manager's laptop screen or in a VRC and, even better, possibly in both simultaneously.

Petrobras is now analysing and testing some solutions provided by both the market and some universities.

3.2.5 Emergency scenario applications

This type of engineering application is growing in importance among oil companies mainly because of the growing concern with the Earth's environment.

Petrobras has developed, together with the Tecgraf/PUC-Rio lab, some systems to deal with emergency situations in E&P activities. InfoPAE [Carvalho02] is a system developed to manage and control actions during an emergency situation (Figure 7). The system was conceived to help and minimise the actions' response times, to validate and optimise the emergency plan's logic and to train the teams responsible for the actions. It provides facilities to manage conventional and geographical data, associating them with the plans. In

terms of E&P activities, InfoPAE is used for oil pipelines and jointly with an oil-spot monitoring application.
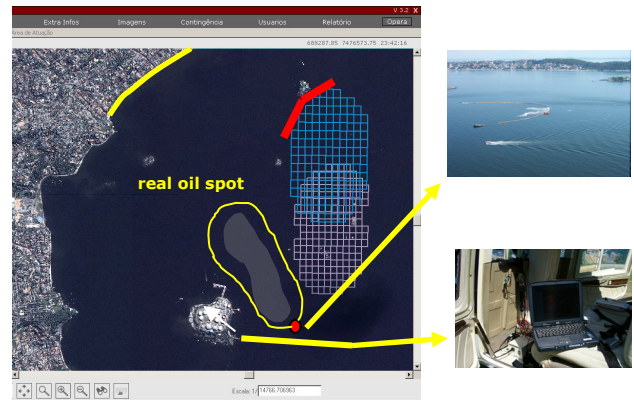
Figure 7: InfoPAE: emergency scenario application.

Dynamic InfoPAE is an integrating system that provides an environment to monitor and execute simulations during an emergency condition. The system allows the centralized control of the applications' executions, which supports collaborative work in emergency scenarios, assuring the reliability of the results obtained during the emergency.

Another typical emergency scenario in the oil & gas area is that of crisis in an offshore structure. The specialists involved are: naval engineers, structural engineers, risers analysts and oceanographers. In this scenario, there are two main possibilities:

If the unit is heavily damaged and has security problems, the unit is abandoned and no person remains inside of it. The only possible work is done by divers.

If the unit has a minimal security condition, it usually remains with two or three operators. Then, it is possible to give them orientation from earth.

The scenario on earth is the following: some specialists remain in their offices, such as the head office and the R&D centre office, while other specialists move to the nearest base to the unit – they will usually be ahead of the whole operation. It is necessary to connect all these specialists by a network system. Each site can have different configurations, such as a VRC, an intranet desktop and a laptop connected to the network. Sometimes there may also be a specialist that is overseas or travelling and who must also connected, for instance by means of a kind of mobile system.

Virtual reality, combined with collaborative versions of simulation tools, such as Sstab, could provide an integrated solution to this scenario (Figure 8).
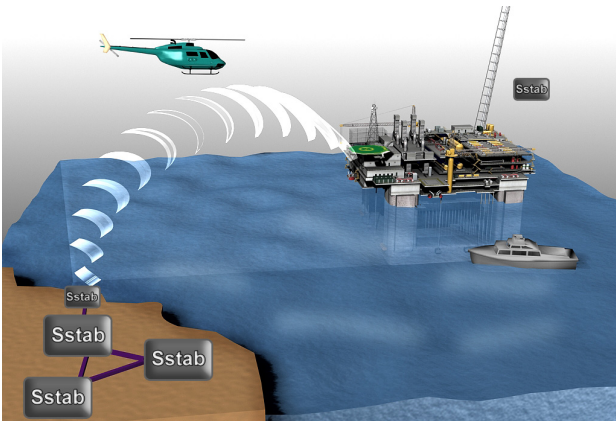
Figure 8: Sstab's collaborative application scheme.

4. CONCLUSIONS

The virtual reality world is so broad and has some many capabilities that it has become almost impossible to cover all the requirements to support every application. The solution is thus to develop specific virtual workspaces for each type of application instead of trying to build a generic one to cover all types of applications. Practical applications in the oil & gas industry are adopting this paradigm, with relative success in many cases.

A very important issue to be considered in developing virtual reality applications is to properly define the users' expectations. By doing this, the chance of success is highly increased.

During the development of E&P applications, especially when using VR resources, we have observed that the users' understanding, expectations and perceptions of the system have varied considerably. So it is very important to have the application very well defined before beginning its implementation.

It appears to be a good strategy to define the best and the minimum requirements of the systems. This way we can achieve our target more easily as well as understand the requirements to be covered to reach the other steps.

As future work, we are experiencing new interaction techniques and VR resources in the applications already developed as well as prospecting new areas of the E&P sector that could benefit from the use of the VR technologies.

5. ACKNOWLEDGEMENTS

6. REFERENCES

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

[Bosquet99] Bosquet, F.: The Design and Implementation of a Geoscience VR Toolkit. *Conference Guide of the 1999 High Performance Visualization and Computing Summit Oil & Gas*, Silicon Graphics, 15.

[Campos02] Campos, J.L.E.: Real-Time Well Drilling Monitoring using gOcad. *Proceedings of the 22nd Gocad Meeting* (2002), 10.

[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.

[Coelho00] Coelho, L.C.G., Gattass , M. and Figueiredo, L.H.: Intersecting and trimming parametric meshes on finite element shells. *International Journal for Numerical Methods in Engineering* (2000), 47, 777-800.

[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.

[Corseuil04] Courseuil, E.T.L., Raposo, A.B., Silva, R.J.M., Pinto, M.H.G., Wagner, G.N. and Gattass, M.: ENVIRON – Visualization of CAD Models In a Virtual Reality Environment. *Proceedings of the Eurographics Symposium on Virtual Environments* (2004), 79-82.

[Deisinger00] Deisinger, J., Blach, R., Wesche, G., Breining, R. and Simon, A.: Towards Immersive Modeling – Challenges and Recommendations: A Workshop Analyzing the Needs of Designers. *Proceedings of the 6th Eurographics Workshop on Virtual Environments* (2000), 145-156.

[Evans99] Evans, F.: Visualization: A Critical Tool for All Stages of the Interpretation Cycle. *Conference Guide of the 1999 High Performance Visualization and Computing Summit Oil & Gas*, Silicon Graphics, 17.

[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.

[Johns00] Johns, C., Nuñez, D., Daya, M., Sellars, D., Casanueva, J. and Blake, E.: The Interaction Between Individuals' Immersive Tendencies and the Sensation of Presence in a Virtual Environment. *Proceedings of the 6th Eurographics Workshop on Virtual Environments* (2000), 65-74.

[Johnson99] Johnson, Z.: There Are No Upper Bounds, Only Leading Edges with RealityCenter. *Conference Guide of the 1999 High Performance Visualization and Computing Summit Oil & Gas*, Silicon Graphics, 16.

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

[Junior01] Junior, P.T.A., Goebbels, G., Kirner, T.G., Lalioti, V. and Goebel, M.: Colaboração em Ambientes Virtuais Distribuídos com Dispositivos de Imersão. *Proceedings of the 4th SBC Symposium on Virtual Reality* (2001), 148-159.

[Knöpfle00] Knöpfle, C.: Interacting with Simulation Data in Immersive Environment. *Proceedings of the 6th Eurographics Workshop on Virtual Environments* (2000), 157-166.

[Macedonia97] Macedonia, M.R. and Zyda, M.J.: A Taxonomy for Networked Virtual Environments. *IEEE Mutimedia* (1997), 4, 1, 48-56.

[Pajon00] Pajon, J.L., Grizon, L., Weibel, S., Requena, S., Bamberger, A. and Jgenti, T.: L'apport de la visualisation immersive dans l'industrie pétrolière. *Séminaire INRIA: Environnements virtuels à base de projections sur grand écrans* (2000).

[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).

[Rodello01] Rodelo, I.A., Kubo, M.M., Kirmer, C. and Tori, R.: Análise dos Principais Fatores para o Desenvolvimento de Sistemas Distribuídos de Realidade Virtual. *Proceedings of the 4th SBC Symposium on Virtual Reality* (2001), 314-325.

[Romeu00] Romeu, R.K., Mundim, E.C., Backheuser, Y., Russo, E.E., Lara, A.Q., Almeida, A.S., Reis, L.P. and Lima, L.A.: Impacto dos Sistemas de Visualização 3D e de Realidade Virtual nos Estudos Integrados de Reservatório. *Rio Oil&Gas Expo and Conference Proceedings* (2000).

[Silva03] Silva, P.M., Machado, M. and Gattass, M.: 3D Seismic Volume Rendering. *8th Int. Congress of The Brazilian Geophysical Society* (2003).

[Silva04] Silva, P.M.: Visualização Volumétrica de Horizontes em Dados Sísmicos 3D. *DSc. Thesis, Dept. of Computer Science, PUC-Rio*, to be published.

[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