Towards the Use of Collaborative Virtual Environments to Crew Unmanned Oil Platforms

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Abstract

This paper presents a human-centered vision of unmanned but crewed platforms, combining an onshore collaborative hybrid environment and an intelligent offshore oilfield. Computer Science plays a major role in this vision since digital environments are paramount for the job. We discuss the importance of research in the fields of Computer Graphics, Virtual Reality and Computer Supported Cooperative Work in this context and present the basic technologies needed to accomplish the task. We instantiate our vision appointing the results of some initial experiments using Virtual Reality in submarine installation operations.

Keywords: Collaborative Virtual Environments, Visualization, Oil & Gas.

1. Introduction

The use of Computer Graphics and Virtual Reality has revolutionised several activities, since the possibility to interactively visualise and manipulate virtual models improves the comprehension and analysis of a large amount of information of spatial nature, exploring the human capability of visual communication and reasoning. With the increasing accessibility of high speed networks, the interconnection of these visualisation applications is a natural evolution.

Collaborative Virtual Environments (CVEs) are a special case of Virtual Reality Environments, where the emphasis is to provide distributed teams with a common virtual space where they can meet as if face-to-face, co-exist and collaborate while sharing and manipulating, in real-time, the virtual artefacts of interest [7]. They can be seen as the result of a convergence of research interests within the Virtual Reality and Computer Supported Cooperative Work (CSCW) communities. CVEs are finally leaving academic and military spheres and becoming increasingly popular, partially due to the Second Life phenomenon (www.secondlife.com).

Studies of collaborative work in real-world environments have highlighted the important role of physical space as a resource for negotiating social interaction, promoting peripheral awareness and sharing artefacts [1]. The shared virtual spaces provided by CVEs may establish an equivalent resource for tele-applications. Therefore, it is natural to see CVEs as an important element for future tele-operated environments. Now, it is necessary to explain which kind of environment we are talking about. By "unmanned but crewed" environments, we mean places of difficult access where men have to "act": space, volcanoes, subsea oil exploration, among others. Due to the extremely competitive nature of the oil & gas business, probably the major efforts in this combined research area are focused on this industry [9, 11, 21]. This is the application area we are going to focus in this research.

The idea of being unmanned is in some cases a necessity due to the impossibility of human access or, as is the case of offshore oil platforms, a business challenge to reduce costs and risks. In the case of oil & gas industry, there is still the aggravation that individuals with the needed expertise are aging and there are not enough skilled workers to replace them, since fewer young people are choosing to pursue careers in oil & gas [22]. Therefore, the trend of having "digital oilfields" controlled remotely is becoming strategic for these companies. It is also important to state that we are not talking about autonomous oilfields, solely controlled by some form of artificial intelligence. We are talking about fields remotely controlled by humans.

Therefore, the challenge is to build a system adequate for a highly heterogeneous scenario, composed of not only geographically distributed teams, but also teams of specialists in different fields. This envisioned system is roughly a Collaborative Problem Solving Environment [10] providing scientific tools and technologies coupled with collaborative environments to support not only the modelling and simulation of complex scientific problems, but also the decision process, essential in the management of the digital oilfields.

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In this text we are going to discuss the role of Collaborative Virtual Environments in these digital oilfields. The basic technologies needed for the implementation of such oilfields are presented in Section 2. In Section 3 Collaborative Virtual Environments are discussed. Section 4 deals with the needed functionalities for collaboration. Finally, we instantiate our vision on Collaborative Virtual Environments for unmanned but crewed oil and gas oilfields.

2. Basic technologies

The vision of intelligent or digital oilfields is roughly an interplay of several technologies that provides resources for gathering raw data, transmitting this information, transforming it into knowledge (for decision making), and remotely operating it (Figure 1).

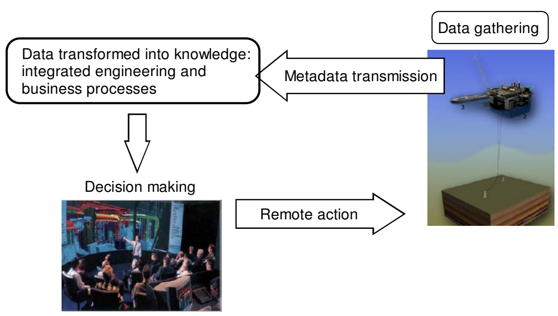

Figure 1. Technologies acting on an intelligent oilfield.

At the unmanned extreme, there are technologies for remote monitoring and tele-operation. Condition and performance monitoring generate a large amount of information that should be transmitted to the headquarters on shore. However, with the current capabilities of monitoring technologies, more than a terabyte of raw data can be generated daily. Therefore, more than simply transmitting raw data, the monitoring infrastructure should be capable of early fault detection and anomalous patterns detection, as well as should scrub, normalize and calibrate data in order to transmit useful information [11].

At the other end, tele-robotics technologies supplement and extend human inspection and intervention capabilities [21]. Also at the unmanned part, a high-bandwidth communications infrastructure plays a central role.

Our research focus, however, lies on the human part of the process, where filtered metadata is transformed into useful knowledge that should be directed to the right person, in the right format and at the right time, enabling better and faster decision making. This transformation of data into knowledge can be visualised from both the business side and the scientific/engineering side. From the business side, an integrated workflow should connect the company end-to-end and also with key partners. From the engineering side, a Collaborative Problem Solving Environment [10] should target the development and integration of scientific tools and technologies coupled with collaborative environments to support the modelling and simulation of complex scientific and engineering problems. These capabilities enable engineers to easily setup computations in an integrated environment that supports the storage, retrieval, and analysis of the rapidly growing volumes of data [17]. Figure 2 illustrates an overall vision of intelligent oilfields.

In the core of the process of converting data into knowledge, there are collaborative visualisation tools,

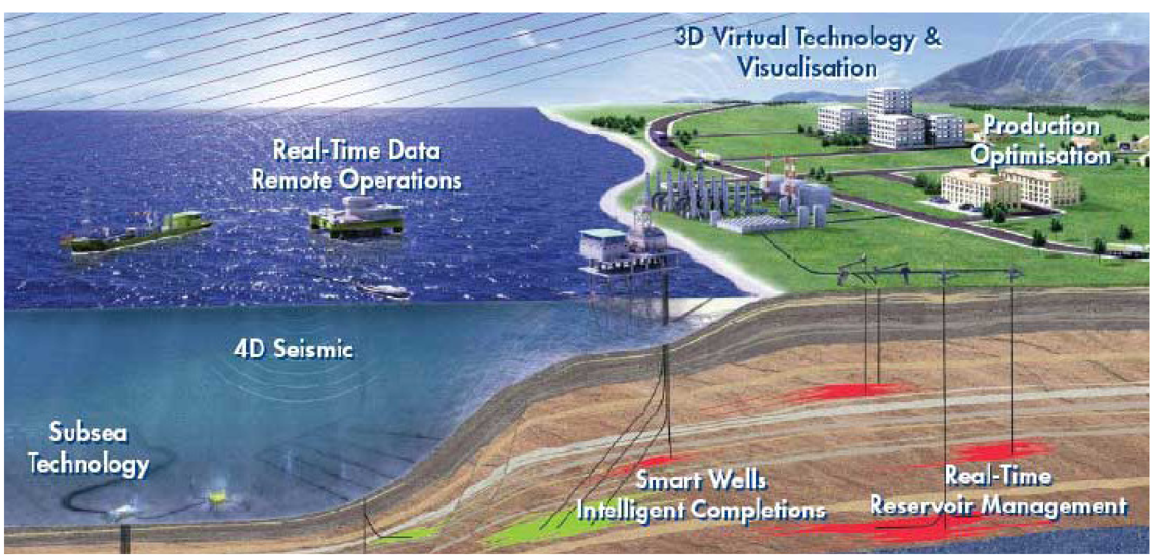

Figure 2. Artist's rendering of assets impacted by intelligent oilfields, from reservoir to onshore decision support centres (from Shell Exploration and Production Company [19]).

namely the CVEs that support a wide range of functions to perform multi-organisational team collaboration, maintenance operations, training, and information analysis, among other fundamental tasks of the intelligent oilfields.

3. Collaborative Virtual Environments

Given the geographical dispersion of operations and professionals in the industry, and the increasing availability of computing, graphics and networking resources, remote collaboration offers great potential to improve distributed cooperation and decision-making. The scarcity of experts also makes this technology very important for consulting and training [16].

CVEs are becoming increasingly used due to a significant augment in cost-effective computer power, advances in networking technology and protocols, as well as databases, computer graphics and display technologies. Moreover, as companies grow worldwide and activities grow in complexity, work involving multidisciplinary teams is becoming vital. In this scenario, visualisation plays a central role as a recognised better common language among different specialists [8].

CVEs have been used mainly by automotive and aircraft manufacturers aiming to improve the overall product's quality and also aiming to reduce project's life cycle, cutting down costs and reducing the time-to-market of new products. Examples of applications are visualisation of real-time simulation of 3D complex phenomena, collaborative virtual design and product development, training and edutainment, tele-presence and tele-robotics, business meetings, among others [17]. The oil and gas industry, as one of the biggest users of high-end hardware and visualisation techniques is well positioned to drive the directions of future research and trends in CVEs [3].

In the research towards intelligent oilfields, CVEs are essential in the conversion from data to knowledge, since they are the means to integrate diverse professionals in a common environment that may represent the real environment. In the following, we present the state of the art in CVEs.

3.1. State of the art

In the last decade, the increasing interest in distributed simulation culminated with the development of the High Level Architecture (HLA), a framework for simulation reuse and interoperability developed by the US Defence Modelling and Simulation Office [13]. HLA originated in military applications where battle scenarios were formed by connecting geographically distributed simulators. It did not originate as an open standard, but was later recognised and adopted by the IEEE [12]. Rather than a networking protocol, HLA defines an architecture with a set of API Standards. Simulation applications (known as federates in HLA) communicate by making calls to the HLA APIs. A piece of software known as the RTI (Run-time Infrastructure) implements the HLA API, and is responsible for transporting data from one federate to another. HLA is likely to be increasingly widely adopted within the simulation community [14], and may be a potential start towards the implementation of scientific virtual environments for intelligent oilfields.

Collaborative Virtual Environments might have not fully matured yet but they've definitely reached mainstream. There is a variety of them like Club Penguin (www.clubpenguin.com) sponsored by Disney and Webkinz (www.webkinz.com) which combines the real plush pet with its virtual version both targeted for kids and Habbo Hotel (www.habbo.com) targeted for teenagers. For gamers Sony is beta testing its Sony Home (www.homebetatrial.com) to be accessed via PS3 consoles. FORTERRA (www.forterrainc.com) that originally was used for simulation by the US Army now is being applied to corporate, health and educational uses. Qwaq (www.qwaq.com) sells itself as the "virtual spaces for the real work" providing the resources to facilitate all kind of meeting arrangements. On the social side of the 3D worlds, There.com (www.there.com), Active Worlds (www.activeworlds.com), Kaneva (www.kaneva.com) and Second Life (www.secondlife.com) rule. The OpenSimulator Project (opensimulator.org) offers an open source virtual worlds server which can be used for creating and deploying Second Life like environments.

The OpenSimulator Project intends to carry on supporting the Second Life Client, which is open source since January 2007, and other clients as well. The Second Life + OpenSimulator combo has proven so far to be a winning choice. Now, with the creation of the Second Life Grid (secondlifegrid.net) organisations can build their private 3D worlds, which is crucial for a vision of an unmanned but crewed oil and gas platform.

4. Communication, Coordination, and Cooperation

Initiatives that started supporting field instrumentation and monitoring are turning into strategic workflows for decision-making. Companies embarking in such initiatives are suddenly overwhelmed at the multitude of technologies available and the challenge of fitting pieces together to really create value.

A critical success factor in an unmanned but crewed oilfield system is the degree to which the collaborative system can support people in order to make better-informed and more proactive decisions [11]. Then, it is important to understand some basic concepts of human collaboration.

Collaboration may be seen as the interplay between communication, coordination and cooperation. Communication is related to the exchange of messages and information among people; coordination is related to the management of people, their activities and resources; and cooperation, which is the production taking place on a shared space. The 3C Collaboration Model is based on these concepts [2].

Communication means the action of making common, to exchange messages for the purpose of mutual understanding, to converse, to dialogue. During collaboration, members of a group normally communicate towards action: they negotiate, make decisions and reach agreements.

Coordination means the action of disposing of something according to a particular order and method, to organize, to arrange. The coordination of collaborative work aims at organizing the members of the group so that the agreements reached through negotiations are realized in the right order and timescale, reaching their objectives within their anticipated limitations. It also aims at ensuring that the effort put into communication and cooperation is not wasted.

Cooperation means the action of operating together. Members of the group act in conjunction on shared objects within a shared space to perform tasks defined and organized during coordination. In cooperating, individuals need to communicate to renegotiate and make decisions on unforeseen situations, reinitiating the cycle of collaboration [5].

Among the groupware functional models, the 3C collaboration model and its variations are probably the most widespread used, mainly due to its simplicity and generality. The most common use of the model is to classify collaborative applications.

In our research we explore the 3C model as a means to represent a groupware application domain and also to serve as a basis for groupware development. Regarding this last aspect, communication, coordination and cooperation components could be plugged to the collaboration component frameworks [6].

5. Instantiating the Vision

What is necessary to make Collaborative Virtual Environments really operational in the "intelligent oil fields"? The basic scenario is a 3D like environment representing the platform and associated subsea equipment in a virtual control room approach. Operators in different localities will work together within this virtual/augmented platform. There, in the offshore platform, purpose-built robots will be tele-operated to handle wellheads, production manifolds, production separators, glycol processors, gas compressors, water injection pumps, oil/gas export metering and main oil line pumps.

These robots that will substitute for the incidental and essential personnel will be represented by Avatars and Non Player Characters in the virtual control room. Using the North American terminology found in the Wikipedia (www.wikipedia.org), incidental personnel comprise roughnecks, tool-pushers, drillers, derrick-men, motormen, floor-hands, worms, pump-operators, tubing-operators, supervisors etc. Essential personnel comprise offshore installation manager, team leader, operations engineer, dynamic position operator, crew manager, ballast control operator, crane operator, maintenance technicians etc.

Without human beings on-board perceptual information, which is critical for platform operation, security and maintenance will have to be supplied by robots and sensors. Sensor-based awareness will play a major role on unmanned but crewed platforms. Fortunately, although instrument technology development was under-funded in last decade sensors' research and technology is now making steady progress [15, 18].

Every major oil and gas company has an intelligent oilfield initiative in place, generally in partnership with major service companies. Shell's Smart Fields, Statoil's TAIL – Integrated Operations, Chevron's iFields, BP's Field of the Future, and Petrobras' GEDIG (Digital Integrated Management of Fields) are examples. The following subsections describe some early efforts of the services companies towards unmanned but crewed platforms. Then, we will describe our experience with a prototype implementation of a Virtual Reality system for subsea installation operations.

5.1. Efforts of the major services companies

The IBM's vision of intelligent oilfield is based on five key implementation components [11]. The two bottom layers are related to gathering data and transmitting it to specialists. The two topmost layers are related to decision-making, integrating business and scientific workflows and providing means for communication, coordination and cooperation. The third layer, at the middle, is the one that connect the dots. It receives the data and integrates applications that use the same data, in order to provide the basis for the workflow. This integration is based in a service-oriented architecture.

ABB (Asea Brown Boveri) is leading a consortium created by Statoil for the TAIL – Integrated Operations project. The term Integrated Operations is defined as "collaboration across disciplines, companies and organizational and geographical boundaries, made possible by real-time data and new work processes, in order to reach safer and better decisions – faster" [21]. As can be seen in Figure 3, the idea comprises 6 subprojects. Once more, there are projects related to sensors (F1), transmission infrastructure (F3 and F5), and decision-support (F2). Differently from IBM's intelligent fields, robotics (F6) and CVEs (F4) have major roles. The focus of CVEs in this project is for preparation, training, executing and supporting maintenance operations.

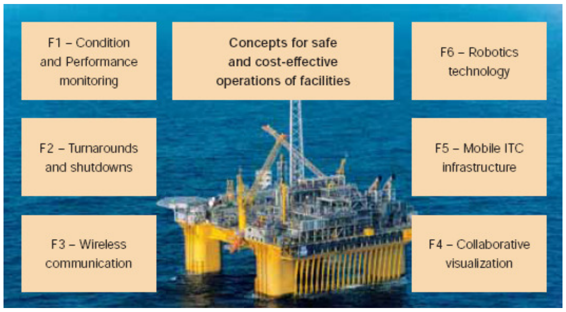

Figure 3. TAIL – Integrated Operations subprojects [21].

In CISCO's vision, a virtual oil company minimizes or eliminates obstacles created by distance, location, and time. Their vision relies on the 3C model, claiming that successful virtualization requires establishing effective cooperation, communication and coordination infrastructures, both technical and organizational [22]. In other words, organizational culture must be reinvented to place value on the 3Cs.

5.2. VROIS

The efforts towards unmanned but crewed platforms are starting to deliver results and, equally important at the moment, to identify the challenges that will demand further research. As an example, we are going to describe a system called VROIS (Portuguese acronym for Remote Visualisation of Subsea Installation Operations). The system goal is to allow that specialists on the company headquarters follow subsea operations in "extended real time" using a computational environment that facilitates the comprehension of the operation [4]. By "extended real time" we mean that we have to consider the latencies of the acoustic modems used to transmit positions in deep waters (the velocity of sound propagation in water is 1500m/s) and of the data transmission to the headquarters. A delay of a couple of seconds may be considered "extended real time" because these operations normally last several minutes (or even hours).

VROIS uses virtual reality resources to provide a better special vision of the submarine installation operation, once the real images obtained by subsea cameras installed in ROVs (Remote Operated Vehicles) generally have limited field of view and are not very clear. The operation can be visualised in a pre-configured virtual environment reproducing the real environment and the mobile objects have their positions updated according to the information received from the acoustic modems. In this virtual environment, users can move the virtual camera, having a better spatial view of the scenario. This can happen in "extended real time" or in a posterior detailed analysis of the operation. Figure 4 illustrates the interface of VROIS and a diagram of the operation.

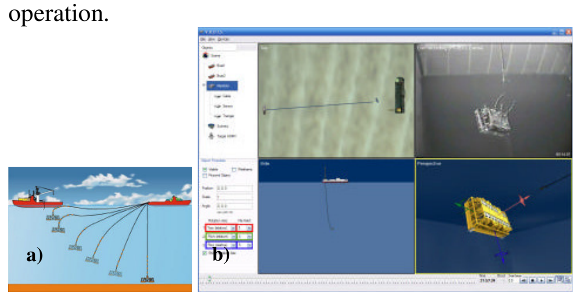

Figure 4. a) Illustration of a manifold pendular throw. b) VROIS showing the transmitted video and equivalent virtual environment from different viewpoints [4].

The first experiments with VROIS show that, although technologically viable, there are still operational restrictions regarding the positioning system, necessary to send equipment position to the program. The monitoring system is expensive and cannot be used in ordinary operations. This demonstrates a research necessity in subsea positioning systems, to make this kind of scenario really operational. A possibility that can be explored is the use of computer vision to help finding this positioning information without the need of the expensive inertial monitoring systems.

The VROIS experience as well as similar ones show that the challenge of having unmanned but crewed platforms managed via collaborative virtual environments still demands a lot of research, making for a fertile research sub-area for the next years.

6. Conclusion

A question that rises when talking about unmanned but crewed platforms is how people can embrace their new roles and the fresh technology [20]. Again, CVEs appears as a central solution for preparatory strategies like wargaming (bringing people together role-playing in virtual environments), process simulations (computer-based renditions of the new technology that people can practice on advance), and learning through building.

The role of Collaborative Virtual Environments in digital oilfields is being defined based on the state of the art of such technology. However, when combined with augmented reality, yet unforeseen possibilities may arise.

Like augmented reality, there are a lot of almost mature new technologies that will make sense for the unmanned but crewed platforms. Unlike the players listed on Subsection 5.1., we have no specific technologies for selling, which will keep us open to new developments in this multidisciplinary field. We are embarking in a long research journey.

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