Convergence of Augmented Reality and Scientific Visualization, and its Application to Energy, Medicine and Sports

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Abstract— What do we find in common among systems that seek to convey meaningful images to an oil reservoir interpreter, a medical doctor and an ordinary sports fan enjoying a broadcasted game on TV? They are generated by a system that processes captured signals and produces images conveying relevant information to the viewer. These processes are based on Computer Vision techniques to analyze the signal in order to predict forms and find features mainly to answer a "what, where and when" type of question. With such information, Virtual Reality techniques are used to produce meaningful images to the human observer. These systems can be understood as the convergence of the Augmented Reality and Scientific Visualization areas. This study presents some industry-demanded systems developed by the Tecgraf group which reflect this convergence.

Keywords: Computer Vision, Augmented Reality, Virtual Reality, Visualization.

I. INTRODUCTION

We are living exciting days in the fields of Visualization, Virtual Reality (VR), and Augmented Reality (AR). Technologies that have been restricted to research laboratories for decades are now mainstream and reaching ordinary people. 3D cinema seems to be finally mature, 3D TV is a short-term promise, Second Life and other massively multiuser online games popularized VR on the web, Wii and similar technologies brought real 3D interaction experiences to the general public, and AR is increasingly being used in videogames and marketing campaigns.

In parallel with these noticeable advances in entertainment and marketing, there are also less visible revolutions taking place in many other scenarios due to the convergence of Computer Vision, AR, Scientific Visualization, and VR. Roughly speaking, the progresses in Computer Vision are enhancing the performance of AR applications which, together with Scientific Visualization and VR, provide the possibility to improve the understanding and analysis of a large amount of information of spatial nature, exploring the human capability of visual communication and reasoning.

In this paper we discuss the application of such convergence in three very different areas, namely energy (more specifically, the interpretation of seismic data), medicine, and sports, describing the systems, the potentialities, and the challenges posed for each one.

I. SPORTS AND ENTERTAINMENT

The mixture of virtual elements and real scenarios is increasingly present in the entertainment industry. Live TV broadcasting of sporting events has evolved significantly in the last few years. Three-dimensional models of the arena and players with virtual annotation are becoming commonplace. The captured 2D image is changed to convey different points of view, trajectories, distances and dimensions. Figure 1 illustrates the first two points.

There are many interesting aspects of this technology, ranging from new research topics to new requirements for the education of future engineers. An important point to note here is that the broadcasting process is becoming three-dimensional. The signal-processing algorithms need to know where the camera is at each frame to be able to correctly add the virtual elements in the scene with the proper perspective. Furthermore, the scene must be mapped and a 3D model is required to treat the interdependence among the objects, such as occlusion and shadows.

Figure 1. 3DReplay enables the inclusion of virtual elements and the production of virtual views from diferent angles [1].

At the other end of the broadcasting process are the users, who are slowly leaving the passive position and becoming directors, deciding from which camera position they want to see a given scene.

To support all these transformations a vast amount of sound scientific research is being carried out. Due to space limitations, here we only cite a few key ones. The paper by Davison [2] is a seminal work in the quest to optically track a camera position and map the scene at the same time. Zitnick and others [3] also show a promising strategy to interpolate between cameras. The work by Paul Debevec and others (see [4], for example), which seeks to capture the light present in the scene and the movement of the actors, greatly contributed to add realism to virtual objects.

II. ENERGY

To illustrate the application in the energy industry, we will focus on seismic data. Nowadays seismic data play an important role in the Oil and Gas industry, and have been used in the whole reservoir lifecycle. They are crucial in the exploration phase to find new oil and gas accumulations, and are important in the production phase to guide water and CO_2 injection processes. These enhanced oil recovery methods are applied to maintain reservoir pressure and keep the oil production constant. Even after the depletion of the reservoir, seismic data have been used to monitor geological CO_2 sequestration in that reservoir. These are just a few uses of seismic data in the Oil and Gas industry.

In seismic interpretation, the geologist or geophysicist examines the collected seismic data in order to infer some information about the subsurface. The type of information sought varies depending on the reservoir lifecycle phase. A fundamental task of the exploration phase is to build the structural and stratigraphic models of the reservoir. The structural model is mainly compounded by the layers, horizons (interfaces between layers) and geological faults. In the stratigraphic model other geological features, such as channels, sand bodies, etc., can be included. Obviously, during the production phase, these models can be revised and refined using more accurate seismic data with better resolution. Also at the production phase, during a water injection process, it is necessary to track the advancing water front to prevent some oil portions from being bypassed by the pushing water. In the recent area of geological CO_2 storage, seismic interpretation is mainly concerned with delineating the spatial distribution of the fluid in order to identify possible leaks.

In modern seismic interpretation, the studied dataset is organized as a 3D regular grid of seismic amplitude samples (a seismic volume for short). The seismic data is acquired by placing a seismic source of energy and some receivers nearby. Several shots are fired varying the positions of the source and the receivers. For each shot fired, the seismic wave that reaches each receiver is measured and recorded over time. The set of values measured by a single receiver in a specific shot is called seismic trace. All of the collected data (traces) are them processed. Several signal-processing stages, such as binning, stacking, and time-to-depth conversion, are required to transform the captured seismic amplitudes into the regular grid that is used as the basis for scientific visualization.

To understand the reservoir, the interpreter relies nowadays on images such as the one shown in Figure 2.

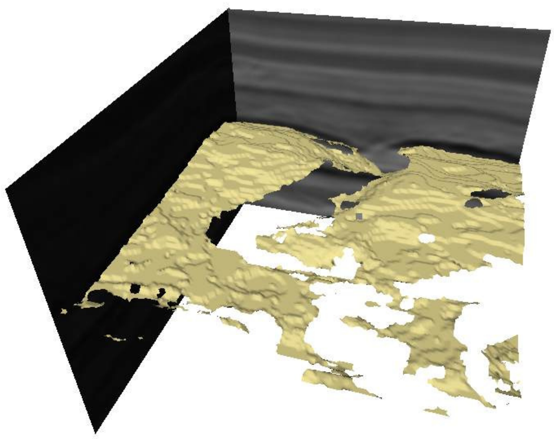

Figure 2. Horizon Visualization of a reservoir [5].

The production of a “realist” image of the horizon by itself is a Scientific Visualization and not an Augmented Reality task. What brings these areas together is the cooperative interpretation process. Immersive visualization (Figure 3) with 4K video conference (Figure 4) faces the same problems as the broadcasting of sport activities discussed in the previous section.

As the entertainment industry resorts to depth images, here we can see a complete 3D model of the reservoir being broadcasted between participants in a seismic interpretation section.

Another major activity in the oil business is the well-drilling process. In this process, acquired seismic data are presented with on-line perforation data and virtual models of the field to a geographically disperse group of engineers and geologists.

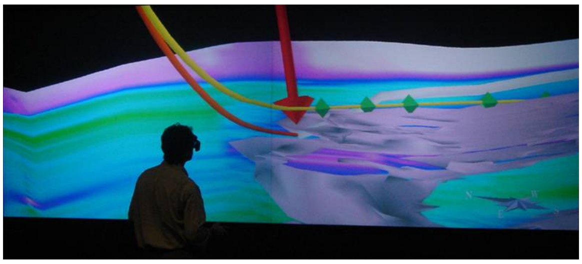

Figure 3. Immersive siesmic visualization.

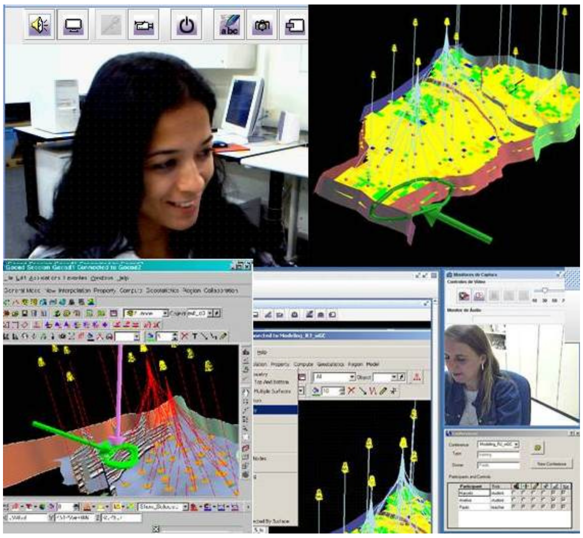

Figure 4. Geographically disperse cooperation process.

III. MEDICINE

Medicine may also benefit from Augmented Reality and related technologies. Advanced image acquisition technologies, such as Magnetic Resonance Imaging (MRI) and Computerized Axial Tomography (CT), provide a non-invasive way to look inside the patients. These devices may be combined with AR to give the physicians the ability to look and navigate inside the patients, and to analyze their anatomic structures. Moreover, the use of AR in Medicine may be used to discover the location of lesions, to assist surgical procedures, and for training purposes.

We believe that the use of AR may significantly simplify learning, planning, visualization, treatment, and surgical procedures. The following subsections present potential uses and examples of the application of AR in real scenarios.

A. *Potential uses*

Virtually any modality of image acquisition can be combined with AR. Some of the most common are MRI, CT, Ultrasound, and Digital Subtractive Angiography. All of these techniques produce slice images that can be spatially combined to create volumetric data. With such data, it is possible to reconstruct a 3D model of the object of interest (a lung nodule, for example) and to apply AR with diverse goals, such as surgical training and identification of structures, among others.

AR provides the physician the possibility of carrying out a pre-operative planning before a specific surgery, which may increase the precision of the procedure and reduce the risks for the patient. For instance, a surgery to extract a lung nodule may use AR to precisely locate the lesion, avoiding the injury of healthy vessels and tissue, and reducing larger traumas.

AR may also allow a physician to orientate a surgery remotely. To continue with the lung nodule removal example, consider a situation in which a physician in a rural area must perform the surgery urgently but does not have enough experience in this kind of procedure. In this case, another physician could remotely assist the rural physician in an interactive and realistic way, since the expert physician may navigate and examine the nodule and other structures close to it. In addition, this solution avoids having to move the patient to a distant location.

Another application of AR in Medicine is training. Apprentices need to learn in practice how to make certain surgeries. However, practicing with humans is very dangerous and must be carefully supervised. Therefore, AR enables a safer and realistic training, with a high level of interaction.

B. *Applications*

In the last decades, many research centers throughout the world have been investigating the use of AR applied to Medicine.

AR systems cover a wide range of medical scenarios, such as laparoscopic liver resection [6] and needle biopsy [7]. Wieczorek et al [8] used GPU programming to enhance AR performance in some medical procedures. Navab et al [9] present some AR applications to help in the diagnosis and surgery of minimally invasive medical procedures (see Figure 5).

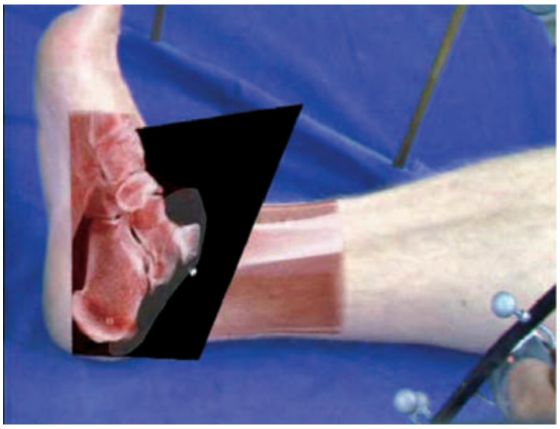

Figure 5. EVI software system enables in-situ visualization of medical imaging data using the Ramp head-mounted display system [9].

Other groups have proposed frameworks for use in image-guided procedures. For example, 3D Slicer [10] is an integrated visualization system which incorporates image registration, segmentation and visualization. It is mostly used for image analysis and planning, but it has also been applied to intra-operative guidance [11]. MeVis2 is a well-known platform for diagnosis and treatment of cancer and diseases of the cardiovascular system, lungs and brain which is mainly aimed at surgery planning. The Image-Guided Software Toolkit (IGSTK) [12] seeks to provide system-level support for image-guided procedures.

IV. Conclusions

The works mentioned in this work exemplify the application of AR technology in real situations. While they demonstrate the evolution of this technology, they also indicate the challenges posed for further research, such as the best forms of image registration and, especially, how to enhance the performance of the hardware used.

The main point is that this convergence of AR and Scientific Visualization is breaking the barriers of apparently diverse fields. What these fields have in common is that they rely heavily on digital images that are becoming more and more 3D. With two-way communication and the possibility of new points of view, replays and annotations, users will also change their role and become participants even in the process of broadcasting events.

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