EU-TeleInViVo – Three-dimensional Ultrasound Telemedical Workstation

a report by

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Introduction

Worldwide, people living in rural and remote areas struggle to access timely, quality medical care. Residents of these areas often have substandard access to specialty healthcare, primarily because specialist physicians are more likely to be located in areas of concentrated population. The European Commission (EC)-funded Telematics Technologies Programme Project, European Union Interactive Visualiser for Volume Data (EU-TeleInViVo), is an applied international and intercontinental telemedicine project, which is proving in practice that telemedicine today can improve dramatically the medical care and healthcare that is provided to every person, anywhere.

The EU-TeleInViVo project has set up a transportable telemedicine workstation – PC and telecoms capabilities – integrated in one case with a lightweight, portable ultrasound station. The system developed is low in price and weight, is transportable, non-radiating and supports a very large range of applications varying from gynaecology over pathology to abdominal scans. It is a medical teleconference workstation that is able to provide healthcare service where this is not possible by the usual means, for example, ecological disaster areas, remote rural areas or isolated islands. Since advanced telecoms means are usually not available or are very expensive in such locations, the system has been designed to work over simple, low-bandwidth telephone lines.

Medical care can be provided through this system almost anywhere, at anytime. The physicians and healthcare organisations are therefore able to guarantee high-quality care, without the patient having to travel or be carried over long distances. Ultrasound supports a very large range of applications that vary from gynaecology to cardiological examinations and, currently, it is the only economically and practically affordable imaging modality.

Members of the EU-TeleInViVo Consortium are:

- Fraunhofer Institut für Graphische Datenverarbeitung (IGD) (co-ordinator), Germany;
- Centro de Computação Gráfica (CCG), Portugal;
- Hospitais da Universidade de Coimbra (HUC), Portugal;
- United Nations Educational, Scientific and Cultural Organization (UNESCO), France;
- Centro de Alta Tecnologia en Analisis de Imagen (CATAI), Spain;
- Dr Staerk Computer (DSC) Systeme GmbH, Germany;
- Hospital de Ponta Delgada (HPD), Portugal;
- Pie Medical BV (PIE), Netherlands; and
- Zentrum für Graphische Datenverarbeitung (ZGDV), Germany.

Materials and Methods

The use of advanced technologies allows the workstation to collect three-dimensional (3-D) ultrasound data of the patient, i.e. to perform an 'echo-tomography'. The doctor in the field scans the corresponding part of the patient. By means of the built-in flexible telecoms channel – from a simple phone line and Internet to Integrated Services Digital Network (ISDN), Global System for Mobile communications (GSM) or satellite – the acquired 3-D dataset is transferred to a remote expert who can be almost anywhere in the world. After data transmission, both doctors are linked online over the telecoms channel performing 'virtual echography' on the 3-D data that is replicated in each site. They view identical images on their screens in realtime and practically without lag, including through narrow-band telecoms channels.

The solution that is implemented partly lies on the principle of 'scanning the data and not the patient'. The main idea is to establish a type of 'information equivalence' between the patient and the representation of that patient in digital form, so that there is little to no loss in examining the patient

through the data representation, compared with what would be lost during a direct, in-person examination. Given that it is faster and cheaper to ship information around than to ship people (patients and doctors), volumetric representations become compelling as a substitute for the live patient. The point for the radiologist is that the volume representation can be 're-sliced' from any direction that might be desired. This avoids the need to acquire a whole new set of images – requiring the patient to make another trip to the hospital – if for some reason the original set leaves 3-D relationships ambiguous.

The system is available in two versions. The first is a fixed workstation (see *Figure 1*) running the EU-TeleInViVo software, which connects to an existing ultrasound scanner, equipped with a magnetic tracking system to measure the spatial position and orientation of the ultrasound probe for the creation of a 3-D ultrasound data volume. The second is an integrated portable system, which combines, in one solid case, an ultrasound board and Intel-based PC parts that are connected to the ultrasound board via a frame grabber (see *Figures 2* and *3*).

The EU-TeleInViVo fixed workstation is based on an ultrasound device that already exists in the trial site's radiology or ultrasound department. It extends the existing device, first, by the capability to acquire 3-D ultrasound data sets and, second, by the necessary hardware for teleconsultations. This expansion is performed with a powerful PC, including a frame grabber card, for the acquisition of the original ultrasound frames via the ultrasound video output – Vertical Helix Scan (VHS) or Super Vertical Helical Scan (SVHS) – and an electromagnetic tracking system for recording the spatial co-ordinates of the ultrasound frames. With these two forms of information – ultrasound frames and their position and orientation in space – 3-D ultrasound data sets of a patient can be reconstructed or 're-sampled'.

The portable EU-TeleInViVo workstation consists of two main components: a PC and an ultrasound device that is integrated in an electronic board at the size of a typical PC main board. The ultrasound system is connected to the PC via several lines – a video cable for connection of the ultrasound video output to the input of a frame grabber, which makes the video frames of the ultrasound device available at the PC. On the other hand, the PC hardware controls the functionality of the ultrasound board via a control line. The PC is also equipped with a spatial motion tracking system, which can record the spatial position and orientation of the ultrasound probe. This data set can be transferred over a communication line that is integrated in the PC – ISDN, modem and network – to a distant expert who runs another EU-TeleInViVo application and who, after transmission,

Figure 1: The Fixed Workstation Installed in Coimbraz

Figure 2: The Portable Workstation

Figure 3: The Portable Workstation being Moved

has all of the information – the same 3-D ultrasound volume data – available at his or her own application. Both can then interact collaboratively on the data and produce a common diagnosis (see *Figure 4*). With a battery integrated in the power supply of the system, it can be used without an external fuse as a portable emergency system.

The software part of the EU-TeleInViVo workstation is based on an InViVo ScanNT®

Figure 4: Sharing the 'Virtual Patient'

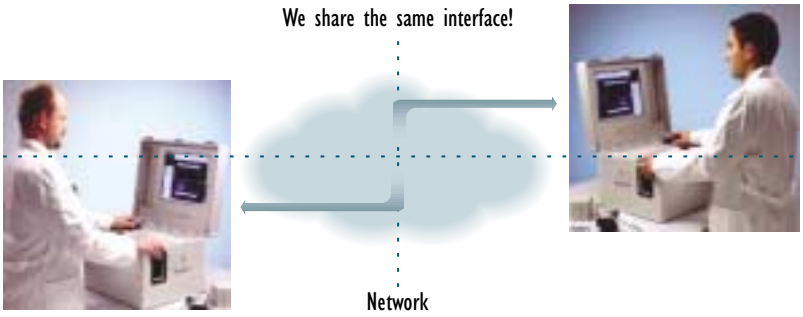
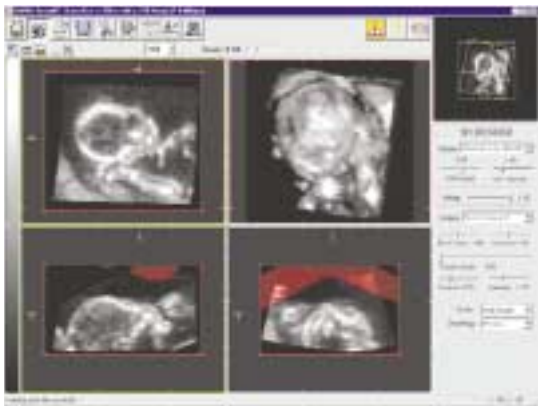


Figure 5: The User Interface of TeleInViVo



software package[1], which has been developed over several years at Fraunhofer IGD (see *Figure 5*). The communication layer is based on the HOUCOM software package that was developed by Fraunhofer IGD and ZGDV.

The issue of the transmission of large data sets over the (usually low) bandwidth that is available is important. A wavelet-based image compression[2] algorithm has been implemented for the size reduction of the image data sets to be transmitted.

Results

The system that has been developed is tested in different socioeconomic conditions and is being adjusted accordingly to meet the needs of developing countries and countries in transition. Currently, seven EU-TeleInViVo portable devices have been manufactured – one for each partner in Fraunhofer IGD, CATAI, CCG, HPD and Aralsk in Kazakhstan and two for the trial sites in Uganda. Fixed EU-TeleInViVo workstations – a PC connected to a local ultrasound scanner – have been set up in HUC, CATAI, CCG and Fraunhofer IGD. Another unit is expected to operate soon at the Almaty Diagnostic Centre in Kazakhstan.

The HUC is co-ordinating the pilot medical trials of the EU-TeleInViVo system with the Hospitals of Ponta Delgada (HPD), La Laguna (Tenerife, Spain, monitored by CATAI) and Mulago Hospital (in Kampala, Uganda) and Almaty Diagnostic Centre (in Almaty, Kazakhstan) both monitored by UNESCO. In addition, secondary locations in the Canary Islands, Uganda and Kazakhstan perform local trial sessions with the principal hospitals in these areas (see *Figure 6*). This is one of the first telemedicine networks worldwide (see *Figure 7*), covering such diverse socioeconomic, cultural and environmental domains.

Over the last 20 months, around 600 acquisitions and consultations have been performed and evaluated. The transmission time varies between about five minutes per case via ISDN, to approximately 10 minutes over analogue modem and to around 15 minutes using the Internet. However, Internet times may vary significantly depending on the quality of the connection. The teleconsultation sessions averaged a time of about 15 minutes. However, this varied substantially between five and 40 minutes, depending on the severity of the case.

When the diagnosis that was proposed by the reading site was compared with the clinical pathological follow-up or the previous diagnostic of the patient, 90% specificity, 88% sensitivity and an accuracy of 89% have been reported on average. These are considered to be excellent results for a new, innovative system in its introductory phase.

Discussion

Apart from being a telemedicine device, the EU-TeleInViVo project brings to remote areas the revolutionary advantages of 3-D ultrasound. This is a new emerging technique, which is maximally contributing to the recent uprising of this imaging modality, suppressed during the past years by other, but expensive, not readily available and sometimes invasive, imaging methods such as computerised tomography (CT), magnetic resonance imaging (MRI) or nuclear medicine. Hundreds of teleconsultation sessions have been performed until now between HUC and the rest of the trial sites, as well as within these sites themselves, proving that the system is reliable, accurate and allows detailed and correct diagnoses to be carried out from a distance.

Despite this multitude of technologies and concepts being integrated in one single compact device, the users who are participating in the initial

1. *G Sakas, S Walter, W Hiltmann and A Wischnik, "Fetal Visualization Using 3D Ultrasonic Data",* Computer Assisted Radiology, *Springer Verlag, Berlin, pp. 241–247, June 1995.*
2. *J Villasenor, B Belzer and J Liao, "Wavelet Filter Evaluation for Image Compression",* IEEE Transactions on Image Processing, *2, pp. 1,053–1,060, August 1995.*

implementation phase have found the system easy to learn and use. The EU-TeleInViVo project has existed and operated since early 1999. Its implementation today extends to three continents (Europe, West Africa and Central Asia) and spans over six time zones. Its operation has been tested in well-developed areas in Europe and major cities elsewhere, for example, Almaty in Kazakhstan, as well as in remote locations such as islands (Canary and Azores) and poor regions under development (Uganda, Aralsk in Kazakhstan).

Tangible benefits from the project's implementation (with direct monetary value) are:

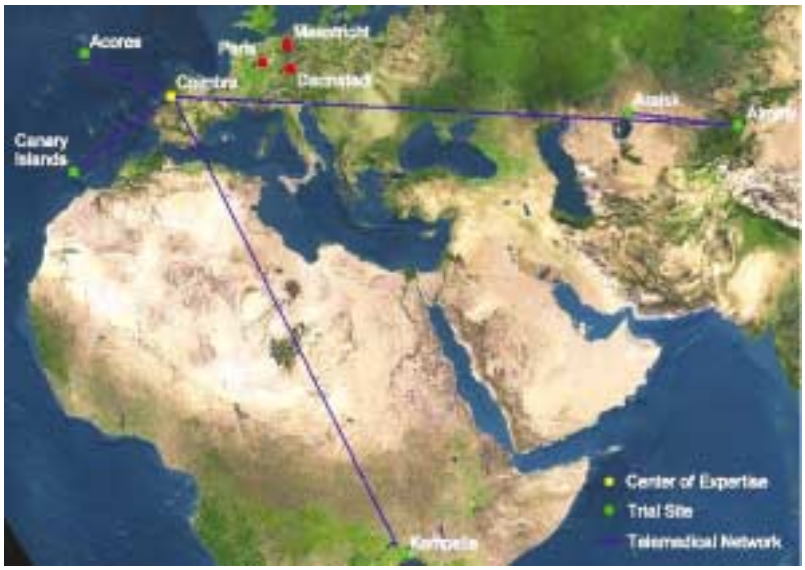
- savings from reduced travel costs of specialists engaged in teleconsultation sessions;
- savings from reduced travel costs of patients;
- savings on hospital accommodation for patients that can be diagnosed remotely;
- savings on hospital processing costs of patients that can be diagnosed remotely;
- savings due to the provision of healthcare in remote clinics or mobile health units *versus* the expansion of urban or regional hospitals, i.e. the difference in the construction and running costs of facilities.

Intangible benefits (with a definite perceived value, but with an actual value that cannot be determined directly) include:

- better opportunity for consultations and second opinions, resulting in avoidance of delays or costly mistakes;
- reduced waiting time and transfer delays that can prevent serious complications in some cases;
- reduced loss of income for patients who do not need to travel;
- reduced expenses for family members who might otherwise accompany the patient;
- improved effectiveness of specialists – broader reach with more patients being seen due to reduced travel;
- improved overall healthcare management, both internally and externally;
- increased collegial support to medical personnel working in remote and isolated areas, resulting in increased job satisfaction; and

Figure 6: Installations in Kazakhstan and Uganda (upper row), Portugal and Spain (lower row)

Figure 7: The Geographical Distribution of TeleInViVo Stations



- improved teaching and learning possibilities and opportunities.

Further indirect benefits from a large-scale implementation of the EU-TeleInViVo project are:

- increased revenues to, for example, equipment providers, hospitals and telecoms services providers;
- enabling specialist and technical personnel to increase their knowledge and qualifications;
- facilitating the decentralisation of care and distribution of competence; and
- promoting the maximisation of scarce central resources, for example, specialists, diagnostics apparatus and computers.

The EU-TeleInViVo project is a great example of how the recent advances in medical imaging, with the help of advanced telecoms, can be applied to provide better healthcare and diagnosis, improve patient handling, reduce health service costs and save lives.

Additional Information

TeleInViVo has been awarded by the IST Grand Prize 2001. Detailed information on the IST Prize and the winners can be found at (www.it-prize.org).

For figures and photographs related to the EU-TeleInViVo Project, one can refer to the Project's Web pages: (http://www.igd.fhg.de/teleinvivo) and (http://www.igd.fhg.de/igd-a7/images-video /teleinvivo/teleinvivo.html).