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The Use of Networks for Interactive Telemedicine to Avoid a Digital Divide of the World

In the Euro-Mediterranean region the level and concentration of medical care is inhomogeneous. Ethical and legal restrictions prevent a dogmatic harmonisation of medical treatments. Standardisation can only be reached by means of communication. Cross national communication is thus far common only in form of medical conferences and seminars; individual patient-oriented consultation is rare. In this context telemedicine can merge distributed medical intelligence and deliver it to the patient in a consolidated way. Furthermore, telemedicine can help to adequately assign patients for specific treatments that are available only at a limited number of sites in the region. However, medical communication requires high quality interactive image communication. Terrestrial communication infrastructures with the required quality of service are thus far not available in all parts of the Euro-Mediterranean region. Satellite communication channels with the bandwidth required for conventional uncompressed transmission of medical images are too expensive for routine use.

New developments in information and communication technologies (ICT) have enabled the transmission of medical images in sufficiently high quality and for low prices. This allows for a reliable telediagnosis to be formulated by the expert at the receiving site on a regular basis.

At the same time, however, these explosive developments in ICT over the last decade bear the risk of creating and amplifying a digital divide in the world, leading to a modified distribution of medical competence between the North and the South of the Euro-Mediterranean area. It is a challenging goal to help close the gap in medical care between the EU and its Mediterranean partners by applying information technology to healthcare networks.

Satellite-based telemedical networks can also be used efficiently to make available telemedical services in areas that are difficult to serve by other means. An example is the telemedical service on-board of ships which up to now could only be assisted by radio communication. The Surgical Research Unit OP 2000 (Operating Room of the Future) has developed and tested several interactive telecommunication components in close cooperation with leading academic and non-academic institutions as well as industrial partners. OP 2000 has played a leading role in the realization of various satellite-based telemedical networks e.g. GALENOS, DELTASS, MEDASHIP, EMISPHER [1–5]. Another aspect of OP 2000 is the enhancement of surgical training by the use of high-immersive visualisation and simulation.

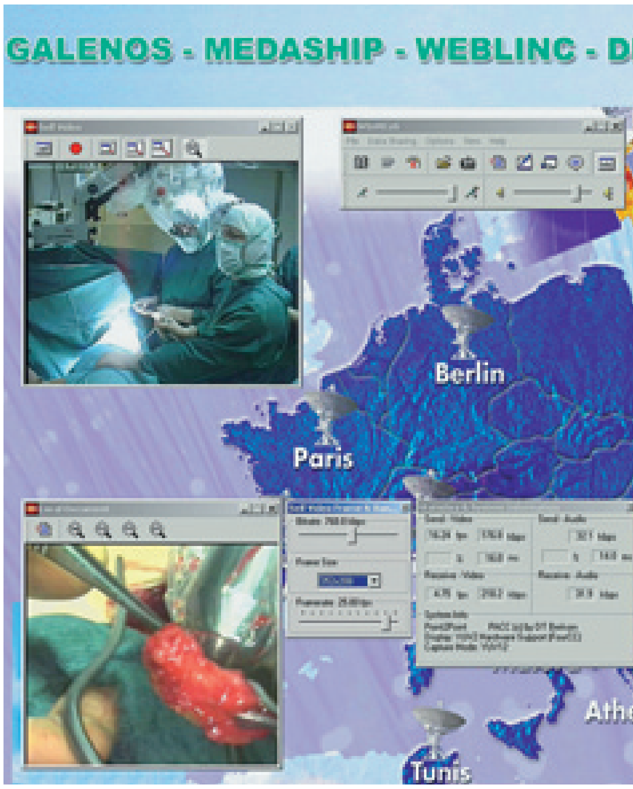


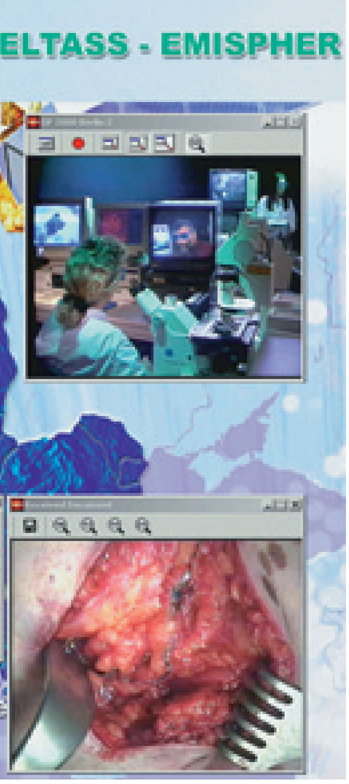
Fig. 1
Wavelet-based interactive Video communication system (WinVicos) with Workstation for Telemedical Applications via Satellite (WoTeSa) serving as a medical video hub.

Materials and Methods

Satellite communication combines broad geographic coverage, multicast capabilities, etc. In the projects presented, mainly Linkway satellite terminals with LAN interfaces are used for communications with a bandwidth of up to 2 Mbps.

In order to achieve optimal performance quality of telemedical applications, the tools used are optimised with respect to transmission quality, interactivity, user-friendliness, flexibility, etc.. The communication software called *WinVicos* (Wavelet based interactive Video communication system) has specially been designed for different telemedical applications (e.g. tele-

Fig. 2
Satellite Antennas at the SRU OP 2000 for communication in MEDASHIP and EMISPHER Networks.



surgery, teleradiology, telepathology). WinVicos is a high-end, interactive video communication software, providing real-time video, still-images and audio transmission. There is a main user dialog that is sufficient for the standard actions of the user. This includes calling the video conference partner (address book), remotely changing bit-rate, frame-rate, video-size, as well as speaker- and microphone-volumes. Besides the main user interface up to four video-windows can be shown on the user's desktop (Fig. 1). WinVicos supports remote pointers in any video or document window. For video compression WinVicos employs a hybrid speed-optimised wavelet-codec (Patent DE 197 34 542 A1, Deutsche Telekom).

WoTeSa (Workstation for Telemedical Applications via Satellite) is the hardware on which the WinVicos system is operated. The hardware requirements are met by an IBM-compatible PC with Pentium® IV processors and a minimum of 3 GHz; 512 Mbytes RAM; an Osprey Video-capture board (Osprey 100 or Osprey 500); a camera with F-BAS and S-Video output as live source (e.g. Canon VC-C4); a second camera as document camera for transmission of non-digital images; standard headset, or microphone in combination with small loudspeakers. The different video inputs of the Osprey video-capture board can be used for the direct connection to various medical equipment (e.g. endoscope, laparoscope, camera integrated in the operating light, surgical microscope, ultrasound equipment, histopathological microscope, etc.). WoTeSa serves quasi as a medical video hub.

The Clinical research Group OP 2000

The clinical research group OP 2000 (Operating room of the future) was founded in 1988 at the Surgical University Clinic of Heidelberg in cooperation with the German Cancer Research Center. First aim was the clinical implementation of laser-induced fluorescence diagnosis (LIFD) and photodynamic therapy (PDT) of malignant tumors. Since 1993 OP 2000 has been established at the Max-Delbrück-Center for Molecular Medicine and the Robert-Rössle-Klinik, Charité Berlin. Besides the development of new molecular-biological methods for the improvement of tumor diagnosis OP 2000 today designs and realizes interactive, satellite-based competence networks. The research group is headed by Prof. Dr. Dr. Peter M. Schlag, Medical Director of the Robert-Rössle-Klinik. For the projects MEDASHIP and EMISPHER about 3,8 million Euro are available. OP 2000 is financially supported by the clinical budget of the participating hospitals as well as by several EU-projects, industrial partners and organizations.

Internet: www.rrk-berlin.de/op2000

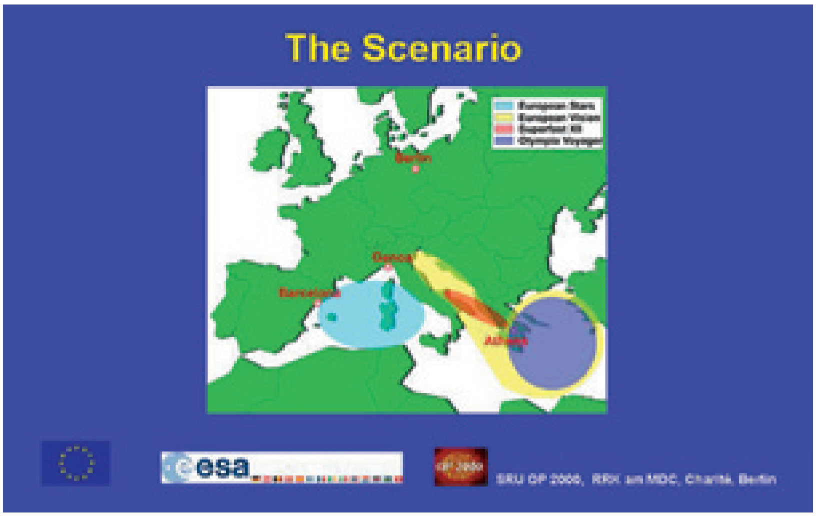


Fig. 3
Ships and hospitals participating in MEDASHIP.

Results

In the MEDASHIP project (Medical Assistance for Ships, 2002–2003, co-funded by EU, in cooperation with D'Appolonia (I), Avienda (UK), Eutelsat (F), and Demokritos (GR)) an integrated system for telemedical support on board of cruise liners and ferry boats was set up and evaluated [6]. Such a system should allow an improved medical care for passengers and crew members, probably in a more cost-effective way.

In case of medical emergency on board of ships, the usual procedure is that the medical staff contacts the closest support center via radio and asks for help and advice. However, the medical information that can be transmitted during a radio consultation is clearly too limited for the experts to give valuable advice. Often it is then decided to meet up with a rescue team (e.g. in a helicopter) to have the patient transported to an expert center for further diagnosis and therapy. This is often accompanied by a forced deviation from the planned route, causing substantial extra costs. However, a telemedicine system for second opinion linked

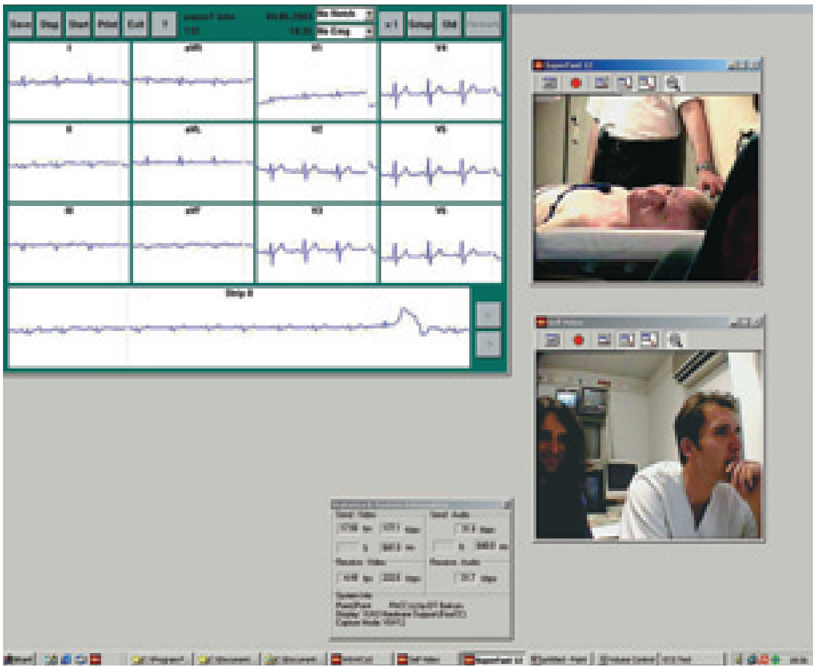


Fig. 4
A physician at Charité is consulting an electrocardiographic examination on board of the ship via interactive telecommunication

to a specialized medical center can contribute to solving various types of emergency. This could also contribute to a patient being able to continue to be treated by the physician on-board if the illness is diagnosed correctly and a crisis not overestimated.

During the project validation phase the service has been tested on-board of three ships (European Stars, Superfast XII and Olympia Explorer) with the possibility of connection to three land-based medical centers (Sotiria, Athens, Evangelico, Genova and Charité, Berlin) (Fig. 3).

On the ships a stabilized satellite terminal (VSAT with satellite tracking) is used. Pathology areas that are interesting for MEDASHIP are cardiovascular pathology, pulmonary pathology, metabolic crises, neurology emergency, pediatric emergency, surgical area, trauma area, urology, gynaecology and obstetrics. As additional equipment two videocameras, electrocardiograph (12 channels) and ultrasound equipment are used. The first videocamera is used for videoconference which is an essential part of the telemedical service and allows the physician in the land-based hospital to see the patient and thus form a better diagnosis. The second camera serves as document camera for the digitalization of analogous patient data and transmission to the consulting physician. The ECG is required in cardiovascular diseases and offers the possibility of a simple and common examination. The ECG can also be used for patient monitoring. The ECG-system is connected to the WoTeSa on-board the ship and can be controlled by the physician from this workstation. By an application-sharing software also the expert can control the ECG-system from his land-based workstation. The main menu with all functions of the ECG as well as the ECG-signals of the patient are transmitted to the expert. In this way the expert and the on-board physician can collaboratively analyse the ECG report (Fig. 4). Diagnostic ultrasound is required in gynaecology, obstetrics and abdominal diseases. The ultrasound system is directly connected with its S-Video output to the Osprey video-capture board. Tests of the satellite transmission of the ultrasound signal have shown that not only fixed images but also live ultrasound examinations can be transmitted at a bandwidth of 500–700 kbps in a good quality for second opinion (Fig. 5).

In the project the quality and availability of the services and the real costs have been evaluated. Forensic aspects have also been analysed and juridical protocols developed. (http://www.medaship.com/)

The *EMISPHER* (Euro-Mediterranean Internet-Satellite Platform for Health, medical Education and Research, 2002–2004, co-funded by EU) project brings together 17 partners from 11 Euro-Mediterranean countries under the leadership of SRU OP 2000 aiming at establishing an equal access to on-line services for healthcare in the required quality of service. EMISPHER provides an integrated internet-satellite platform for the application of various medical services, such as

Fig. 5
A physician at Charité is consulting an ultrasound examination of a patient on board of the cruise ship.

medical e-learning, real-time telemedicine and medical assistance. The platform includes a bi-directional satellite network (up to 2 Mbps) creating a contribution network between 10 Centers of Excellence in the Euro-Mediterranean region (Medical Faculty, Casablanca; ANDS, Alger; Medical Faculty, Tunis; Ain Shams University, Cairo; University of Cyprus, Nicosia; ISTEM, Istanbul; NCSR, Athens; ISMETT, Palermo; CICE, Clermont-Ferrand; and Charité, Berlin) (Fig. 6) and employs ViaSat Linkway technology in combination with WoTeSa / WinVicos as tool for interactive real-time telemedical applications and e-learning. The contribution network is coupled to a larger distribution network in the same area (smaller hospitals, healthcare centers, practitioners, etc.) using receive-only satellite terminals.

The EMISPHER platform hosts initially three main dedicated medical services: e-learning, real-time telemedicine and medical assistance. E-learning: In the EMISPHER Virtual Medical University (EVMU) each of the leading medical centers provides pedagogical material and modules for synchronous and asynchronous e-learning in their medical specialities: endoscopic surgery, gynaecology-obstetrics, reproductive medicine, infectious diseases, interventional radiology, liver transplant and tumour diagnosis and therapy. The central gateway to the internet-based modules of the EVMU is the project's website: www.emispher.org. From here, users have access to the content of the various modules and can register for the participation in real-time e-learning events. The exchange between the partners of various countries and availability of standardised educational modules allows for improved qualifications of undergraduate and graduate students, hospital staff, general practitioners, healthcare officers and other professionals in the medical field.

In the field of real-time telemedicine the following categories of applications are offered: second opinion, teleteaching & teletraining (demonstration and spread of new techniques), telementoring (enhancement of staff qualification), and undergraduate teaching courses and optimisation of the learning curve. The leading medical centers in the project provide expertise in the following medical fields: open and minimally-invasive surgery, multi-organ transplantation, endoscopy, pathology, radiology, interventional imaging, infectious diseases, oncology, gynaecology and obstetrics, reproductive medicine and emergency medicine. These real-time interactive telemedical applications contribute to improved quality of patient care and to accelerated qualification of medical doctors in their respective speciality. Enabling full remote control of the medical equipment allows the remote physician to act as if he were present at the site thus realizing a real telepresence. Thus, this international network of competence contributes directly and indirectly to improved healthcare.

Fig. 6
Map of Centers of Excellence linked together in the EMISPHER project.

The third field of service operated in EMISPHER is medical assistance. As tourism constitutes a substantial economical factor in the Mediterranean region and because of the increasing mobility of the population, continuity of care through improved medical assistance is of major importance for improved healthcare in the Euro-Mediterranean region. Introduction of standardised procedures, integration of the platform with the various local and national communication systems, and training the medical staff involved in medical assistance allow for shared management of files related to medical assistance (medical images, diagnosis, workflow, financial management, etc.) and thus for improved care for travellers and expatriates in the Euro-Mediterranean region. (http://www.emispher.org)

High Immersive Visualisation and Simulation for Training and Telementoring

Especially important for the precision of surgical interventions is the initial education of students and continuous training of surgeons. The training of physicians is supported in a distributed environment called Cooperative Medical Workbench – CMW, an enhanced, high-immersive responsive workbench projection (*Surgical Table*, developed in cooperation with BARCO, Belgium, and GMD, Sankt Augustin, Germany) [7].

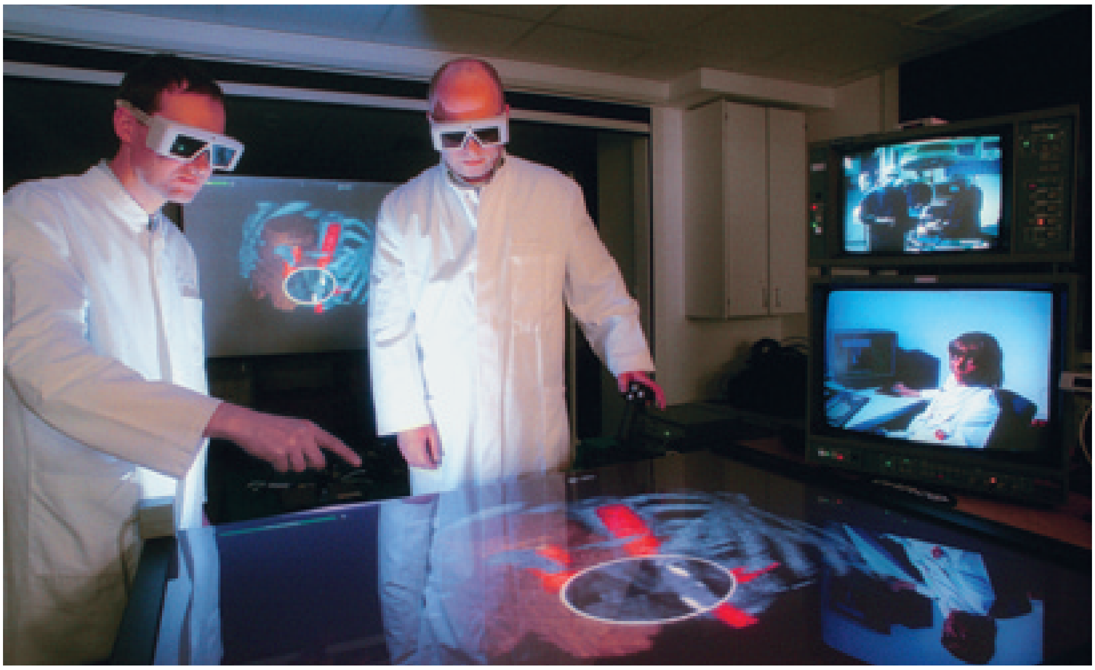


Fig. 7
Realistic simulations of surgical procedures with haptic feedback (work in progress)

The Surgical Table consists of two HDTV-projectors (1600x1200 pixels) integrated in a mobile unit. The size of the unit is comparable with an operating table. (90 x 120 cm projection, 200 x 140 x 75 cm size). Due to the combined application of two HDTV-projectors, polarization technique and shutter glasses the Surgical Table allows for several working modes e.g.:

- Two users work on distinct data sets at the same time on the workbench. For medical second opinion each user has an additional monitor (Fig. 7).
- Two different scenarios of the same data set are projected simultaneously onto the workbench. Both users can work independently with the various virtual manipulation tools (Fig. 8).
- Projection of stereoscopic, full resolution HDTV. Sources for the displayed scenarios are computer-generated, three-dimensional models, computer-based movies, as well live pictures from stereoscopic HDTV cameras.

Working on the Surgical Table the users are tracked and can observe according to their positions the correct perspective of the simulation. The users wear special glasses which through a combination of polarization filters and active shutter glasses allow visibility of their corresponding picture in stereoscopic quality. Simultaneous projection (broadcast quality) of two different stereoscopic views of a virtual scenario and collaborative simulations for two users positioned on opposite sides of the Surgical Table are possible. Both users can work independently with the various virtual manipulation tools (e.g. magnification, rotation, translation of the data set, as well as manipulation of selected anatomical structures). The Surgical Table with the 3D reconstructions of real radiological patient data enables realistic simulations for teaching and training. Work in progress is the transmission of the data of the simulation to a second user via satellite. While the second user works with the various manipulation tools his actions can be observed by the first user allowing to support him by telementoring.

Conclusions

The use of specifically designed networks for interactive telemedicine (distributed medical intelligence) can contribute significantly to the continuous improvement of patient care and to the acceleration the qualification process of the medical staff. This can also help to avoid a digital divide between the EU and its Mediterranean partners by

- Application centers for new treatments,
- Training centers and use of new medical devices from distance,
- Remote treatment of patients,
- Integration of medical competence,
- Centres of distributed medical intelligence.

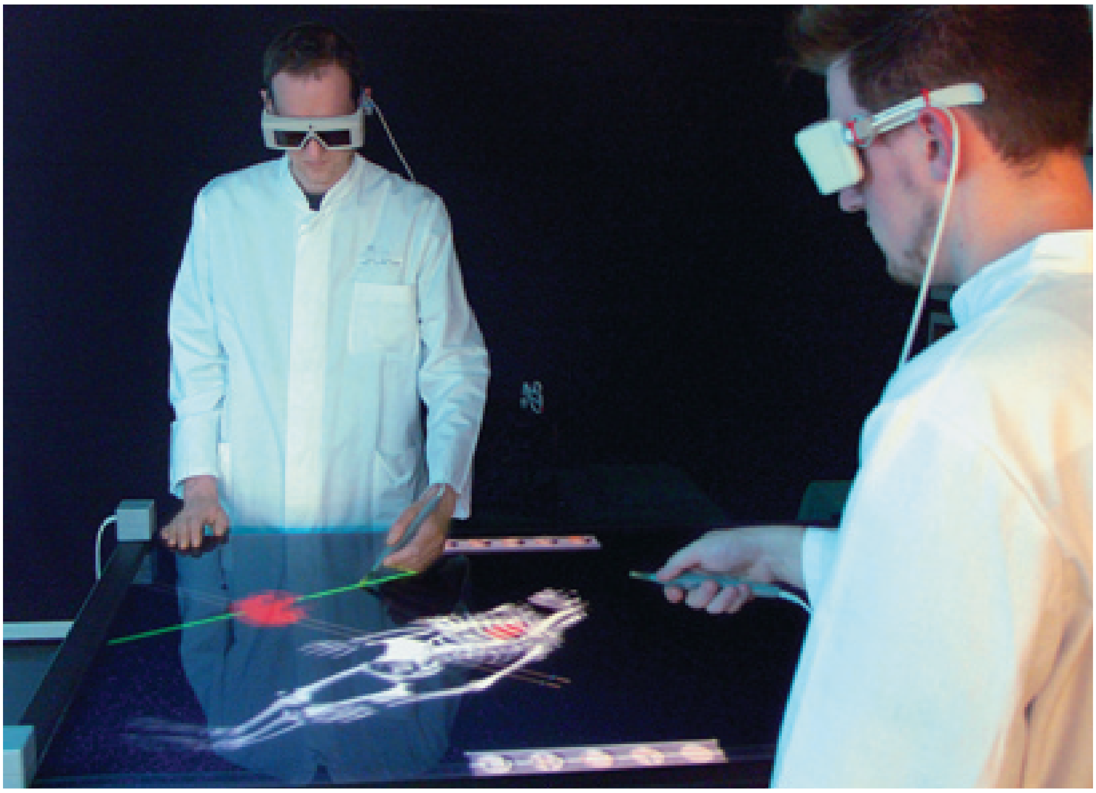


Fig. 8
Surgical Table: Simultaneous display of two different tracked views of the same data set

The described high immersive visualization and simulation environment of the Surgical Table is optimized on the surgeons needs. Work in progress involves, amongst others, the implementation of haptic feedback devices.

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