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PREFACE

In 2013, ICCAS's scientific endeavors focused on expanding promising research fields such as the development of IT infrastructure for the digital operating room, the use of patient models in surgery, and standardization in connection with surgical assist systems. These three fields of research were represented by our three research groups Model-based Automation and Integration (MAI), Digital Patient Model (DPM) and Standardization (STD).

At the beginning of 2013, computer scientist Dr. Kerstin Denecke, a graduate of medical informatics at Braunschweig University of Technology, joined ICCAS to head the Digital Patient Model (DPM) research group. Furthermore, Thomas Neumuth, the head of the MAI research group, was appointed honorary professor of Biomedical Information Systems at HTWK Leipzig University of Applied Sciences. This holds out the prospect of greater scientific and educational collaboration with top researchers at HTWK.

Additionally in 2013, ICCAS paid particular attention to establishing international networks with scientists from all over the world at conferences, workshops and think tanks. Researcher exchange programs exist with the Image Processing and Informatics Lab (IPLab) at the University of Southern California, the ARTORG Center for Biomedical Engineering Research at the University of Bern and the MEVIS Fraunhofer Institute for Medical Image Computing in Bremen. Moreover, numerous speakers from other national research institutions presented invited talks at ICCAS. ICCAS's involvement in the scientific community was strengthened by the election of Thomas Neumuth to the committee of the German Association for Medical Informatics, Biometry and Epidemiology (GMDS). And to evaluate the quality of the scientific work at ICCAS, a two-day technical PhD colloquium was held in October 2013.

The ICCAS Report 2013 is brimming with fascinating facts and reports on our scientific and educational work designed to strengthen the role of computer-assisted surgery today and above all in the future.

Prof. Dr. med. Jürgen Meixensberger
Head of the Board

NEWSFEED

TPU including oncoflow launched at Leipzig University Hospital

In early March 2013, the ENT tumour board at Leipzig University Hospital received a technology boost when it was augmented by new IT systems for data presentation, enabling better planning and decision-making in the treatment of cancer in the head and neck area. The Treatment Planning Unit (TPU) and the IT infrastructure were upgraded with the basic software oncoflow by ICCAS's Model-based Automation and Integration (MAI) group in close collaboration with physicians from head and neck oncology at Leipzig University Hospital. Thanks to oncoflow, electronically managed patient data and image visualization from diagnostics can now be accessed by physicians during their interdisciplinary tumour board meetings. In addition, joint therapy decisions are supported by 3D images of tumour segmentations and the availability of tumour classification. As a result, the TPU enables treatment to be customized to patients' individual needs.

In future, as well as supporting hospital staff in oncology treatment, the system will form the basis for further developments such as digital patient models. One important feature of oncoflow is that it has structured data available from the entire treatment process that can be used to aid the implementation of scientific studies in cancer research and to improve the clinic's quality management.

ICCAS at CARS 2013

Distinguished scientists, engineers and physicians from around the world met up at the twenty-seventh congress of Computer Assisted Radiology and Surgery (CARS) to discuss pioneering innovations in medical informatics and system development for applications in surgery and radiology. For ICCAS scientists, CARS is the year's foremost forum at which they can present their research findings to a wide audience of experts and update their knowledge on worldwide research in computer-assisted surgery. Accordingly, once again ICCAS put in a strong showing at various thematic sessions and workshops.

Girls' Day at ICCAS: Hands-on science

Girls' Future Day was held on Thursday 25 April 2013 – and once again ICCAS welcomed curious girls keen to find out more about computer-assisted surgery. The girls were invited to attend interesting presentations by five female ICCAS scientists and to benefit from their experience in the world of research. This was followed by a practical display of science in the high-tech demo OR, where Stefan Bohn showed some ICCAS research activities on a model.

CeBIT 2013: ICCAS stand welcomes Saxony's Minister-President

The highlight of the *oncoflow* presentation by ICCAS young scientist Jens Meier from the Model Based Automation and Integration group at this year's CeBIT in Hanover was the visit by Stanislaw Tillich. Saxony's Minister-President was given a detailed introduction to the IT system and ICCAS's core activities.

The presence of ICCAS at the main event for the digital world certainly raised its profile. And it was a valuable opportunity to touch base with medical informatics professionals and leading developers in medical data and process integration, such as from Siemens and SAP, paving the way for the next innovative steps of development. Jens Meier received very positive feedback for the oncoflow system and its current assistance functions.

Showcased at the special show "Research for the Future", oncoflow is a modular IT framework that supports data and process integration into the process of oncology treatment. This user-friendly system is already up and running at the Department of Otolaryngology at Leipzig University Hospital.

Franziska Busch and her team during artificial calficification of the aortic valve

PascAL – Joint research between Leipzig University and HTWK Leipzig

Cooperation between the ISTT research group from HTWK Leipzig University of Applied Sciences and ICCAS at Leipzig University in the PascAL project has been in full swing for more than a year. Junior researchers from the fields of medicine and engineering are developing patient simulation models for surgical training and teaching. The initial phase was marked by fundamental research work and process analysis in the clinic, including workflow detection, needs analysis, and devising a framework for training simulators. Current work already deals with the creation of simulation models.

The research ICCAS associate Dr Joumanah Hafez and her colleague M Eng Christian Köhler will shortly unveil the first prototype of a simulation model for pan endoscopy. Models for the tongue, trachea and larynx have been designed and the assembly technology optimized. The realistic pan endoscopy model is now to be installed in a training system that allows investigations and operations to be validated as well as the simulation of difficult operating conditions. ICCAS associate Franziska Busch (medical doctor) and her project group are creating a model to simulate minimally invasive aortic valve replacement. In conjunction with ISTT and Heart Centre Leipzig, a test series on the artificial calcification of the aortic valve is currently in progress. The construction of the various parts of the simulator is in the early stages.

PascAL is funded by the European Social Fund (ESF) and the Free State of Saxony. The research partners on the medical side are Professor Andreas Dietz, director of the ENT Department at Leipzig University Hospital and Professor Jörg Seeburger, senior physician at Heart Centre Leipzig's Department of Cardiac Surgery.

Important role for ICCAS in MICCAI

This September, Dr. Stefan Bohn, Philipp Liebmann and Christian Meißner travelled to the 16th International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI) in Nagoya (Japan) to discuss their research in specific workshops.
Dr. Bohn was the co-organizer of the MICCAI workshop 'Systems and Architectures for Computer Assisted Interventions (SACAI)', where he also introduced a system architecture and communication framework that centrally monitored the status of networked medical devices and systems. Philipp Liebmann presented his work on the behaviour of a process model relating to the problem of missing sensor information and the derivation of possible compensation strategies. At the same workshop, Christian Meißner explained a method that recognizes surgical activities by means of acceleration sensors and radio-frequency identification (RFID).

ICCAS at the GMDS Annual Meeting 2013

At the beginning of September 2013, the German Society for Medical Computer Science, Biometry and Epidemiology (GMDS) hosted its fifty-eighth annual meeting in Lübeck. The event is an important platform for developments and research activities throughout Germany addressing the design of the future patient care.
ICCAS was on hand with presentations by Max Rockstroh in the workshop on BMBF project OR.NET Secure and Dynamic Networking in the Operating Room and Clinic and Matthäus Stöhr in the session Modeling of Systems and Processes. Furthermore, Dr. Kerstin Denecke and Dr. Stefan Bohn participated in the extensive programme. Professor Thomas Neumuth took part as newly elected member of the GMDS committee in this event.

ICCAS in Copenhagen for Medinfo2013

Dr. Kerstin Denecke and Stefan Kropf took part in the 14th World Congress on Medical and Health Informatics (Medinfo2013) from 20 to 23 August 2013. The international event drew more than 1,200 scientists from across the world all trying to improve information and data processing in healthcare through innovation in health and medical informatics as well as bioinformatics. Dr. Denecke took an active part with two scientific contributions. The junior research group leader of the DPM group gave a presentation at the forum "Panel on Social Media" and participated in the poster session on "Ontologies, knowledge representation, data models".

MAI MODEL-BASED AUTOMATION AND INTEGRATION

RESEARCH VISION

To gear the technical infrastructure in the operating room to the situation-dependent support of surgery.

MODEL-BASED AUTOMATION AND INTEGRATION

Prof. Dr. Thomas Neumuth
Group Leader MAI

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Operating rooms are among the most expensive and labour-intensive units in hospitals. There is hence enormous interest in developing new concepts and systems for operating rooms. For this purpose, the 'Model-based Automation and Integration' (MAI) group develops advanced technical systems to provide optimal support for the work of the operating room staff. Research is currently focusing on the integration and presentation of pre- and intraoperative information to support surgical management.

The group's main developments address surgical workflow recognition systems, situation monitoring and the storage infrastructure, workflow management systems, treatment planning and integration systems. Its findings have been presented at industry expos such as CeBIT and conhIT, and discussed in dedicated workshops at the CARS and MICCAI conferences.

Its projects are currently funded by the BMBF German Ministry of Education and Research, the BMWi German Ministry of Economics and Technology, and Siemens Healthcare.

Selected Publications

Schumann S, Bühligen U, Neumuth T. Distance Measures for Surgical Process Models. Methods Inf Med. 2013; 52(5): 422–431.

Rockstroh M, Franke S, Neumuth T. Requirements for the structured recording of surgical device data in the digital operating room. Int J Comput Assist Radiol Surg. 2013.

Liebmann P, Meixensberger J, Wiedemann P, Neumuth T. The impact of missing sensor information on surgical workflow management. Int J Comput Assist Radiol Surg. 2013 Sep; 8(5): 867–75.

Franke S, Meixensberger J, Neumuth T. Intervention time prediction from surgical low-level tasks. J Biomed Informatics. 2013; 46(1): 152–159.

Forestier G, Lalys F, Riffaud L, Louis Collins D, Meixensberger J, Wassef SN, Neumuth T, Goulet B, Jannin P. Multi-site study of surgical practice in neurosurgery based on surgical process models. J Biomed Inform. 2013; 46(5): 822–9.

INTRAOPERATIVE DETECTION OF DEVICE INFORMATION BASED ON VIDEO DATA

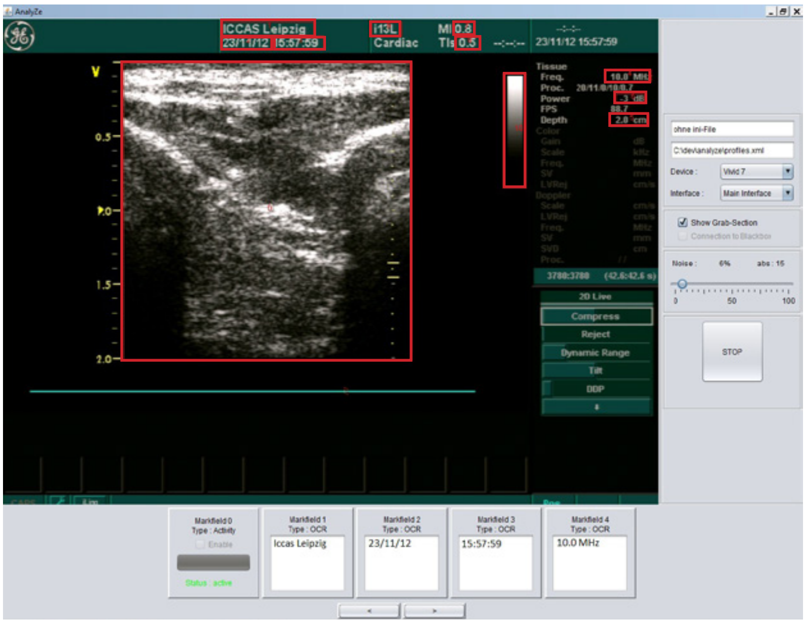

Fig. 1 – Graphical user interface of the analyzing software. The red areas indicate the analyzed fields. Depending on the type of the marks, different analysis algorithms are used. In this picture the ultrasound device is currently in use. The analyzing software monitors the relevant areas and stores the extracted information into the surgical recorder

Abstract:

To obtain intraoperative device information without using proprietary interfaces, we have developed a system that analyzes the video data output of medical devices used in the operating room. The developed algorithm can detect the usage of different devices and extract information by using OCR text recognition.

Many devices in the operating room lack structured interfaces. Consequently, relevant information needs to be obtained by other means. A significant proportion of the available medical devices in the operating theater, such as ultrasound, endoscopy, microscopy and navigation, provide a video output.

To enable a generic analysis of this video data, an editor has been developed in which various significant areas can be defined within the video stream. Each area can be associated with meta information such as the type of field (e.g. textual information). The regions of interest are saved in XML format. In the second step, the intraoperative video data is recorded and transmitted to the analyzing computer by a video-grabber. The analy-

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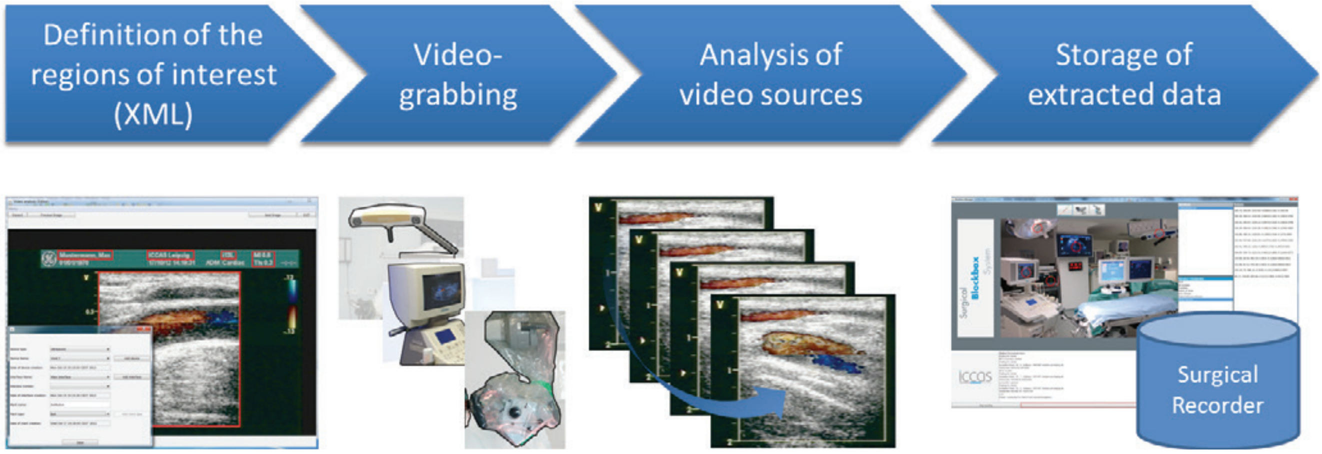

Fig. 2 – Sequence of data acquisition based on video data. From left to right: Relevant areas within the video data are marked and saved with an editor. The video signal is duplicated by video splitters and transmitted using video grabbing devices. The analyzing software monitors the relevant areas and stores the extracted information into the surgical recorder

sis software monitors the defined areas and analyzes the changes depending on the type of region. Each device which provides information via a video output can be monitored by its own video-grabbing device and associated analysis software. If a change occurs in an area, it is transmitted to the Surgical Recorder, developed at ICCAS, where the data is stored in a structured manner and made available for further analysis.

We are currently performing an evaluation study in neurosurgery department of the University Hospital of Leipzig. Recordings of intraoperative navigation equipment, ultrasound devices and surgical microscopes are made. The images are manually annotated (e.g. active or not). Subsequently, the results of the video analysis algorithm are compared to the manual annotation. Here the same algorithm is used for each of the recorded video sources. However, the algorithms are parameterized differently. We currently anticipate very good results for intraoperative navigation and ultrasound. The generality of the algorithm allows the analysis of microscopic videos and has the potential to assist the identification of surgical processes.

The project enables subsequent systems to analyze the surgical situation by providing device and activity information which cannot be captured through existing interfaces. Its functionality is to be demonstrated in a subsequent study, in which the stored information will be compared to manually recorded workflows. ■

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A SURGICAL RECORDER FOR INTRAOPERATIVE DEVICE DATA

Fig. 1 – Graphical User Interface (GUI). The red circles show which devices are connected to the surgical recorder. After choosing one of these circles the available services and the currently available data are shown on the right side. On the console at the bottom the technician can view status and error messages

Abstract:

In the project 'Surgical Recorder', we have identified different requirements for a central storage solution for the operating theater. The feasibility of this approach has been demonstrated in a prototype.

Given the growing complexity of the surgical working environment and increasing mechanization, solutions must be found to reduce surgeons' workload. Analysing the current surgical situation in the operating room requires the availability of all relevant data at a centralized unit and in a structured way.

This project presents a concept and a prototype development of a storage system able to handle all incoming intra-operative medical device data. The requirements for such a system are described and a solution presented for data transfer, data processing and data storage. In a subsequent study, the prototype was tested for correct and complete

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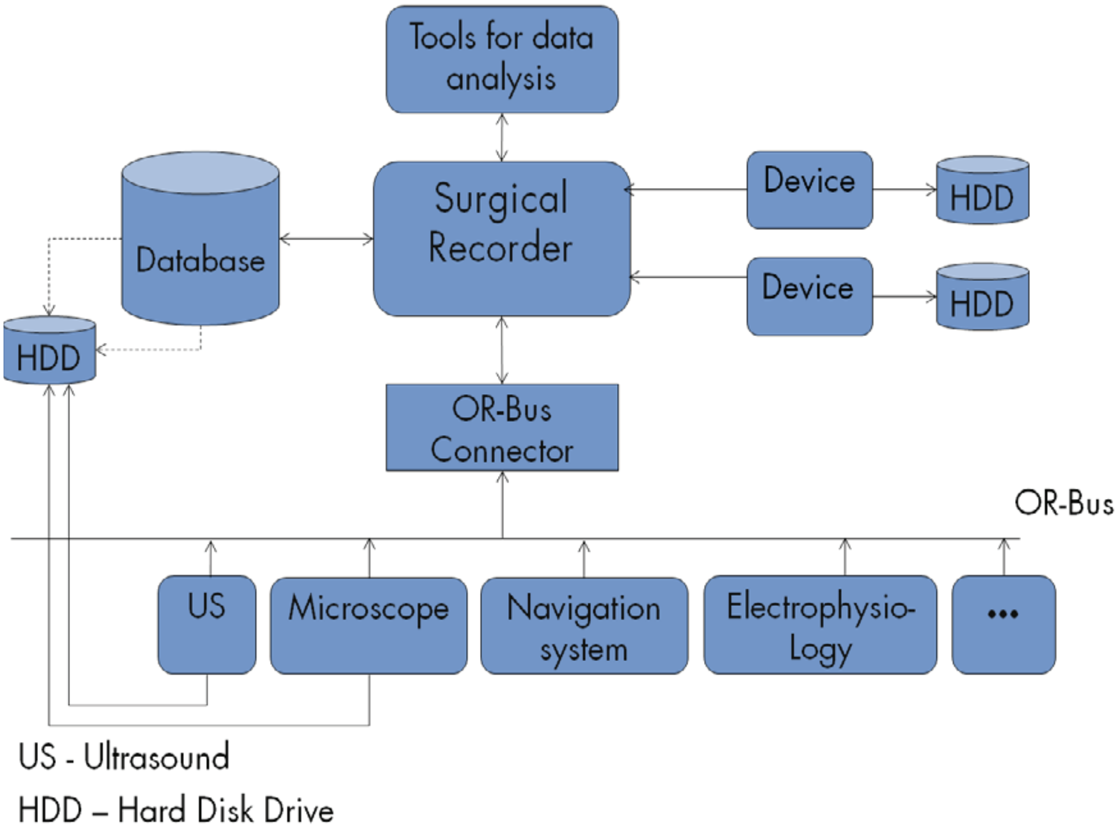

Fig. 2 – Integration of the surgical recorder in the OR environment

data transmission and storage as well as the ability to record a complete neurosurgical intervention with low processing latencies. To evaluate the capability of the surgical recorder we developed several medical devices. With these, we simulated 40 brain tumor removals based on real workflow recordings. To assess the load limit of the prototypical implementation we developed tests with synthetic data that were several times larger than the data to be expected.

The developed system is able to store the data generated correctly, completely and rapidly enough, even if much more data than expected is transmitted during a surgical intervention.

The surgical recorder supports the automatic recognition of the surgical situation by providing centralized data storage and accesses the interface to the OR communication bus. In the course of the project, more devices are to be connected to the surgical recorder and other technologies such as RFID, time-of-flight cameras, etc. are to be used. The data generated by these devices is also to be stored or referenced in the surgical recorder in order to support the analysis of the OR situation. ■

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TOWARDS INTRAOPERATIVE DETECTION OF SURGICAL INSTRUMENTS

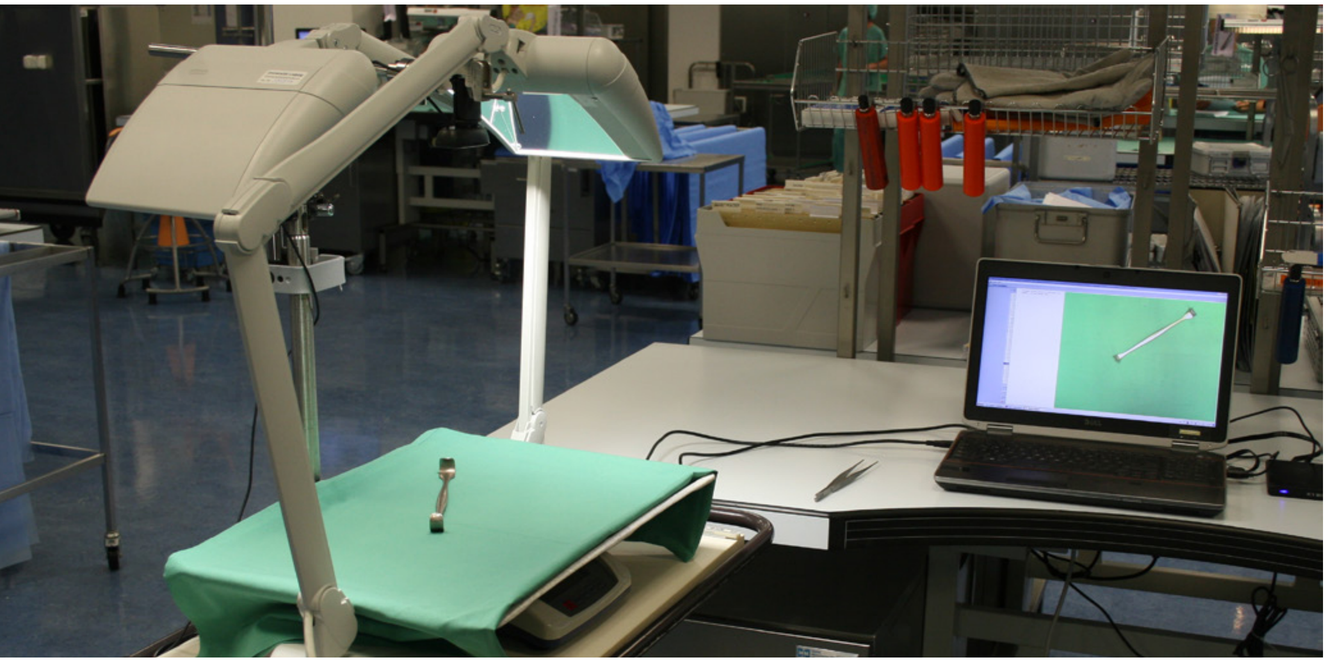

Fig. 1 – A first prototype at the central sterilization department

Abstract:

Automatically recognizing the status of ongoing interventions in the operating room (OR) using multiple sensors will allow support systems to provide situation-based assistance for the staff in clinical practice and contribute to efficiency and patient safety. This work presents a method for the intraoperative detection of surgical instruments without modifying them.

Automatically recognizing the status of ongoing interventions in the operating room (OR) using multiple sensors will allow support systems to provide situation-based assistance for the staff in clinical practice and contribute to efficiency and patient safety. However, a steady stream of information gathered from the technical equipment used in the OR is insufficient to obtain a full picture. Identifying the surgical instruments used provides a crucial source of information for automatically retracing surgery.

The aim of this new approach is to overcome the factors which currently hamper the existing ways of identifying the instruments used during surgery. Current methods nearly all rely on modifying surgical instruments, for example by adding visual or RFID markers,

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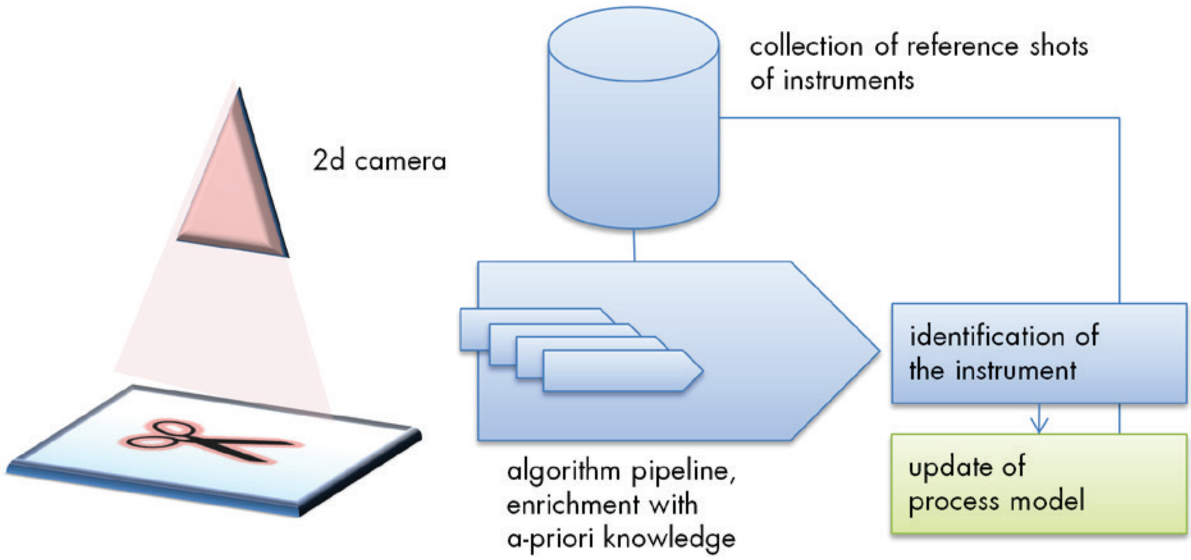

Fig. 2 – Conceptual sketch of the overall system structure

which poses many drawbacks. They include limited feasibility issues because of size limitations or issues concerning the autoclavability of additional materials as well as the possibly discontinued accreditation of existing equipment. Another important obstacle is the financial constraints in connection with the large amount of equipment used in modern operating theatres, especially if area-wide instrument modifications are considered by the hospital management.

This work presents a method for the intra-operative detection of surgical instruments without modifying them (Fig. 1). The key decision to rely on visual detection by cameras (rather than RFID or other marker-based technology) makes specific demands on the underlying software architecture. The main design features include graphical support for easy data inspection, the traceability of steps within the instrument detection algorithm pipeline, and the suitability of the system for distributed and parallel computing. Implementation meets the demands of the structured requirements analysis conducted and includes a graphical user interface with an XML-based data core. Initial tests with the instrument data of several complete surgical trays have confirmed that the architecture is able to cope with the needs. An initial prototype setup of a detection system has been assembled and evaluated in cooperation with the central sterilization management department of Leipzig University Hospital (Fig. 2). Early tests show promising results for the use of the system with a wide variety of instruments. An upcoming study based on an enhanced version of the application will evaluate the system with the instrument table situation in the operating room. ■

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A CONCEPT OF A TRAINING SYSTEM FOR PERSONS HANDLING SURGICAL INSTRUMENTS IN THE OPERATING ROOM

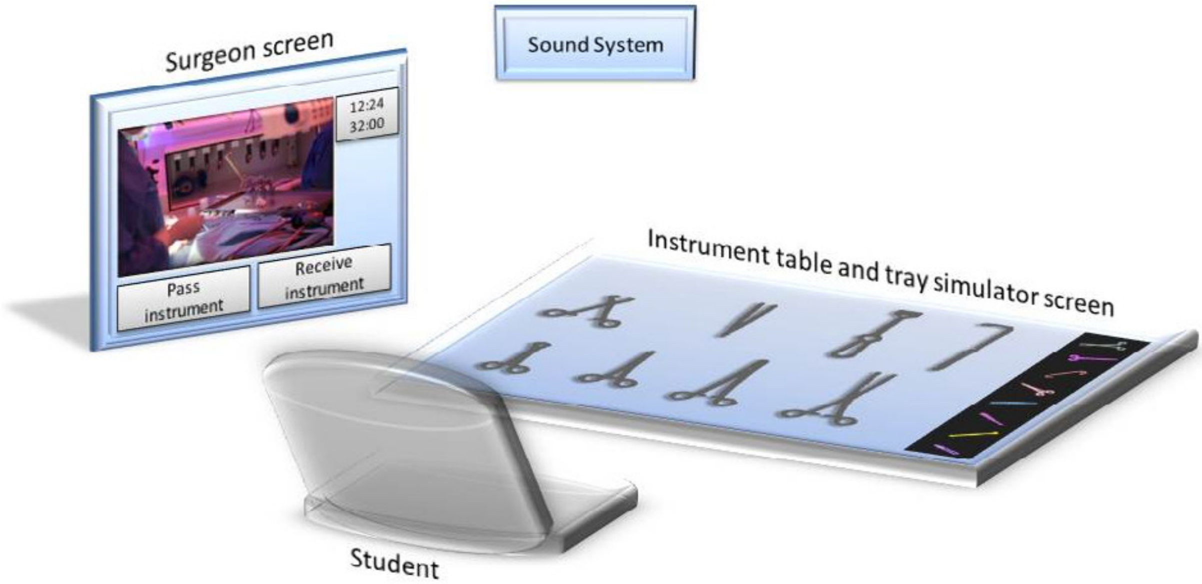

Fig. 1 – Conceptual sketch of the overall structure of the simulator

Abstract:

People who have to handle surgical instruments in their daily working routine face specific challenges, such as identifying and distinguishing a wide range of sometimes very similar instruments. The project presents a surgical instrument training system which can be used by a student without the need for a human supervisor.

People who have to handle surgical instruments in their daily working routine face specific challenges. Above all, they need to be able to identify and distinguish a wide range of sometimes very similar instruments.

Extensive research has been conducted into the simulation of surgical operations. Approaches with a huge percentage of computer-generated simulation such as virtual reality mostly focus on a single technique or a single type of surgery, e.g. laparoscopic interventions. Due to their computer-based structure and their focus on the specific technical skills of a specialized surgeon, human interaction in the operating room is neglected in these approaches. There is currently no system available that focuses exclusively on the skills and

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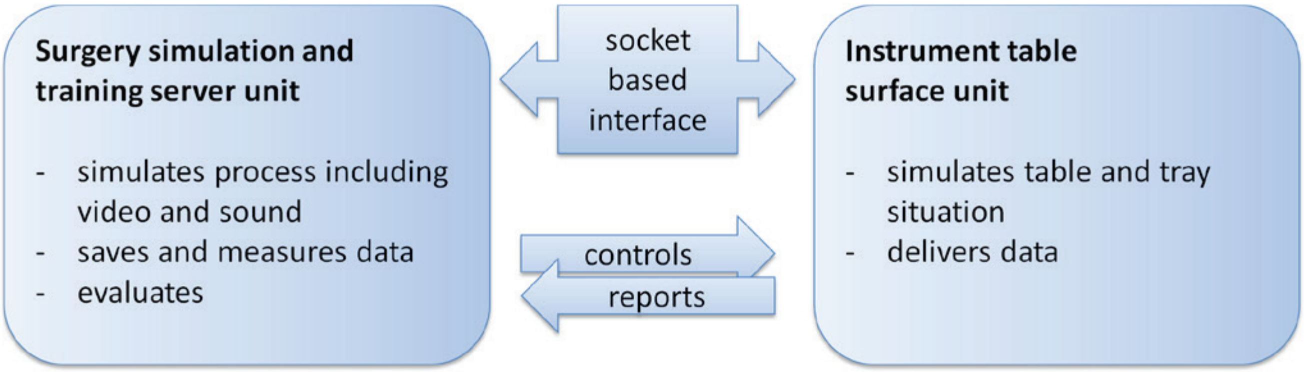

Fig. 2 – Simplified base architecture of the simulator system

needs of scrub nurses on an entirely technical simulation basis.

The project presents the concept of a surgical instrument training system which can be used by students without the need for a human supervisor. The system works without real surgical instruments. The central component is the simulation of an instrument table on a Microsoft Surface 2 system with multitouch functionality (Fig.1). A certain degree of realism for the student can be acquired, since all virtual instruments and objects on the table can be moved, rotated and stacked.

The trays containing instruments for the operation that are not on the table yet but may be necessary as the operation proceeds are simulated by a selection menu on the side of the table, where the contents of the trays can be scrolled through and additional instruments can be added to the main area via drag-and-drop.

The second main component is the surgeon screen, which shows a video of the type of operation being taught. The training videos are recorded in real operations from the assistant's point of view and afterwards enhanced with additional information stored in an accompanying XML metafile. The test person passes an instrument to the virtual surgeon by selecting it on the instrument table simulation and clicking on the 'Pass instrument' button of the Surgeon Screen System, which features touch functionality. Fig. 2 gives a short insight into the intended architecture of the system. The original sound of the operation is also played back, including all the surgeon's verbal comments.

Current work on the project is focusing on producing an initial working prototype.

Upcoming enhancements will deliver first simulations of complete surgical interventions and evaluate them with persons handling surgical instruments in the operating room. ■

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SENSOR BASED AUTOMATIC RECOGNITION OF SURGICAL WORKFLOWS

Fig. 1 – Surgical intervention play and manual workflow recording

Abstract:

The project's aim is to automatically monitor current surgical activities and the progress of an intervention. The first step was the development of an instrument detection system based on Radio Frequency Identification (RFID) to omit the 'used instrument' information in the surgical workflow record – an approach that was demonstrated by evaluation to be successful.

Given the growing number of medical devices used in operating rooms, surgeons and their assistants are having to handle increasingly complex user interfaces and their specific parameters and configuration options. In addition to taking the focus away from the surgery itself, this is also a significant source of malfunctions. One way of overcoming this problem is to use automatic control devices so that the medical personnel can concentrate on their main task. To achieve this, the resulting system has to be aware of the current surgical activity and the progress of an intervention.

Previous works revolved around human observers with tablet PCs manually recording surgical activities. The main thrust of this

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Europa fördert Sachsen. ESF Europäischer Sozialfonds

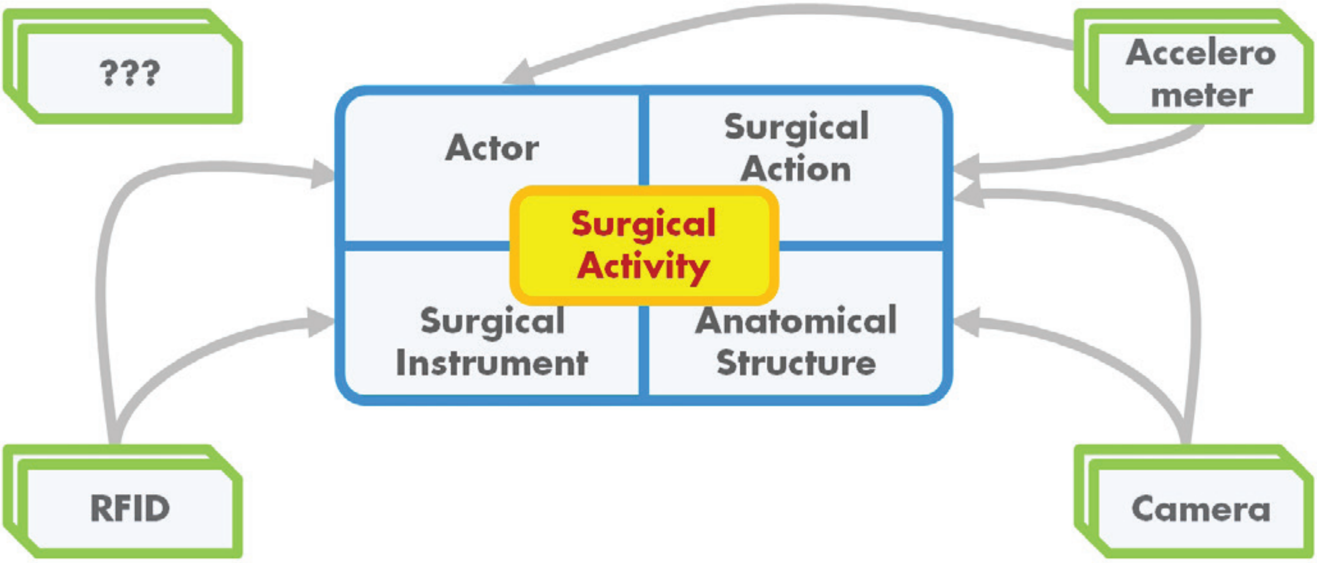

Fig. 2 – The surgical activity and its aspects

project is to substitute manual input with automatically acquired data. However, the high complexity of activity recognition in surgery makes it difficult to replace manual input in a single technological step. Our approach is the successive substitution of activity aspects with an automatic system. The first step was the development of an instrument detection system based on Radio Frequency Identification (RFID) to omit the 'used instrument' information in the surgical workflow record – an approach that was demonstrated by evaluation to be successful. The second step was the integration of an acceleration measurement system to infer surgical actions like 'incision' etc. Since each system by itself tends to produce ambiguities, their information needs to be combined using a methodology based on sensor fusion. The goal of this approach is the automatic inference of surgical activity and all its aspects. This is accomplished by using a hierarchical recognition concept in which each layer follows the same recognition process. It consists of signal specific feature segmentation and sequence classification steps which in combination form the hierarchical structure. Results of multiple evaluation studies based on simulated surgical interventions showed that the system is able to distinguish a set of surgical activities. The studies took place in our demonstration OR at ICCAS, which can be compared to a real operating room. The next step in this project will be the integration of additional measurement systems to cover remaining activity aspects such as 'treated structure', the enhancement of existing and the evaluation of alternative recognition algorithms. ■

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THERMOGRAPHY FOR MEDICAL APPLICATIONS

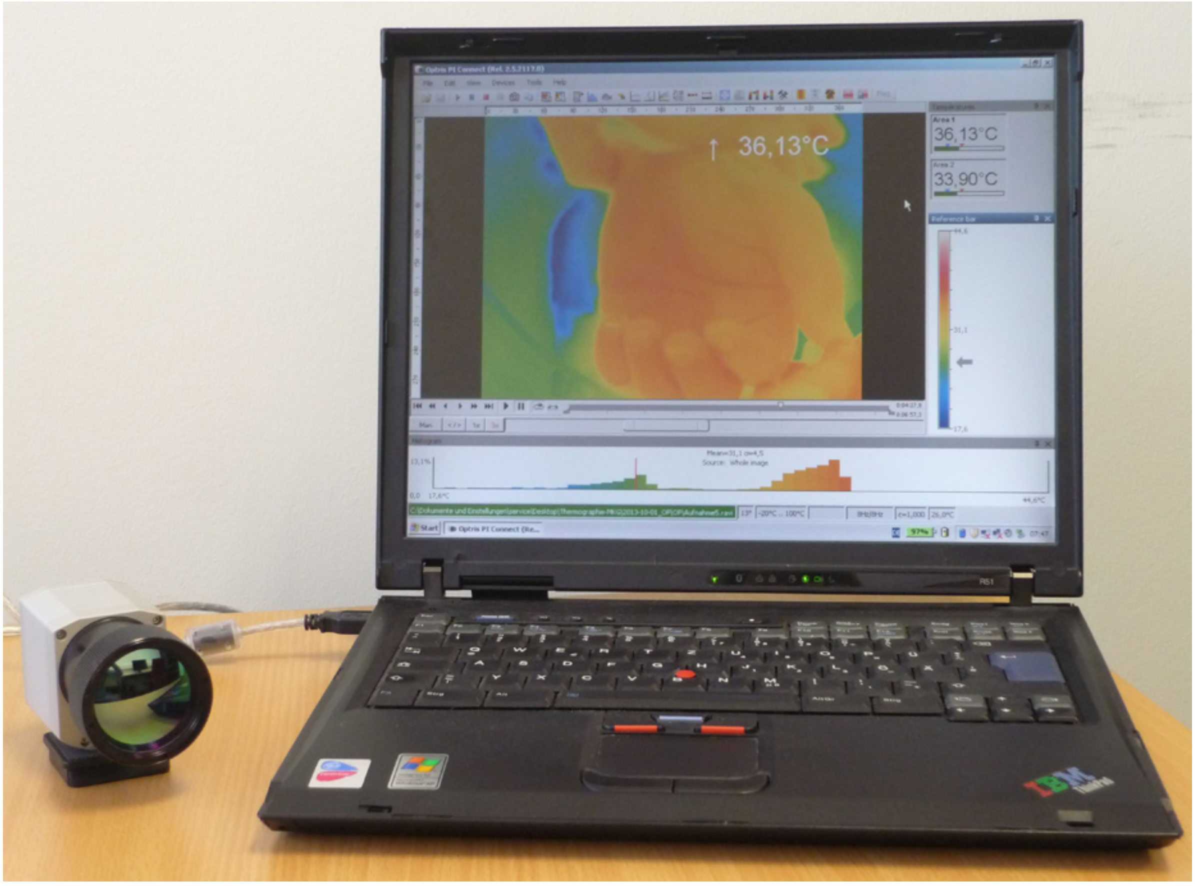

Fig. 1 – Thermal camera connected to the laptop and showing a thermal image of the hand

Abstract:

The goal of this project is to develop temperature sensors along with measuring and evaluation tools for surgical applications. The system includes a thermal camera connected to a laptop used for the acquisition, visualization and evaluation of thermal images. It has been tested on the task of bone drilling (with and without cooling) to analyse the temperature reached.

Infrared thermography is based on the electromagnetic radiation emitted by warm bodies, which is invisible to the human eye. Thermal cameras include sensors that convert both emitted and reflected radiation into images where the pixel values are proportional to the temperature of the body. This technique is totally non-invasive, contactless and easy to use. It is suitable for medical applications and especially the operating room. The objectives of this project are therefore to develop temperature sensors as well as measuring and evaluation tools for surgical applications.

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The system includes a small thermal camera (PI 160, Optris GmbH, Germany; 45 mm x 45 mm x 62 mm) with a sensitivity of 100 mK. The frequency of image acquisition is 120 Hz and the image size 160 x 120 pixels. The camera is connected to a laptop using a USB connection. An application enables the acquisition, real-time visualization and analysis of thermal images (PI Connect, Optris GmbH) (Fig. 1). Different colour maps are available to depict the thermal images. Regions of interest (ROI) can be selected in the image and the minimum, maximum or mean temperature in the ROI is shown. These values can be displayed in curves as a function of time. Since thermography is a contactless technique, there is no need to sterilize the camera. We are testing the camera to make sure that it still works properly when covered by a sterile envelope in case this is required by surgeons. In the operating room the camera is positioned on a tripod for more stability at a maximum distance of 50 cm from the ROI. A lens with 41° x 31° FOV is used.

The system was tested on the task of bone drilling in order to analyse the maximum temperature and to prevent possible damage to tissue close to the drilling position. An ox bone was first warmed up in a warm water bath. Once the bone had been taken out, drilling was performed using a 5 mm milling cutter with a speed of 40,000 rpm. The same experiment was performed with additional cooling of the milling cutter with water at room temperature and a flow of 60 ml/min. Thermal images were acquired and a hot spot corresponding to the highest temperature found in the image was shown. In the first experiment, the highest temperature obtained was 74°C and corresponded to the position of the milling cutter (Fig. 2, left). With the cooling system, the hot spot was located outside

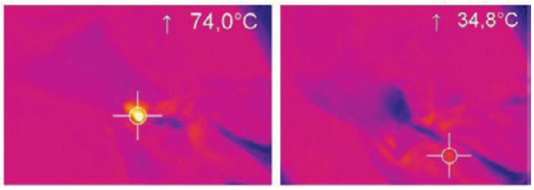

Fig. 2 – Experience with a milling cutter without (left) and with (right) cooling system

the milling cutter position, a maximum temperature of 26°C was being measured at this position (Fig. 2, right). ■

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SURGICAL ACTIVITY RECOGNITION SYSTEM

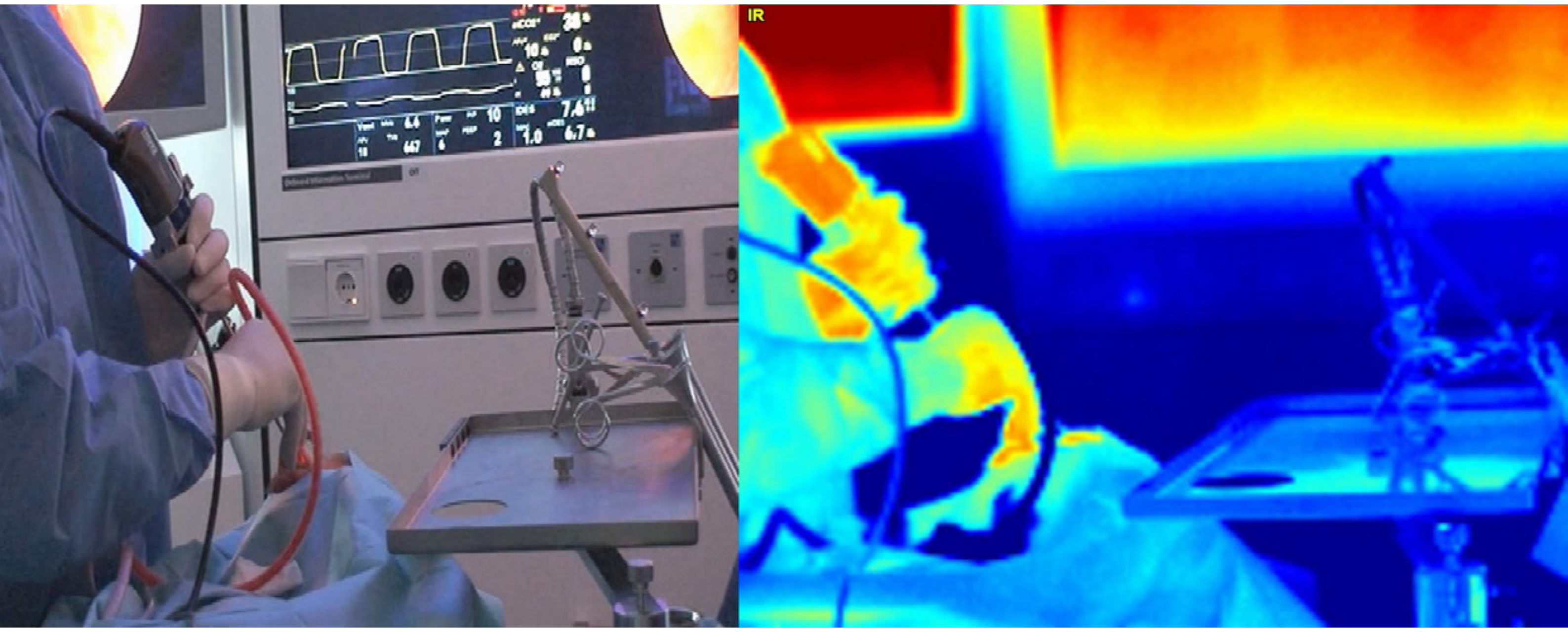

Fig. 1 – Visual and thermal image of suction during a FESS operation

Abstract:

Recognizing surgical tasks requires the robust recognition of surgical activities. In this project, we are developing a surgical gesture recognition system using infrared thermal imaging. This system provides the basis for modelling surgical workflows and developing assistance systems.

In recent years, methods such as the Surgical Process Model (SPM) have been developed to describe highly complex surgical processes. Information from surgical processes is currently used for post-surgical analysis and studies. A surgical operation usually consists of interventional phases each denoting a section of an operation and ending with a certain goal. A phase consists of multiple sequences of surgical activities which are identified using sensor data.

Currently, only motion data and visual images are used to identify surgical activities; information from thermal imaging is omitted. Yet thermal imaging provides precious information because the medics' hands and the instruments used display characteristic temperature features (Figure 1).

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The project's aims are to recognize surgical activities (tasks) from thermal images. The thermal images are pre-processed to remove the background and to segment the areas containing hands and surgical instruments. Afterwards, a hierarchical temporal memory (HTM) network is used to distinguish between different surgical activities. The HTM was developed to model the structural and functional properties of the human neocortex. It allows unknown images to be categorized by combining the principles of Bayesian networks and clustering algorithms.

For system validation and to estimate accuracy, a simulated FESS was performed and recorded with a thermal camera. Students acting as a surgeon and an assistant performed

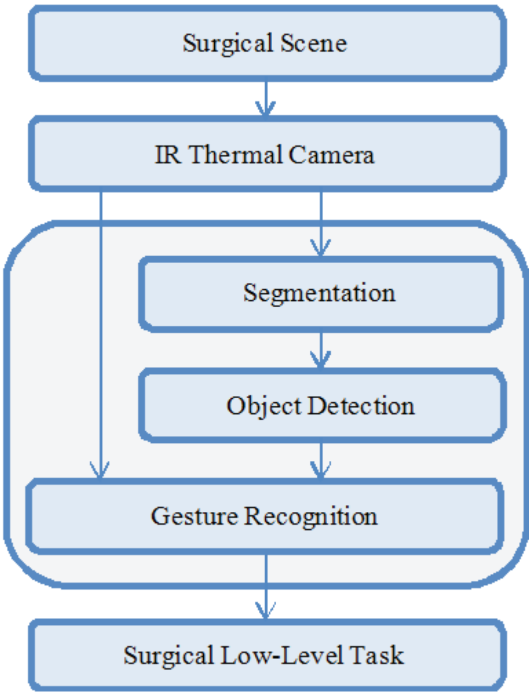

Fig. 2 – Structure of the software

the simulated surgery on a phantom. The surgical scripts were based on the workflows of previously recorded surgery. The activities making up the operation were announced to the actors by a recorded voice, ensuring a steady workflow throughout the multiple passes. Three different workflows representing different operations were recorded four times each, making a total of 12 videos. Each workflow lasted approximately 20 minutes.

Our study showed that low-level tasks can be recognized from infrared thermal images. The system can hence be used to identify low-level tasks in real-time. Using a standard Windows-based desktop PC to run the software, our system takes about 300 milliseconds to process a thermal image and classify the surgical activity. Accordingly, this system can be used to recognize surgical activities online and to provide input data to surgical assistance systems and workflow management systems.

In conclusion, our system is capable of recognizing surgical activities by means of thermal imaging. However, the overall recognition rate needs to be further improved when using the system as an input for surgical assistance systems. ■

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MULTI-PERSPECTIVE WORKFLOW MODELING FOR ONLINE SURGICAL SITUATION MODELS

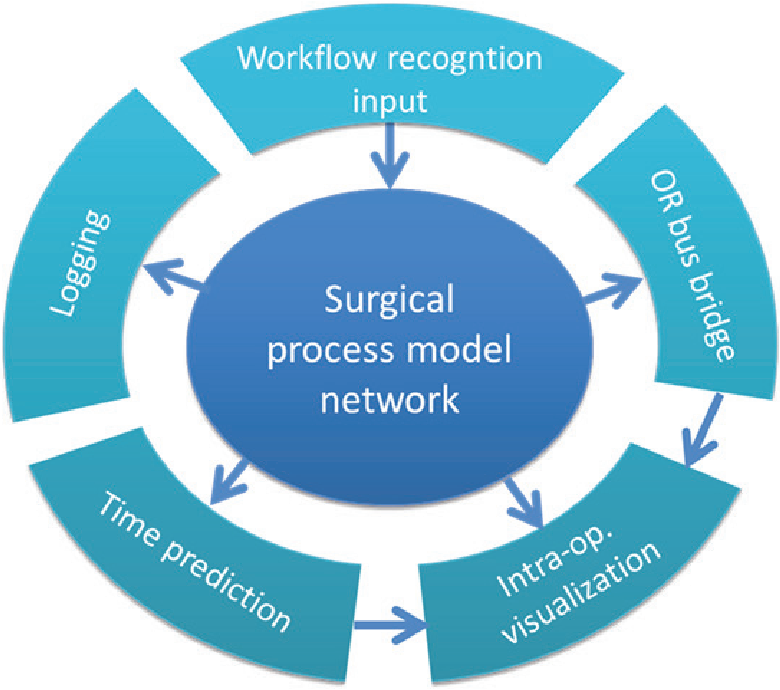

Fig. 1 – Application modules of the surgical workflow management system

Abstract:

Surgical workflow management is expected to enable situation-aware adaptation and smart systems behavior in an integrated operating room. Work in the project is currently focusing on online situation models as a crucial prerequisite for a cooperative technical environment for the surgeon and the OR staff.

Surgical workflow management is expected to enable situation-aware adaptation and smart systems behavior in an integrated operating room (OR). The overall aim is to unburden the surgeon and the OR staff from manual maintenance and information-seeking tasks. One major step towards smart systems behavior would be the stable classification of the surgical situation in multiple perspectives based on recognized low-level activities.

The present work proposes a method for classifying surgical situations based on multi-perspective workflow modeling. The starting points of our work were actual surgical procedures recorded as individual surgical process models. The recordings were compiled into generalized surgical process mod-

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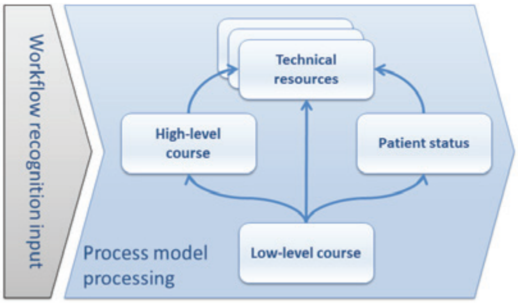

Surgical situation model

Perspective	Example value
Low-level course	Surgeon cuts the dura mater with a scalpel (and its history as surgical worflow trace)
High-level course	*Dura incision*
Patient status	*Skull occluded*
Technical resource 1	*Unlikely required*
Technical resource 2	*Likely required*
Technical resource 3	*Not used yet*

Fig. 2 – Schema of the surgical situation classification method and example perspectives

els representing averaged courses of specific intervention types. The model structure was based on detailed work steps. Additional high-level information was captured by a top-down modeling approach. The high-level models were based on Markov theory, including application-specific adaptations. A model network interconnecting different types of surgical process models was implemented.

Overall, various aspects of a surgical situation description were considered: low-level tasks, high-level tasks, patient status and the usage of medical devices. These aspects were compiled into an online situation model as a formal representation of the surgical situation. This situation model expresses various aspects of the surgical situation and their interconnections. The model also forms the basis for communication between surgical workflow management and the surgical assistance systems. The process information enables situation-aware autonomous adaptation. However, the concrete adaptation and its risk management are part of the assistance system itself.

A study involving 60 brain tumor removals was conducted to evaluate the performance of our approach. Additionally, the uncertainty of workflow recognition techniques was considered. The robustness of the proposed method against incomplete and distorted workflow recognition input was tested. A correct classification rate of over 90 percent was measured for high-level tasks and patient status. Overall, a decline in the classification rate was observed when the distortion of the input increased. Missing input had a slightly greater impact on performance than distorted recognition data.

The autonomous adaptation of medical systems and smart systems behavior do not only

Fig. 3 – Screenshot of the intraoperative visualization of process related information

depend on current low-level task. They require a more general kind of understanding of the situation. The integration of various surgical process models into a network provides a more comprehensive situation description. Multi-perspective surgical workflow modeling will be a significant prerequisite for reliable, smart systems behavior. It will hence contribute to a cooperative OR environment that increases patient safety and reduces costs. ■

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OUTCOME QUALITY ASSESSMENT BY SURGICAL PROCESS COMPLIANCE MEASURES IN LAPAROSCOPIC SURGERY

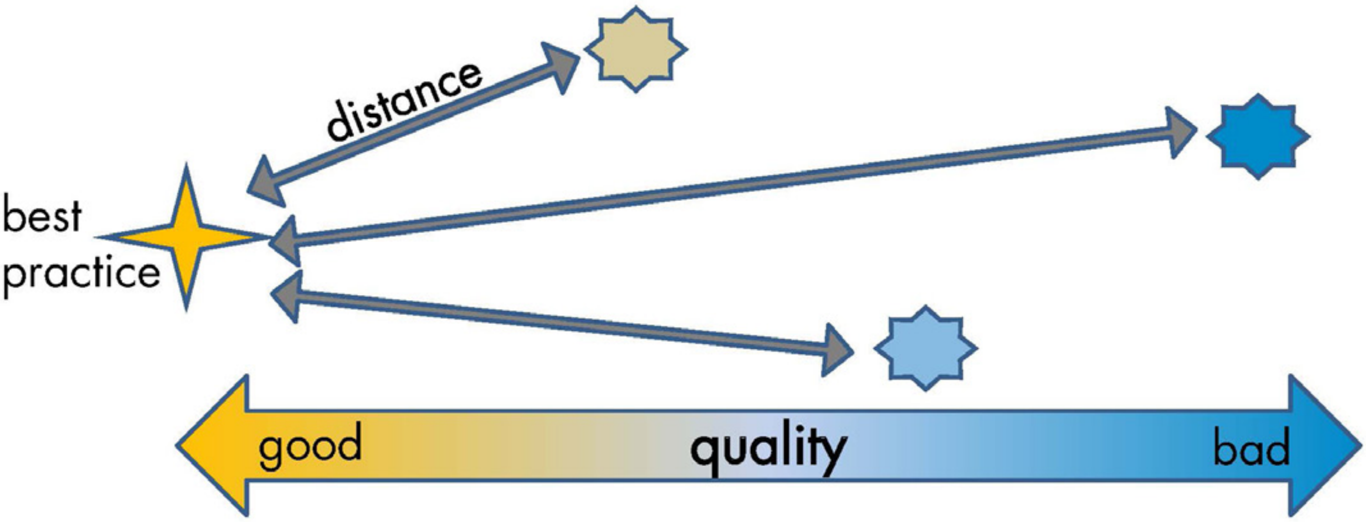

Fig. 1 – Hypothesis: The bigger the distance of a surgical process to best practice the worse is the outcome of the process

Abstract:

The effective and efficient assessment, management and evolution of surgical processes is essential for first-rate patient care. We assessed the relationship between the course and the outcome of surgical processes. By assessing 450 surgical processes from minimally invasive surgery training sessions in paediatric surgery, we examined the hypothesis that there is a significant relationship between the course of a surgical operation and the quality of its outcome.

The effective and efficient assessment, management and evolution of surgical processes is essential for first-rate patient care. Hence, the quality of the outcome is of great importance alongside economic interests. Process benchmarking examines the correspondence between an intraoperative surgical process and another process that is considered best practice.

The quality of output is regarded as good if the process conforms with best practice standards, whereas deviation leads to diminishing quality. Analysing this common understanding of surgical processes is the subject matter of this work. We assessed the relationship between the course and the outcome of surgical processes. By assessing 450 surgical processes from minimally invasive surgery training sessions in paediatric surgery, we examined the hypothesis that there is a significant relation-

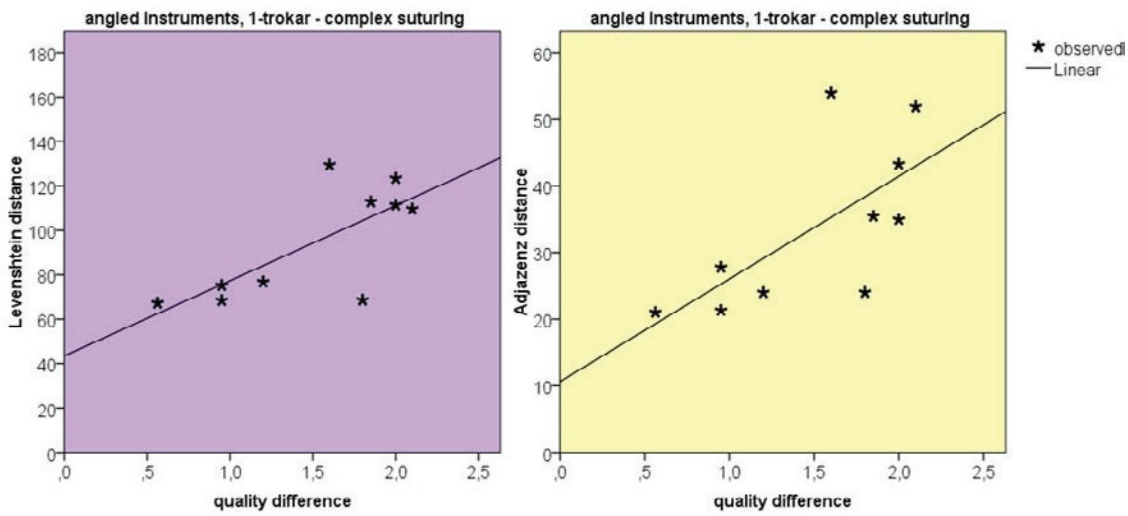

Fig. 2 – Results of the linear regression for one task (complex suturing) in one setting (angled instruments and 1-trokar incision) for both distances. There is a correlation between quality of outcome and process compliance

ship between the course of a surgical operation and the quality of its outcome. The results showed a significant correlation between the quality of process outcome and process compliance. We also showed that deviating from best practice leads to the decreased quality of outcome.

Furthermore, the conventional analysis of surgical processes is retrospective, the findings being used to support future operations so that if problems recur, they can be better solved or avoided. Moreover, surgical workflow management in the operating room requires information about the ongoing surgical intervention. This information can be obtained by predicting distances of ongoing surgical processes.

The mains aim of the second project was to analyse the distance measurements of surgical processes while they are underway. The distances were measured and analysed while the surgical intervention was still taking place. Coherence during surgery proves the hypothesis that there is a correlation between the distance of a process from a reference while it is underway and the distance after the completion of the process.

High process compliance supports good quality and therefore excellent patient care. This is important to identify requirements, generate feedback for the surgeon with due regard to human factors, and change the workflow to improve the quality of outcome. ■

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EVENTOR – EVENT-BASED NETWORKING IN THE OPERATING ROOM

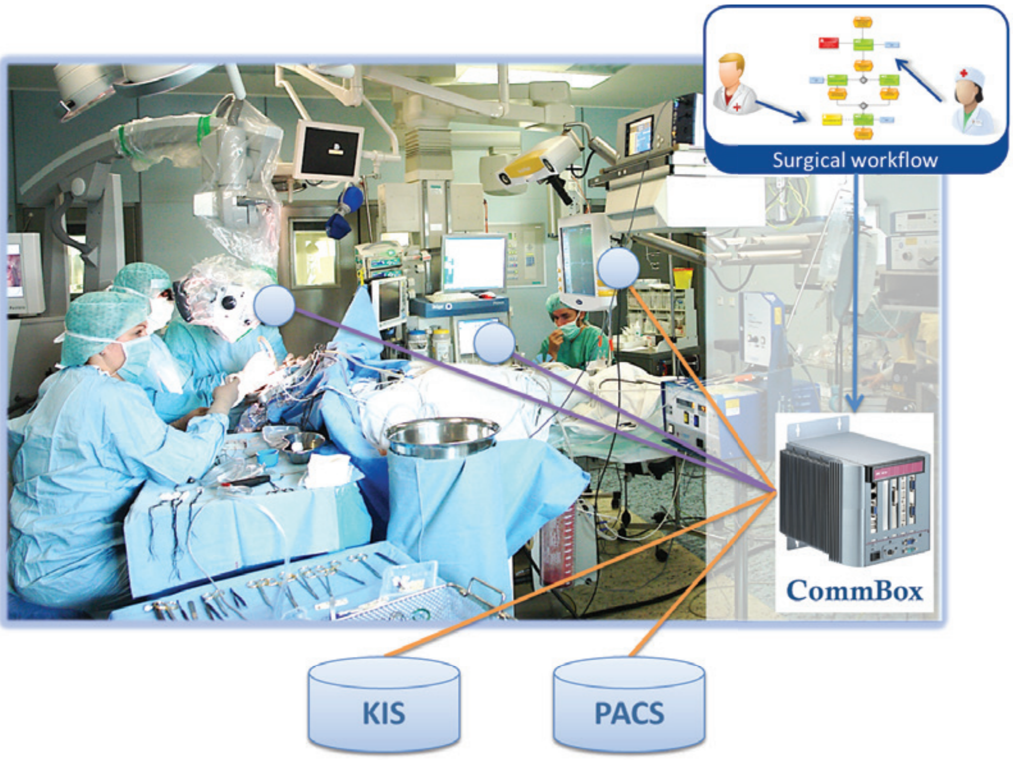

Fig. 1 – Schematic representation of the EVENTOR concept with the CommBox as centralized workflow-processing unit interconnected with various medical devices

Abstract:

The aim behind EVENTOR is to enable the workflow-driven interconnection of medical devices, which do not share a common interface. A centralized unit integrates process logic and communication frameworks and implements various communication protocols.

The introduction of new technology in the operating room (OR) has exacerbated surgeons' workload due to very time-consuming system configuration, device operation and information-seeking tasks. Concepts and proprietary solutions for integrated operating rooms have emerged in recent years. Medical equipment and assistance systems share their information and control functions via various OR bus implementations which allow the integration of information and centralized control. However, flexibility in the OR setup and the introduction of new technologies are hampered by the lack of a single standard for intraoperative device communication.

EVENTOR is being conducted in cooperation with SWAN – Scientific Workflow Analysis GmbH. The project aims to enable the workflow-driven interconnection of medical devices which do not share a common interface.

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EVENTOR

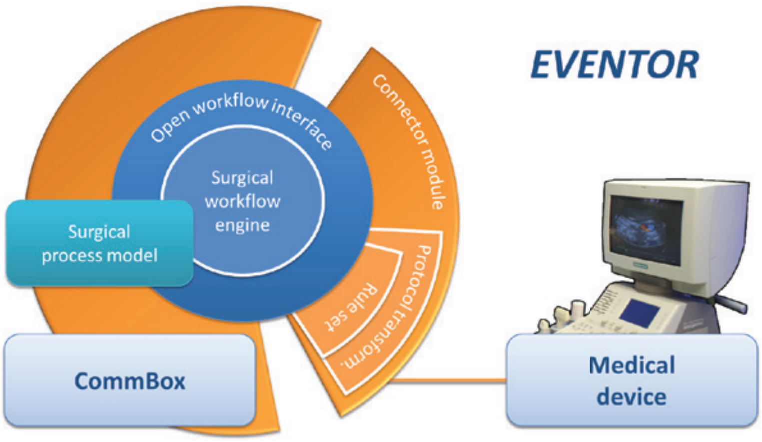

Fig. 1 – The internal architecture of the CommBox with a connector module including rule set processing and protocol transformation for the attached medical device

A centralized unit known as the CommBox is to be developed which implements various communication protocols by integrating process logic and communication frameworks. The interfacing of medical devices is to be controlled by process logic based on surgical process models. As a result, the CommBox will be able to automatically set up communication pathways between components of the overall OR system depending on the surgical situation. Surgical process models represent specific types of surgery by breaking them down into work steps. A workflow engine, the core component of the CommBox, processes these models to follow the surgical process. Each medical device can be attached to the process logic using connector modules. The process logic's open interface enables application-specific connector modules to be developed for medical devices of any kind. Each connector module provides two main functions: protocol transformation and situation adaptation. Workflow-driven adaptation for each medical device type is implemented by processing a rule set. It derives the communication pathways that need to be established from the surgical situation provided by the workflow engine. The actual data transport medium depends on the specific circumstances. Videos for instance are handled by a dedicated video bus with a control unit connected to the CommBox via a connector module.

The integration of process logic and communication frameworks facilitates assistance functions such as the situation-aware configuration of devices, the import of data from external systems, and integrated information visualization. We will develop prototypes for selected clinical use cases (e.g. brain tumor removals) to demonstrate the feasibility of this approach. A set of surgical process models for a type of surgery has been compiled. Brain tumour removals tend to be lengthy and complicated, and require many different technical systems such as navigation, intraoperative ultrasound and electrophysiology, calling for workflow-driven configuration and communication. The process of developing the EVENTOR framework includes risk management according to EN ISO 14971. The prototype will be evaluated under laboratory conditions and in clinical practice. ■

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OR.NET – SECURE AND DYNAMIC NETWORKING IN THE OPERATING ROOM

SUBPROJECT: INFORMATION QUALITY ASSURANCE IN THE NETWORKED OPERATING ROOM

Abstract:

For networked devices, providing reliable and complete information is of essential importance. Ensuring proper data quality is just as important as the networking of the devices itself. The goal of this project is to automatically assess individual patient data with respect to the requirements specified for certain use cases. An Automatic Image Quality Assessment (AQUA) component permanently monitors the (image) data streams in order to review their validity for specific tasks.

In recent years, the networking of medical devices has become increasingly important. Particularly image-guided procedures have significantly extended the possibilities for surgeons, allowing for example minimally invasive surgery. It is essential that the information provided by networked devices is reliable and complete. However, the mere technical availability of data does not necessarily ensure that the required information is provided. For example, modern software tools for image-guided surgery define specific requirements regarding the quality of image data in both the planning and the intervention stage. For subsequent systems, insufficient data could be just as fatal as the failure of the data source. Therefore, safeguarding proper data quality is equally important as the networking of the devices itself. Given the growing integration of medical devices, automatically assessing the quality of data streams is becoming more and more important. In order to guarantee the safe functionality of individual processing modules, the patient's individual data needs to be compared to the requirements specified for a specific task. Measuring the quality of image data streams on a semantic level is very difficult and no established monitoring components exist yet.

This project is investigating general concepts for automatically measuring the quality of medical images. The requirements for specific use cases, which form the basis for assessing an image's suitability for answering a certain question, are being analyzed. This frame-

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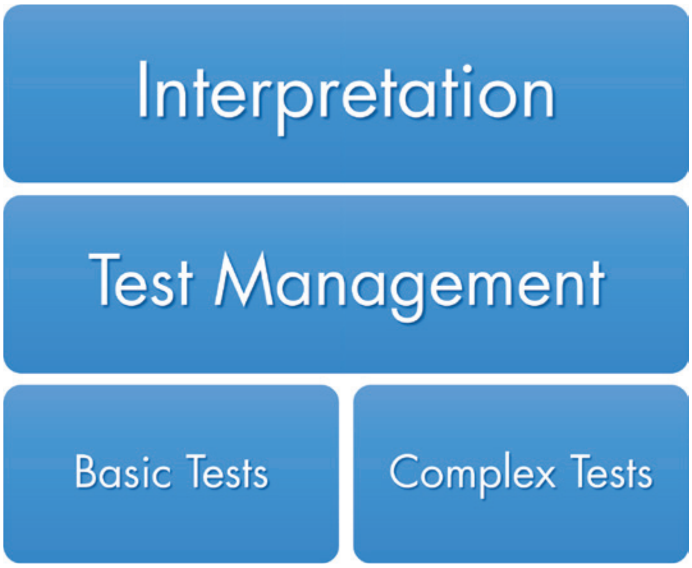

Fig. 1 – Layered architecture of the AQUA framework, which permanently monitors the quality of a patient's individual image data streams in order to review their validity for specific use cases

work for Automatic Image Quality Assessment (AQUA) will be integrated into OR.NET architecture to create a monitoring component, which permanently reviews the validity of relevant image data streams. The AQUA framework will consist of several layers (see Fig. 1). In this architecture, basic tests refer to both the analysis of the meta-information stored in the DICOM header and fundamental image quality tests, such as signal-to-noise ratio (SNR) and blurring. Complex tests include for example the detection of typical imaging artifacts as well as the detection of structures within the image and whether the structure of interest is completely shown by the image. The test management layer controls which tests have to be performed for a specific use case and how they need to be parameterized. It is also responsible for storing the test results. Finally, these results are analyzed by the interpretation layer, which decides whether the patient-specific measures are acceptable for a certain use case.

Intra-operative imaging plays an important role during surgery. However, this typically requires registering the images acquired intra-operatively with the pre-operative planning data. Objectively assessing the quality of registration results would allow the more effective utilization of intra-operative imaging technologies. Therefore, quality measures for registration results will also be explored in this project. ■

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FUSION OF FLUOROSCOPY AND INTERVENTIONAL ULTRASOUND

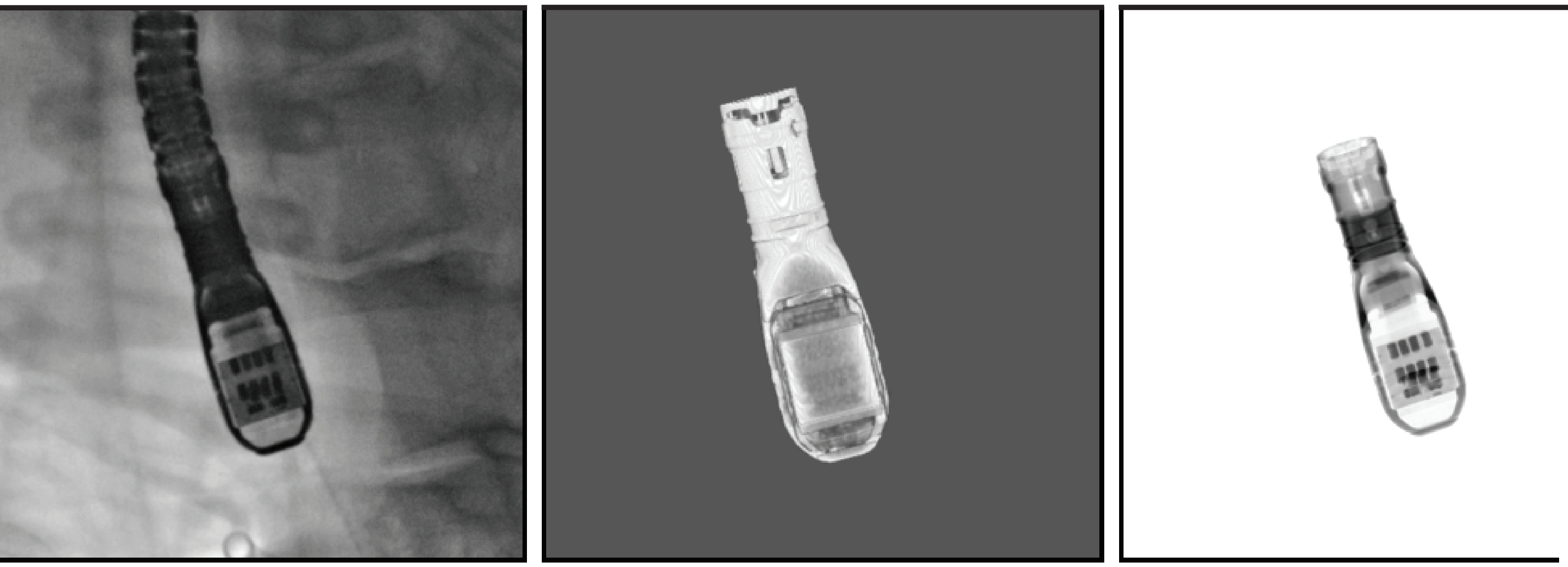

Fig. 1 – Left: X-ray image containing the TEE probe. Center: Volume rendering of the TEE probe model. Right: Digital reconstructed radiograph (DRR) of the TEE probe model

Abstract:

Ultrasound and X-ray are the two enabling imaging modalities used in transcatheter-based minimally invasive procedures in structural heart disease. X-ray fluoroscopy provides excellent instrument imaging while ultrasound shows high-quality images of soft tissue. Fusing these two modalities could potentially improve the surgical workflow and catheter navigation. X-ray fluoroscopy can be fused with trans-esophageal echo (TEE) with the help of 2D/3D registration. An ultrasound probe model is registered to the X-ray image which inherently provides a registration of ultrasound images to X-ray.

More and more procedures in the field of structural heart disease are becoming minimally invasive and catheter-based. They include for instance trans-catheter aortic valve implantation, trans-catheter mitral valve repair, the closure of atrial septal defects and left atrial appendage. This shift from open-heart surgery to trans-catheter procedures is driven by the availability of new catheter devices and the intra-procedural imaging.

These procedures are usually performed under fluoroscopic X-ray and trans-esophageal echo (TEE). Intra-operatively, these modalities are mainly used independently of each other: X-ray imaging is performed by the cardiologist or surgeon at the left or right side of the patient whereas ultrasound imaging is carried out by the anesthesiologist at the patient's head. An image fusion of the two systems could improve mutual understanding of

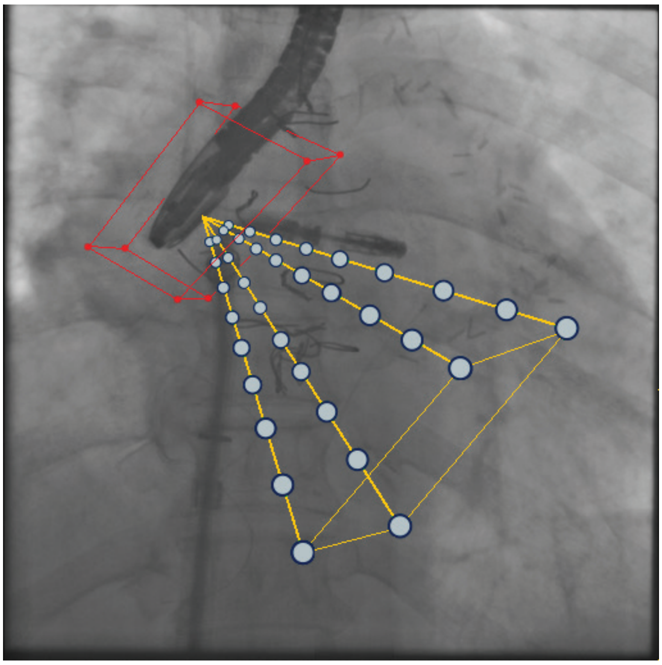

Fig. 2 – Possible visualization of a registration of a TEE probe. The 2D/3D registration inherently provides a registration of the ultrasound (symbolized as pyramid structure) to the X-ray image

the image contents and ultimately even lead to new kinds of procedures. The ultrasound and X-ray images move relative to each other because the position of the imaging devices is changed by the operator, as well as because of the motion of the patient's heart and breathing. Therefore, almost real-time updating is needed in order to synchronize the relative position of the two images. The success of such an approach heavily depends on the clinical usability of a fusion system.

One way of fusing ultrasound with fluoroscopic X-ray is 2D/3D registration. A TEE probe is detected in the X-ray image and thereby derives the 3D position of the TEE probe relative to the X-ray detector, which inherently provides a registration of the ultrasound image to the X-ray image. To estimate the 3D position, a model of the TEE probe is registered to the X-ray image via a 2D/3D registration algorithm. The 3D position of the probe is iteratively adapted using an optimization method until a similarity measure between the projected probe model image and the X-ray image is maximized. The method does not require any modifications to the TEE probe and does not entail setting up the system specifically for each procedure.

Fusing ultrasound and fluoroscopic X-ray images could potentially improve the whole workflow of today's minimal invasive cardiac interventions. It could be of great help for better image interpretation and faster and more accurate interventional navigation. This might increase the patient's safety and could also shorten the procedure time.

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DEVELOPMENT AND EVALUATION OF A CLINICAL INFORMATION SYSTEM SUPPORTING ONCOLOGICAL TUMOR THERAPY

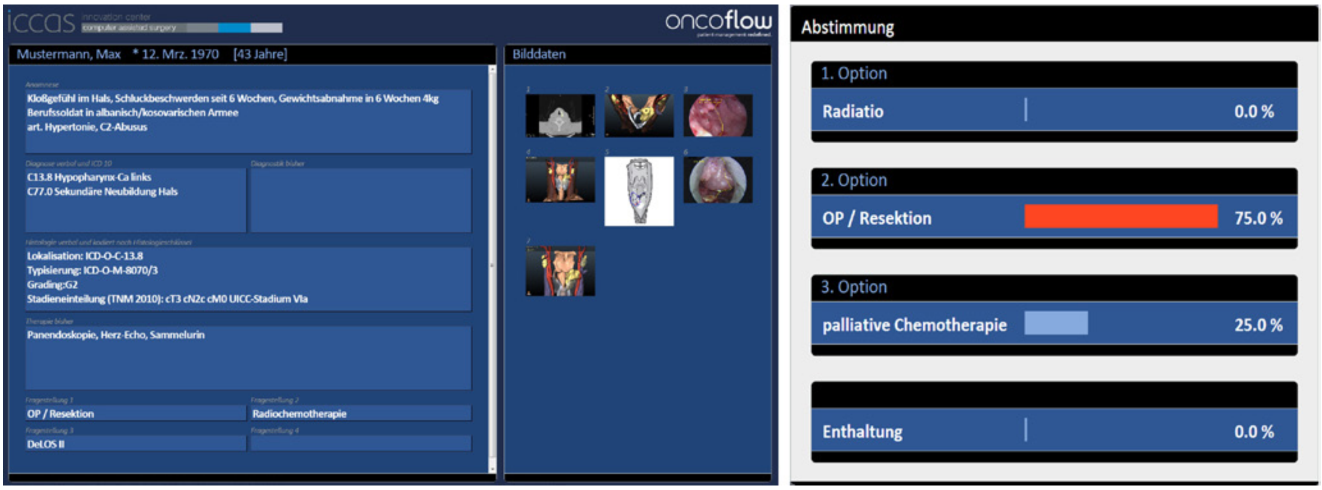

Fig. 1 – left: Compact overview of current patient with endoscopic images, right: voting result screen

Abstract:

The oncoflow information system supports physicians and surgeons in head and neck tumor therapy. Therapy-related information is automatically imported from various information sources, integrated within a structured information model, and used to improve the treatment process as well as the decision-making process on the tumor board.

Therapy planning for tumor patients is a lengthy, challenging process due to the complexity of disease patterns, multiple treatment options and the involvement of different medical disciplines. Numerous assistance and decision support systems are used in daily clinical routine to relieve physicians and surgeons from recurring and time-consuming tasks as well as to provide support for complex therapy planning scenarios (see Figure 3). However, these systems do not integrate well into the clinical workflow and are poorly integrated into the clinical IT landscape, while their possibilities for sharing patient-specific information with each other are limited. The clinical information system oncoflow is intended to support the physician and clinical staff throughout the entire treatment process. All necessary patient-related information is automatically imported into a centralized database via communication interfaces with relevant clinical information systems such as the Hospital Information System (HIS) and the Tumor Therapy Manager (TTM). Each information entity is stored in a structured way for further electronic processing, work-

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flow assistance in daily clinical routine and usage in clinical trial studies, or for quality management purposes. The information is conveniently accessible for the clinical staff within a structured web interface. Based on the previously acquired patient-specific information, oncoflow supports the physician with various workflow support functions. An overview of the current medical status of a patient is crucial, especially for physicians who are not familiar with the current patient. The treatment summary in oncoflow addresses this issue and provides a condensed patient overview summarizing the main information in the current treatment phase. A prototypic rule-based implementation aggregates the latest information available originating from each process step into a one-page overview (see Figure 2). Upcoming clinical certifications from the DKG German Cancer Society (Deutsche Krebsgesellschaft) make high demands on tumor conferences. The existing requirements for cancer centers and the few compelling studies about the outcome of tumor boards form the basis for the implementation of a comprehensive tumor board assistance module. The module provides tumor board management including the creation and mailing of invitation letters

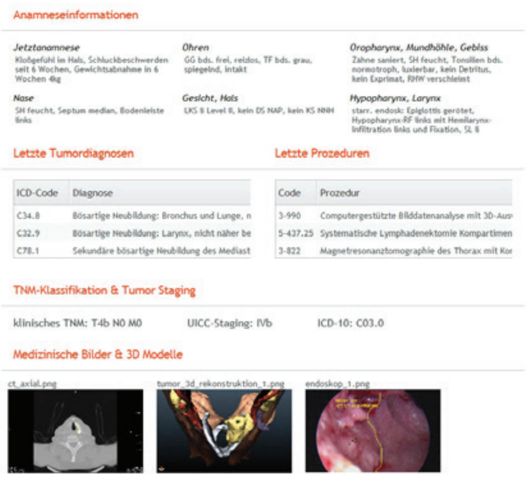

Fig. 2 – The treatment summary gives a brief overview of the patient's current medical status

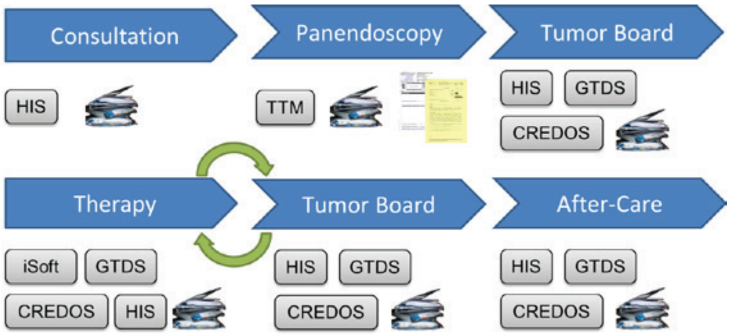

Fig. 3 – Treatment process and clinical information systems used for patients with head and neck cancer

and results documentation as well as extensive documentation features during the tumor board to make the decision-making process more transparent (see Figure 1). Additionally, the tumor board module has been designed according to the certification requirements of the DKG. The next steps in this project are the integration of additional information sources, the development of further clinical assistance functions, and supporting the entire patient treatment process in daily clinical routine.

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SPARC – SURGICAL PLANNING AND RESOURCE CENTER

Fig. 1 – Overview of the SPARC system environment

Abstract:

Since improving efficiency in operating rooms is very important in order to cut costs, we are developing a workstation to provide a centralized overview of all the operating theatres in a hospital.

High costs and risks are incurred in hospitals due to the inefficient management of resources in operating theatres. Therefore, both costs and risks in operating rooms need to be reduced. In order to ensure patient safety and improve surgeons' workplaces, technicians have to monitor equipment (e.g. medical devices, medical software) in several operating rooms at once. In addition, hospital managers want the capacity of operating rooms to be used economically. Accordingly, an overview of all the operating rooms in a hospital with the help of a partially automated resource management system is the key to improving the clinical workflow.

The Surgical Planning and Resource Center (SPARC) implements a central environment by analyzing important information for different users. Structured data is obtained from

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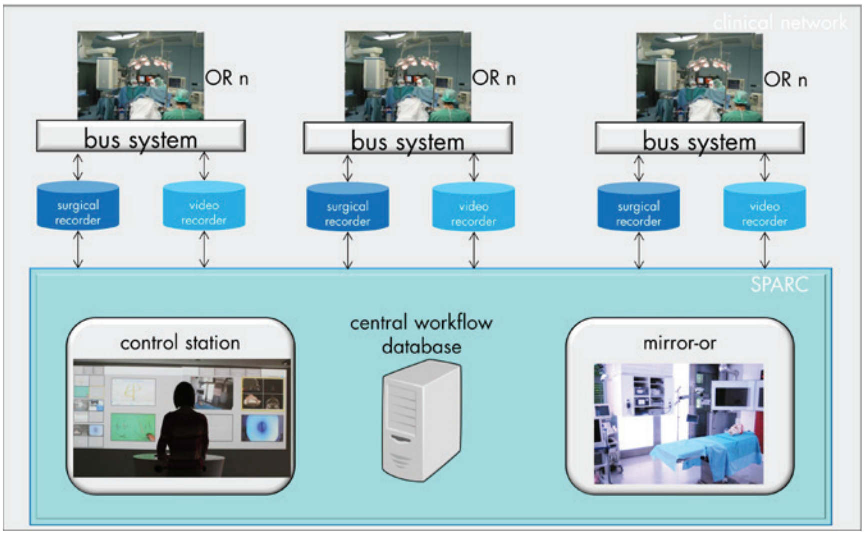

Fig. 2 – The user interface of the SPARC at ICCAS

medical equipment with the help of the Surgical Recorder. Medical device data and video data are transferred by a safe network to the SPARC control room (see Figure 1).
At first, SPARC was connected at ICCAS to the demonstration OR, where FESS surgery is reproduced. Medical device data from a navigation system, an endoscope and AIDA (a hospital information system) are transferred to SPARC. Using-SPARC are created three different views of the operating room (see Figure 2). The first shows the Surgical Process Navigator, which is used to analyze different parameters such as the progress of a surgery or the equipment to be used next. This information can be used by various groups. For example, the operating room manager can use SPARC to plan the next operation or a hospital technician can monitor the equipment used with the aid of SPARC. The second view uses multiple software tools to monitor the situation in the operating room. For example, technicians or maintenance engineers may spot malfunctioning equipment, so that it can be replaced in time. The third view shows the data of the medical equipment used in the operating room. In future, we plan to set up a network at Leipzig University Hospital which enables all the data to be obtained from the various operating rooms and analyzed at ICCAS in real time. As a result, we will be able to evaluate the SPARC user interface for the different user groups. ■

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IT INFRASTRUCTURE FOR THE INTEGRATED TUMORBOARD - TREATMENT PLANNING UNIT (TPU)

Fig. 1 – Information presentation within the ICCAS Treatment Planning Unit (TPU)

Abstract:

Tumor boards are interdisciplinary team meetings where physicians from different disciplines try to find the optimal treatment for difficult cases of cancer. The overall process of data-handling, the presentation of patient information, and decision-making in tumor boards are optimized by the new concept of the Treatment Planning Unit, which was launched at Leipzig University Hospital in early 2013.

The treatment of head and neck malignomas is a long-term process that requires interdisciplinary collaboration between departments and the appropriate handling of diverse information such as pretherapeutic imaging, histologic findings, therapy decisions and precise planning due to the complex anatomy involved. However, current IT systems and paper-based records do not reflect the actual clinical data flow sufficiently. Furthermore, the decision-making process within clinical team meetings in tumor boards is mostly based on images within PACS and paper-based patient records. A web-based clinical information system known as oncoflow

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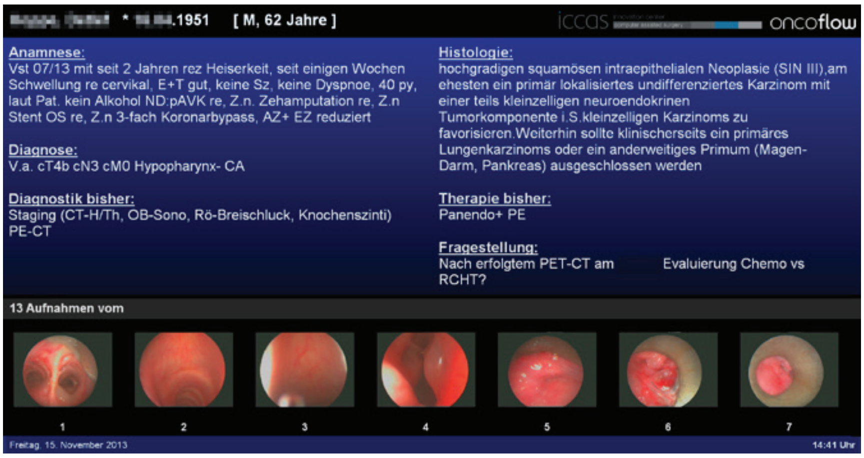

Fig. 2 – Integrated tumorboard display with relevant patient information and diagnostic images

has been designed and implemented using a modular software architecture (cf. S.34) to support the entire clinical treatment process as well as the tumor board. To improve efficiency within tumor boards, the new concept of the Treatment Planning Unit (TPU) has been introduced in this project. In early 2013, the former tumor board meeting room at Leipzig University Hospital was rebuilt according to the TPU design developed at ICCAS. The integrated tumor board now includes additional large screen displays to show digital patient data from different diagnostic modalities (Fig. 1). Furthermore, the lighting conditions have been improved and the seats rearranged to optimize interdisciplinary collaboration within the TPU. The oncoflow web system acts as an invisible IT infrastructure within the TPU. oncoflow supports the entire tumor board process electronically in a consistent, structured manner. The patient registration for the tumorboard is designed as paperless process using an e-mail based invitation of the tumorboard members. Interfaces with diagnostic systems such as endoscopy, modeling tools (e.g. Dornheim Neck Segmenter) and clinical IT systems (e.g. SAP i.s.h.med) have been created and integrated into oncoflow. Accordingly, all relevant patient details, images and 3D models are available for presentation on the large integrated displays and projectors so that all the tumor board members are equally informed about each patient's health status (Fig. 2). An electronic voting system aids decision-making in complex cases. The result is a consistent, automatically generated tumor board report that includes the therapy decision. Furthermore, the IT systems from nuclear medicine are integrated into the TPU to allow the inclusion of nuclear medicine diagnostics. The integrated TPU tumor board thus supports the process of determining the optimal treatment for each individual patient. To facilitate the concept of patient-specific healthcare, the TPU IT infrastructure has also been designed to act as a knowledge base for the research conducted at the Digital Patient Model (DPM) group at ICCAS. These digital models will provide additional support for decision-making for complex cancer cases (cf. S.48).

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MAGIC LENS FOR MINIMAL INVASIVE CARDIAC SURGERY

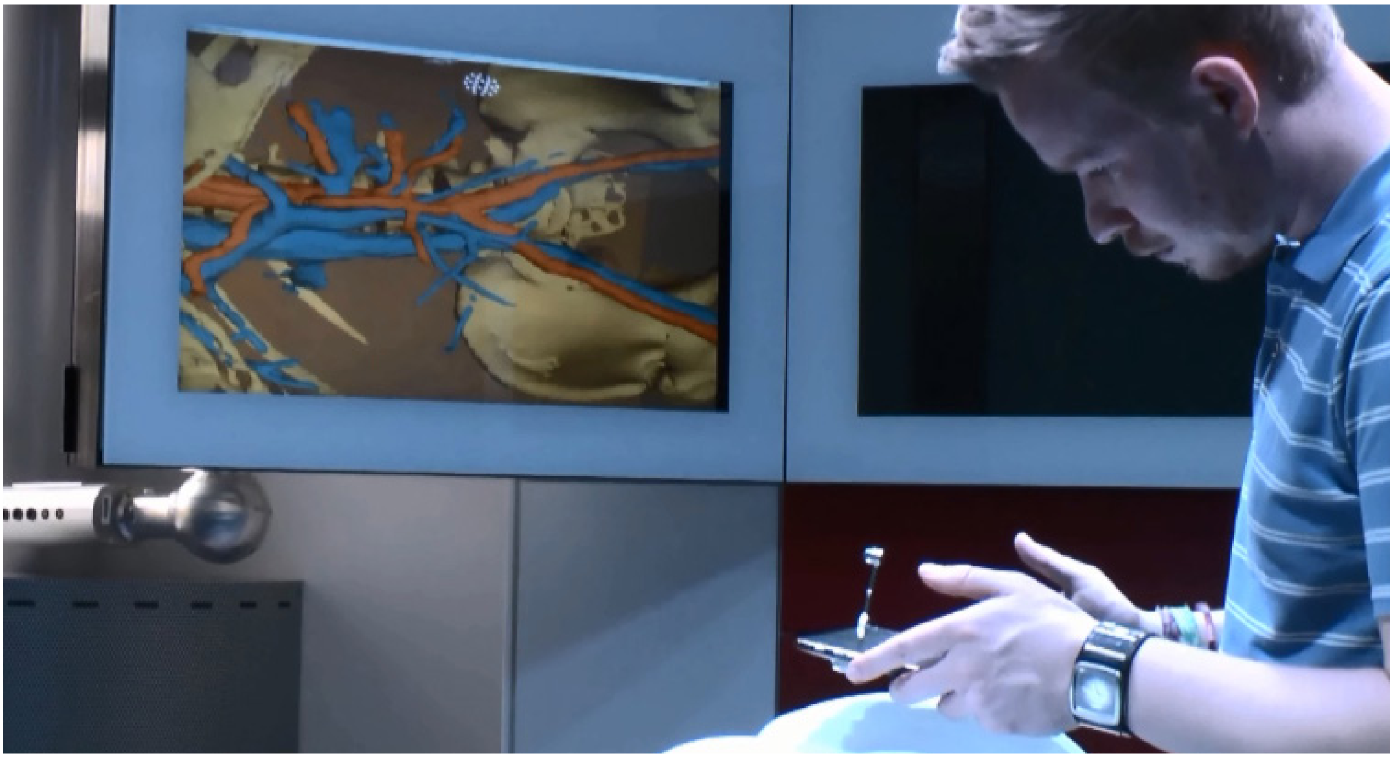

Fig. 1 – The magic lens in the Demo-OR at ICCAS

Abstract:

The Magic Lens is an augmented reality system for minimal invasive cardiac surgery. It is used to visualize anatomical structures under the patient's skin. The prototype demonstrates a way of interactively integrating preoperative patient data into the surgical area.

In minimal invasive cardiac surgery, incision points need to be reliably identified. However, since this can be a challenging task, we simplified it in this project by implementing a surgical assistance system. The augmented reality prototype which was developed adapts the Magic Lens concept for minimal invasive cardiac surgery. A Magic Lens is a mobile device that displays additional information depending on its position and the position of the user, and which can be used to visualize anatomical structures under the skin.
Routinely acquired pre-operative images were used to generate segmentations of anatomical structures. Intra-operatively, the system combined two sensors: optical tracking and a time-of-flight camera. Optical tracking was used to accurately measure the lens position whereas a time-of-flight camera was employed to track the surgeon. As both sensor

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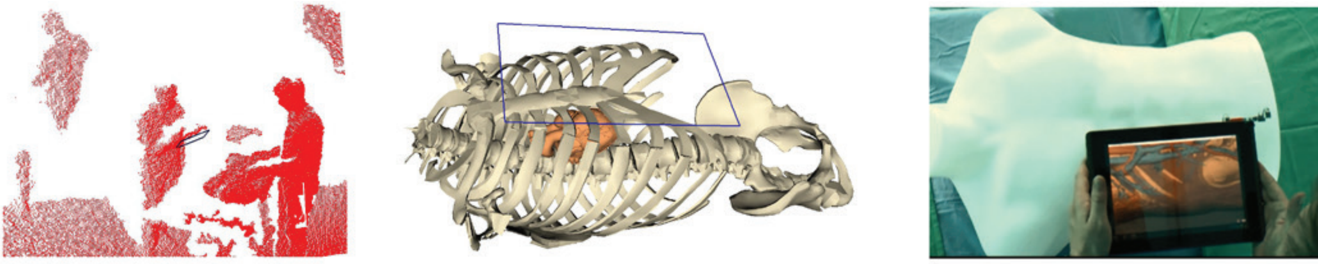

Fig. 3 – The magic lens concept with tracking of persons and magic lens (left), 3D visualization of segmented heart and bones (middle) and display on a tracked tablet (right)

systems were registered to each other, the system was able to track the surgeon and the Magic Lens simultaneously. Furthermore, the system was registered to the patient via surface registration techniques. Based on this setup, 3D surface segmentations of relevant anatomical structures could be displayed corresponding to the surgeon's angle of view.

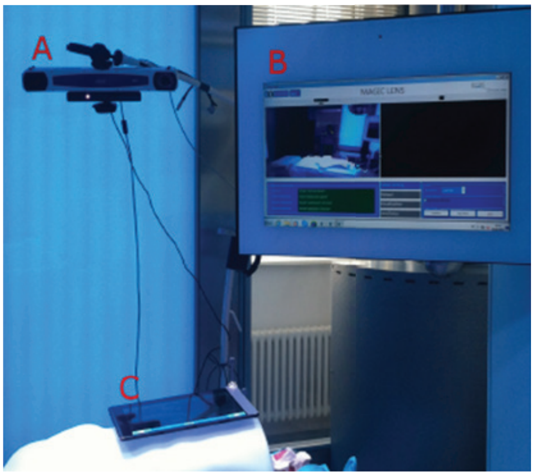

Fig. 2 – The technical setup of the magic lens with tracking system (A), workstation (B) and lens (C)

The 3D visualization was updated simultaneously with any movements and displayed segmented anatomical structures under the patient's skin. Several visualization scenarios were identified based on surgical use cases. The lens was able to adapt the presentation of anatomical structures with various presets. Additionally, an easy-to-use interaction concept allowed presets to be selected directly at the lens.

The current prototype provided the surgeon with context and focus dependent anatomical information, and hence fulfilled the two basic requirements of the Magic Lens concept. The prototype demonstrated a way of interactively integrating preoperative patient data into the surgical area. A preliminary user study involving seventeen cardiac surgeons was conducted to evaluate the interaction concept and the potential acceptance of such a system. The study findings indicated the strong potential of the proposed concept and provided important hints for the further development of the technology. The additional overlay of real-time video needs to be implemented to simplify the correlation between augmented information and situs. In future work, the system may also be extended to other use cases. ■

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EVALUATION OF 3D INTRAOPERATIVE CONTRAST-ENHANCED ULTRASOUND IMAGING FOR BRAIN TUMOR SURGERY

Abstract:

The goal of this clinical study is to evaluate 3D intraoperative contrast-enhanced US imaging for the visualization of brain tumours. During surgery, US image data of different tumour types is acquired before and after tumour resection. Initial results show that the use of US contrast agent significantly improves tumour margin visualization and the rate of gross total tumour resections.

Intraoperative imaging is crucial to optimize brain tumour surgery. Ultrasound (US) equipment is suitable for the operating room because it is relatively inexpensive, easy to handle, and provides images in real time. In B-mode images, tumour borders may be depicted badly because of artifacts as well as in the case of diffuse tumours. Therefore, our goal was to evaluate 3D intraoperative contrast-enhanced US imaging using a contrast agent intended to improve tumour visualization.

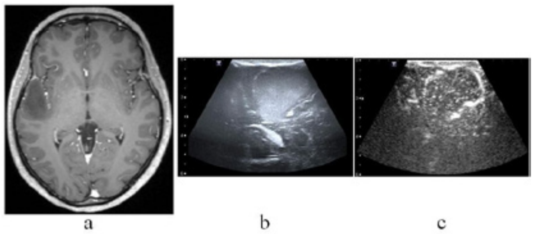

Fig. 1 – Representation of a low-grade glioma in preoperative cT1MR data (a), in intraoperative US B-mode image (b) and in intraoperative CEUS image (c). The last image shows that the representation of low-grade glioma is possible in CEUS data

The study involved 100 patients with different kinds of brain tumours. The operations were guided with a sononavigation system based on preoperative contrasted T1MR (cT1MR) data and linked to a common US device. Right after the craniotomy, two ultrasound volumes were acquired through the dura mater: 3D intraoperative B-mode US data (3D-iUS) and 3D intraoperative contrast-enhanced US data (3D-iCEUS), obtained after injection of the contrast agent. After tumour resection, this procedure was repeated. Moreover, three biopsies located in the resection cavity and, if possible, with contrast enhancement, were extracted. One day after the operation, post-operative MR data was acquired to check the presence of tumour remnants.

The first part of the evaluation was to qualitatively and quantitatively analyse the quality of tumour visualization in the US volumes acquired before resection based on visual observations and the computation of geometrical parameters. Secondly, the findings of biopsies were correlated with the information provided in the post-resection US volumes and the presence of tumour remnants established from the radiological reports. The results were obtained on 4 low-grade gliomas, 28 high-grade gliomas and 18 metastases.

Tumour depiction before resection

» Low-grade gliomas can be seen in the CEUS images even though they are mostly not enhanced in cT1MR data (Fig.1c).

» The contrast agent significantly improved the depiction of high-grade glioma margins in 52% of patients (Fig.2c).

» In the case of metastases, CEUS imaging overcomes possible artifacts responsible for blurred margins (Fig.3c).

» The tumour size and borders tend to be more accurately shown in 3D-iCEUS data than in 3D-iUS data.

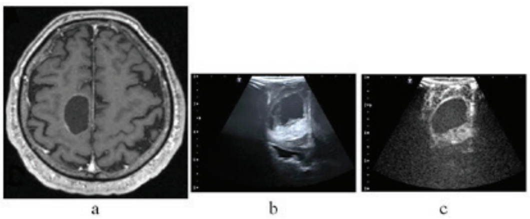

Fig. 2 – Representation of a high-grade glioma in preoperative cT1MR data (a), in intraoperative US B-mode image (b) and in intraoperative CEUS (c). The tumor margins look here sharper with the use of contrast agent

Tumour resection control

In 24% of patients with high-grade glioma, a tumour remnant was detected in the 3D-iCEUS data and removed. Therefore, a gross total tumour resection was achieved in 54% of the patients of this group, whereas studies mainly report a rate of 30-35% with conventional operations. Examination of the biopsies showed the high sensitivity of the 3D-iCEUS technique for the detection of tumours and infiltrated tissue in 85% of cases with a low specificity of 28%. Moreover, a gross total resection was achieved in 75% of patients with low-grade gliomas, compared to levels of just 20-30% in the literature. ■

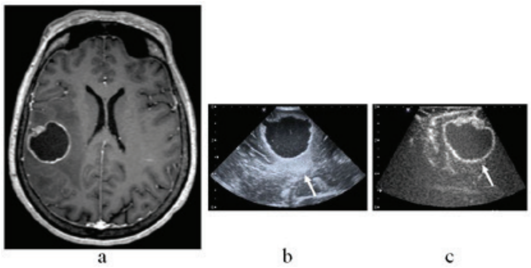

Fig. 3 – Representation of a metastasis in preoperative cT1MR data (a), in intraoperative US B-mode image (b) and in intraoperative CEUS (c). An artifact due to the cyst within the metastasis disturbs the delineation of the margins at the tumor bottom (white arrow). The border is perfectly sharp in the CEUS image

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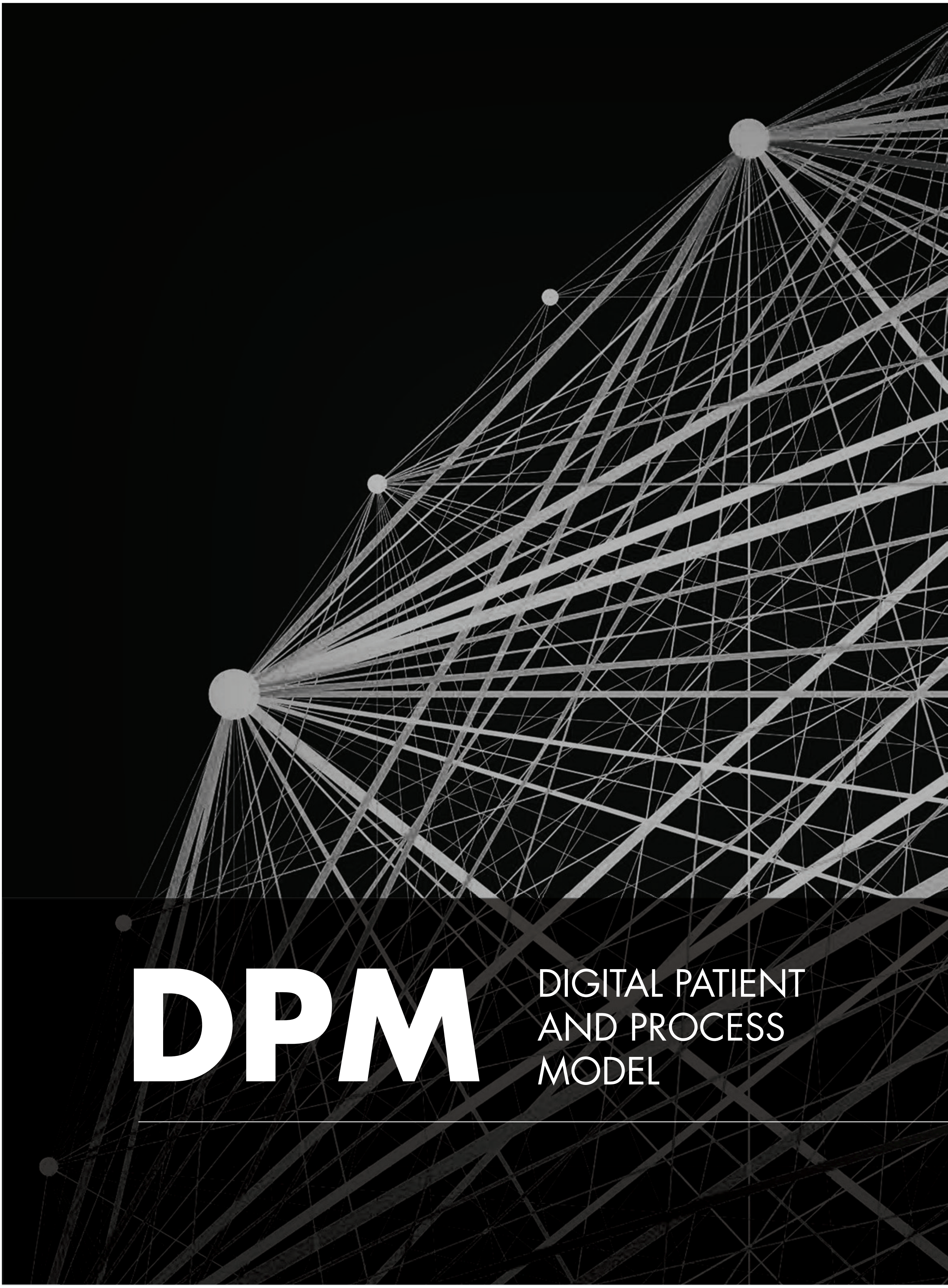
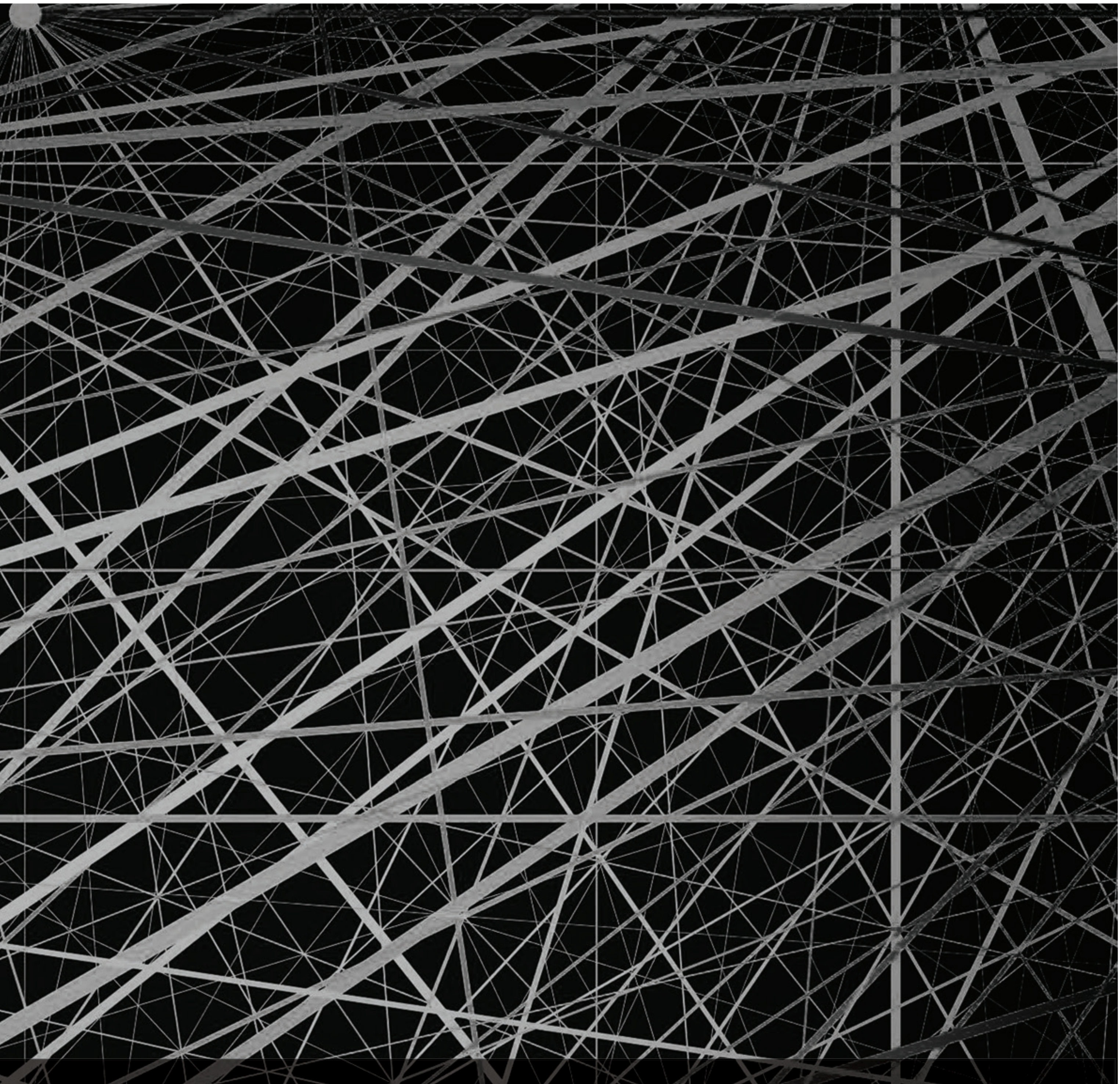


DPM

DIGITAL PATIENT AND PROCESS MODEL



RESEARCH VISION

Supporting diagnosis and treatment by providing medical knowledge together with semantically linked and enhanced patient data.

DIGITAL PATIENT AND PROCESS MODEL

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The digital patient record consists of a large number of isolated data entries that are provided by heterogeneous health information systems and medical devices. This data is often very complex and can only be completely considered in the decision-making process by a physician if made available in a clear, understandable manner before, during and after surgery. The objective of the research group is to integrate isolated patient data to automatically generate digital patient models. Patient models are intended to provide a comprehensive view of patients, their disease and disease occurrences, and thus provide the basis for applications in knowledge discovery, clinical decision support and therapy planning.

Research in this field concentrates on developing information structures for digital patient models as well as algorithms for processing and managing different types of clinical data. Moreover, knowledge is modelled for its inclusion in clinical decision support systems.
Work this year centred around three main topics: (1) knowledge modelling, (2) information extraction and (3) image analysis. One main achievement is a model of treatment decisions in connection with laryngeal cancer by means of a Multi-entity Bayesian Network. Furthermore, an algorithm for detecting defects in vertebral bodies in radiological images has been developed to support the classification of defects at the cervical spine.

Projects in this area are currently funded by the German Federal Ministry of Education and Research (BMBF) and the European Regional Development Fund (ERDF).

Selected Publications

Dänzer S, Freitag S, von Sachsen S, Groll M J, Steinke H, Leimert M, Meixensberger J. Statistical Model-based Segmentation Method for assisting Cervical Spine Interventions. In: Thiery J Beck-Sickinger A, Arendt T, editors. 11th Leipzig Research Festival; 2012 Dec 14; Leipzig, p.153.

Denecke K. Model-based Decision Support. Requirements and Future for its Application in Surgery. Biomed Tech. 2013; 58(1).

Stöhr M, Meier J, Sommer G, Dietz A, Lemke H, Denecke K. Modeling and Support of Decision-making regarding the Treatment of Laryngeal Carcinoma in the Head and Neck Tumor Board. In: German Medical Science GMS Publishing House 2013. 58th Annual Conference German Association for Medical Informatics, Biometry and Epidemiology (GMDS); Sep 2013 01-05; Lübeck.

PATIENT-SPECIFIC TREATMENT MODEL USING MEBN: EXAMPLE OF LARYNGEAL CARCINOMA

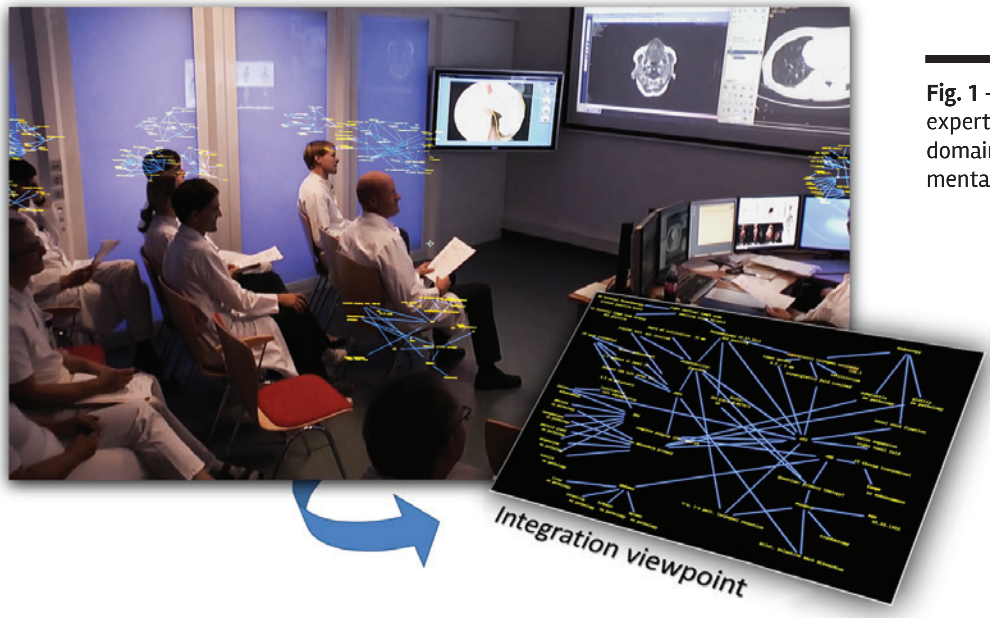

Fig. 1 – Tumor board with experts from different medical domains, each with an own mental model

Abstract:

These days, it is impossible for individual physicians to consider and handle all available patient information in an equitable manner. A Multi-Entity Bayesian Network is used to model and simulate a physician's complex decision-making processes, to support objective decision-making, and hence ensure patients' safety.

Our increasing understanding of the complexity of oncological diseases and the dramatic growth of patient information available theoretically allow individual treatment for each patient. However, the decision-making process involved in finding the most appropriate treatment for a specific patient is very complex since all the available medical information obtained from the medical records, scripts and elsewhere has to be mentally processed by the physician. An abstract presentation or 'model' of the patient is created, commonly referred to as a 'clinical judgement'. Physicians from different clinical fields usually have varying viewpoints mainly based on their individual background knowledge and experience. Thus, physicians may have different abstract models for the same patient (Fig. 1), making a unanimous decision difficult or even impossible. As a result, optimal treatment cannot always be guaranteed.

The aim of this project is to develop a patient-specific model (PSM) to assist treatment decisions by simulating physicians' complex decision-making processes. The model could form the basis for a decision support system or be used to visualize complex decision-making processes. The project is currently focusing on modelling treatment decisions in connection with laryngeal cancer. Under close cooperation over a year between

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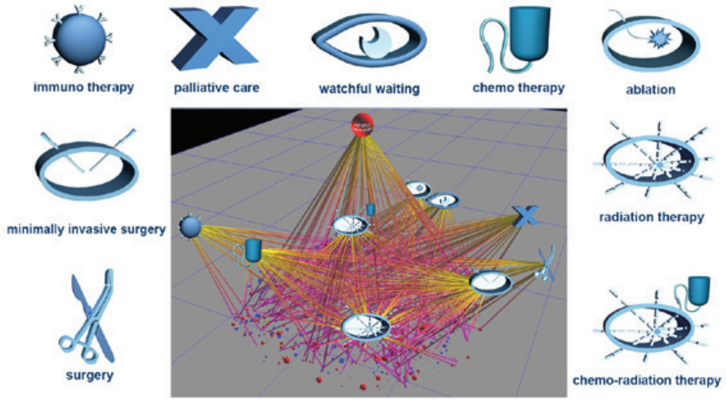

Fig. 2 – Example for a 3D graph visualization of a patient's point of view

an ENT physician and a computer scientist, all the necessary information items specific to laryngeal cancer treatment were collected and arranged according to their relevance and direct causalities. This information was then integrated into a Multi-Entity Bayesian Network (MEBN).

MEBNs are used to model and simulate abstractions of real-life situations and processes. They are based on both mathematical correlations between random variables (representing uncertainty and what is known with reasonable certainty) and a graph denoting the conditional dependence structure between these random variables.

The collected information entities (IEs) concerning for instance medical examinations, medical imaging, patient behaviour and patient characteristics (e.g. age, gender, tobacco and alcohol consumption) are integrated into the model as random variables. Direct dependencies between the IEs are established and conditional probability distributions (CPDs) are added to each IE based on their causal dependencies. These CPDs serve as weights of causal influences and are necessary for the computational aspects of the network, for example to infer the likelihood of unknown information in the network from the given patient data. Based on the developed network and added patient information, this MEBN becomes a patient-specific Bayesian network (PSBN) and allows the probabilities of the unknown information that the user wants to estimate to be computed.

At this early stage in the project, the model contains approximately 800 IEs with over 1000 dependencies. For the user-friendly handling and an overview of the model, the PSBN is to be visualized as a 3D graph in the near future. Depending on the type of user (e.g. medical specialists or even the patient) and their information need, the graph will be shown in different geometric constellations or topologies focusing on different information representations. The complexity of the graph will be simplified by intuitive symbols (Fig. 2).

The future aim is to develop a system that supports physicians not only by proposing decisions but also by providing explanations regarding the factors of influence involved in a decision. Such a treatment model is, however, only as good as the information sources from which it is derived and does not include immeasurable information entities such as the physician's intuition or hunches. It is only an abstraction that will never represent the entire patient. Accordingly, PSBNs are merely intended to assist doctors and not to release them from their decision-making responsibilities. ■

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SENTIMENT ANALYSIS IN MEDICAL NARRATIVES

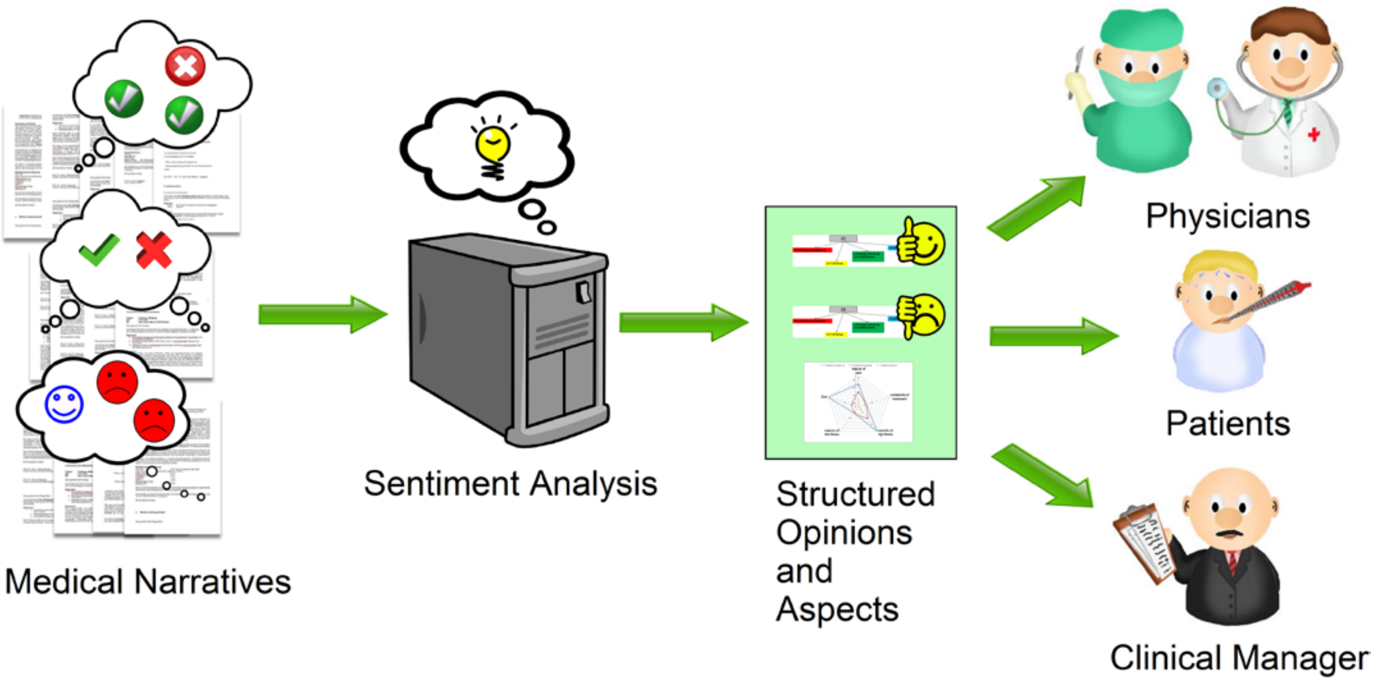

Fig. 1 – Schematic diagram for medical sentiment analysis

Abstract:

Sentiment analysis has been widely applied to collect opinions from user-generated content in social media. However, the sentiments expressed in medical narratives have not yet been well analysed and exploited. Given the further development of the principle of evidence-based medicine and digital patient modelling, opinion in the medical narrative will increasingly play an essential role in the clinical decision support process. In this project, new algorithms are being developed to detect opinions in a medical context and to make them available in decision support applications.

Sentiment analysis is conventionally used to collect user feedback on products and public opinion on social events from Web 2.0 media. Given the further development of digital patient modelling and the concept of evidence-based medicine, facts and knowledge are required as a basis for the modelling process. The opinion in a medical text can provide important aspects for decision support tasks and relation reasoning between different types of evidence. Moreover, the extracted opinion can also help the patient to better understand the medical report and improve quality management in the hospital. However, sentiment analysis has not yet been well exploited in a medical context. A medical report is written in a relatively objective manner: few adjectives and adverbs are used, while mainly symptoms, anatomical concepts and nega-

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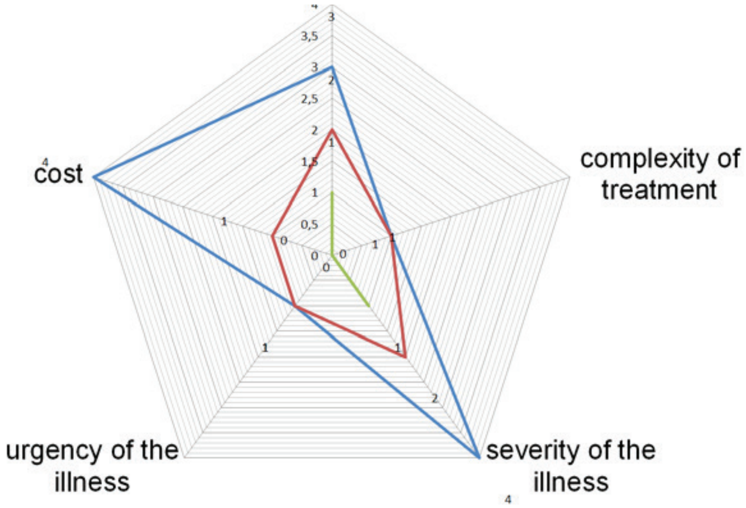

Fig. 2 – The opinion aspects from three medical reports (continuous treatments) are illustrated in the radar chart. Lines with different colors connect the opinion aspects of the corresponding reports generated at different timestamps. The area covered by connection lines indicates the overall situation of this patient. According to the chart, the situation of this patient has been improved obviously after this series of treatments

tions are employed to reflect the patient's situation.

Due to the objective nature and special distribution of terms in medical narratives, the conventional approaches based on adjectives and adverbs can no longer fully serve the recognition of polarity in medical texts. According to the experience obtained from manual annotation, the frequently used terms in medical text are summarized in the corresponding fine-grained categories such as illnesses, symptoms and anatomical concepts. The implicit sentiment aspects referring to these terms can be studied further.

More specifically, the frequently used terms (illnesses, anatomical concepts, symptoms) in the medical narratives can imply different aspects of the patient's situation. Five implicit sentiment aspects are therefore defined to characterize the opinions in a medical context (see Figure 2):

1) Degree of pain
2) Cost
3) Urgency of the illness
4) Severity of the illness
5) Complexity of treatment

In this project we are currently working on creating a knowledge base for medical sentiment analysis. Medical terms are annotated with respect to the five sentiment aspeby physicians based on their knowledge and available guidelines. Based on this knowledge base, we will develop algorithms to identify opinions in medical texts according to the five implicit sentiment aspects. These algorithms will form the basis for future applications of sentiment analysis to support for example patient treatment in the following ways (see Figure 1):

1) For physicians, it can highlight different aspects of examination and treatment results. Monitoring the patient's health status can be enabled. Fine-grained opinion retrieval can also be integrated.

2) For patients, the system will serve as a medical report translator.

3) For the hospital manager and resource planner, the system can provide basic quantitative measurement based on different medical narratives which can be used as a reference for planning and scheduling.

Appropriate visualization methods such as a radar graph combined with temporal features will be integrated into the system to meet different user needs.

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DIGITAL PATIENT MODEL – INFORMATION MODEL

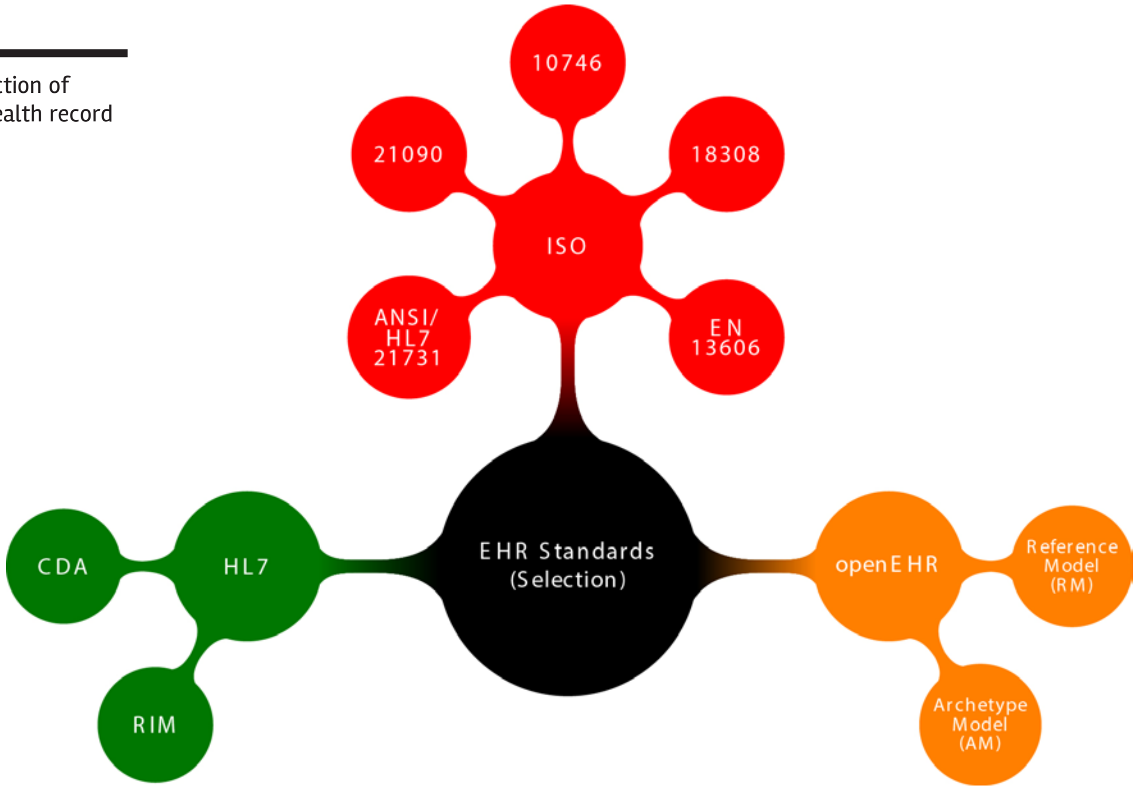

Fig. 1 – Selection of electronic health record standards

Abstract:

The aim of the project is the development of a standard-based information model for the Digital Patient Model (DPM). The use of the openEHR standard will enable international cooperation in the generation of new archetypes for the domain of surgery.

Patient data is distributed in heterogeneous information systems and sometimes locked away without any possibility of easily exporting it. Physicians need to interact with several systems to get a complete view on the health status of a patient, which is time consuming. Researchers need to access and reuse patient data, for instance for calculations or studies. It is crucial to have all relevant patient data available and accessible for the decision making process and the diagnosis.
The objective of this project is to develop a suitable information model for the domain of surgery that allows the description of patient data relevant to diagnosis and treat-

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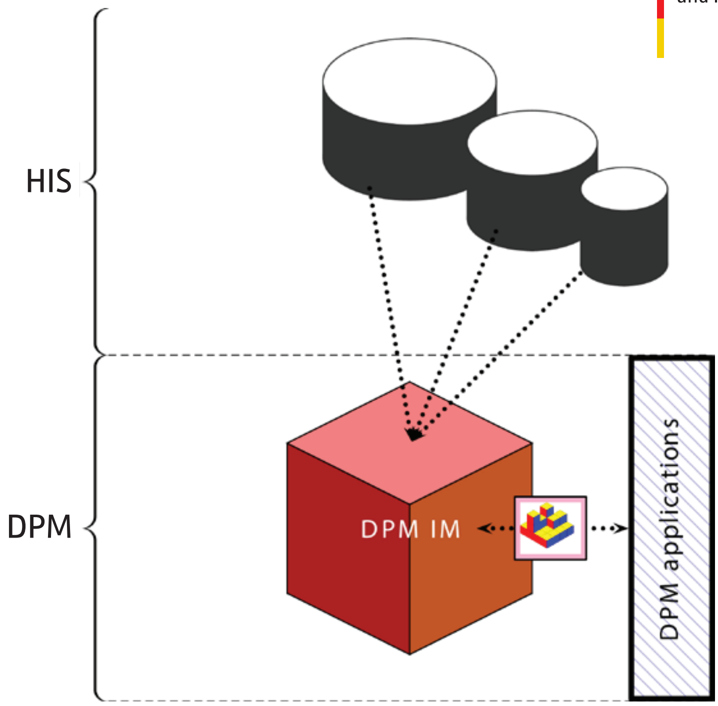

Fig. 2 – Information model for a Digital Patient Model

ment. Interoperability among health information systems is already addressed by several standards organizations. ISO and HL7 have published standards to show how electronic health records (EHR) should be structured to ensure interoperability within and between hospitals.
Figure 1 shows a selection of important EHR standardization initiatives.
Our work is based on the openEHR standard. OpenEHR meets the EN 13606 requirements but goes beyond EN 13606 by offering building blocks (archetypes) in a global repository. An active domain modeling community is co-operating worldwide to build archetypes of high quality that we will reuse and adapt for our purposes in the context of model-based surgery. The main concept of this standard is a two-model approach which separates knowledge from information. In this way flexible, customized archetypes can be defined which are built on top of a static reference model. This enables patient data to be stored in reusable building blocks upon which multiple applications can be built.
Figure 2 summarizes the project: Patient data stored in hospital information systems is mapped to an information model (IM) of the digital patient model (DPM). The information model includes relationships to external ontologies or terminologies. Applications use the building blocks developed, guaranteeing long-term accessibility and reusability. In addition, this will enable us to use an appropriate retrieval technique: the archetype query language (AQL). The use of AQL to query patient data will form the technical core of retrieval applications.
Potential applications of the openEHR-based information model include:

1) Information retrieval: Archetypes for extracted information can be identified and queries to retrieve documents or patient data with relevant content can be carried out.

2) Data availability: An information system for the long-term monitoring of patients undergoing surgery to treat tumors of the pituitary can be set up based on the archetypes and the reference model. ■

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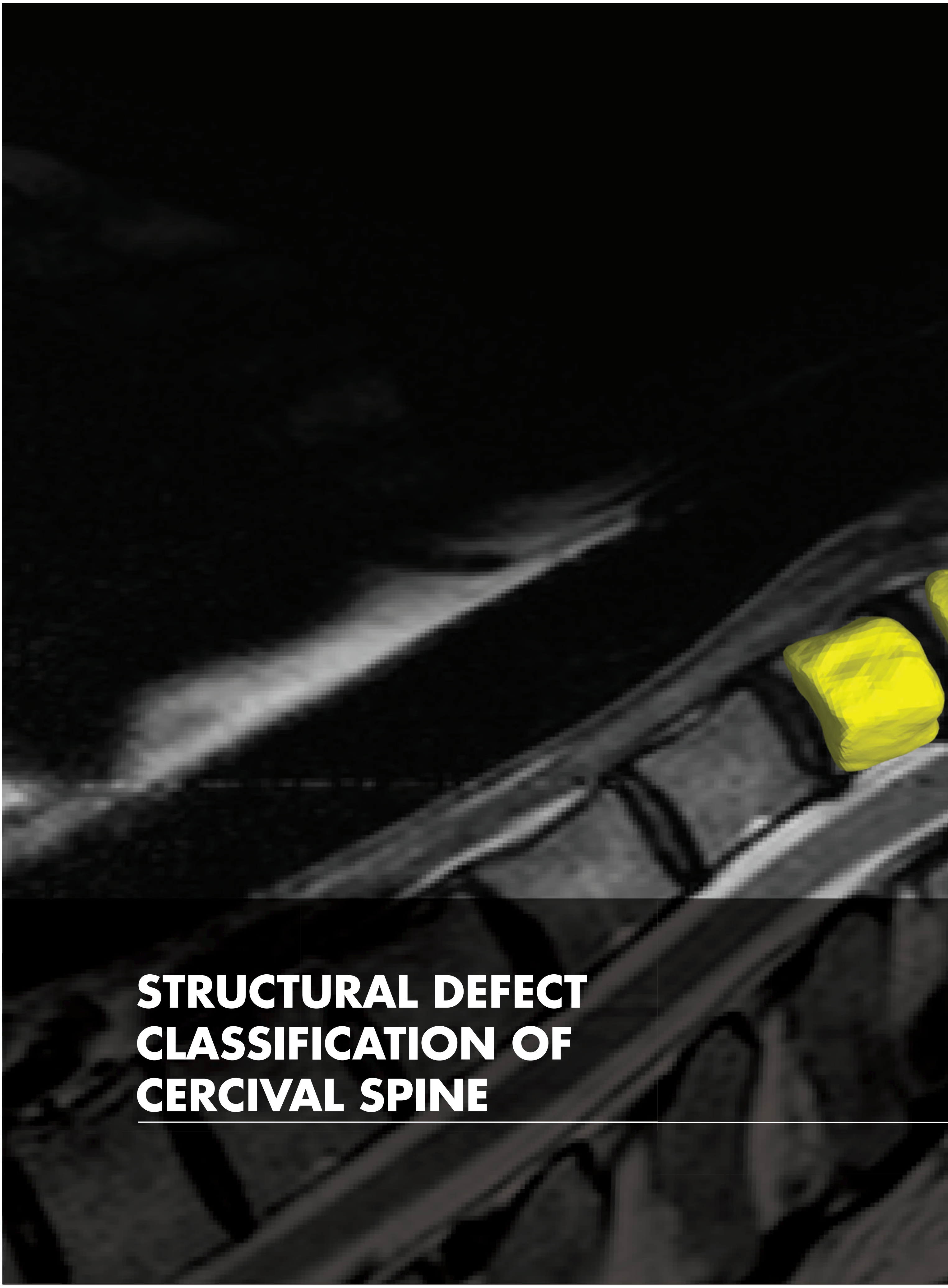
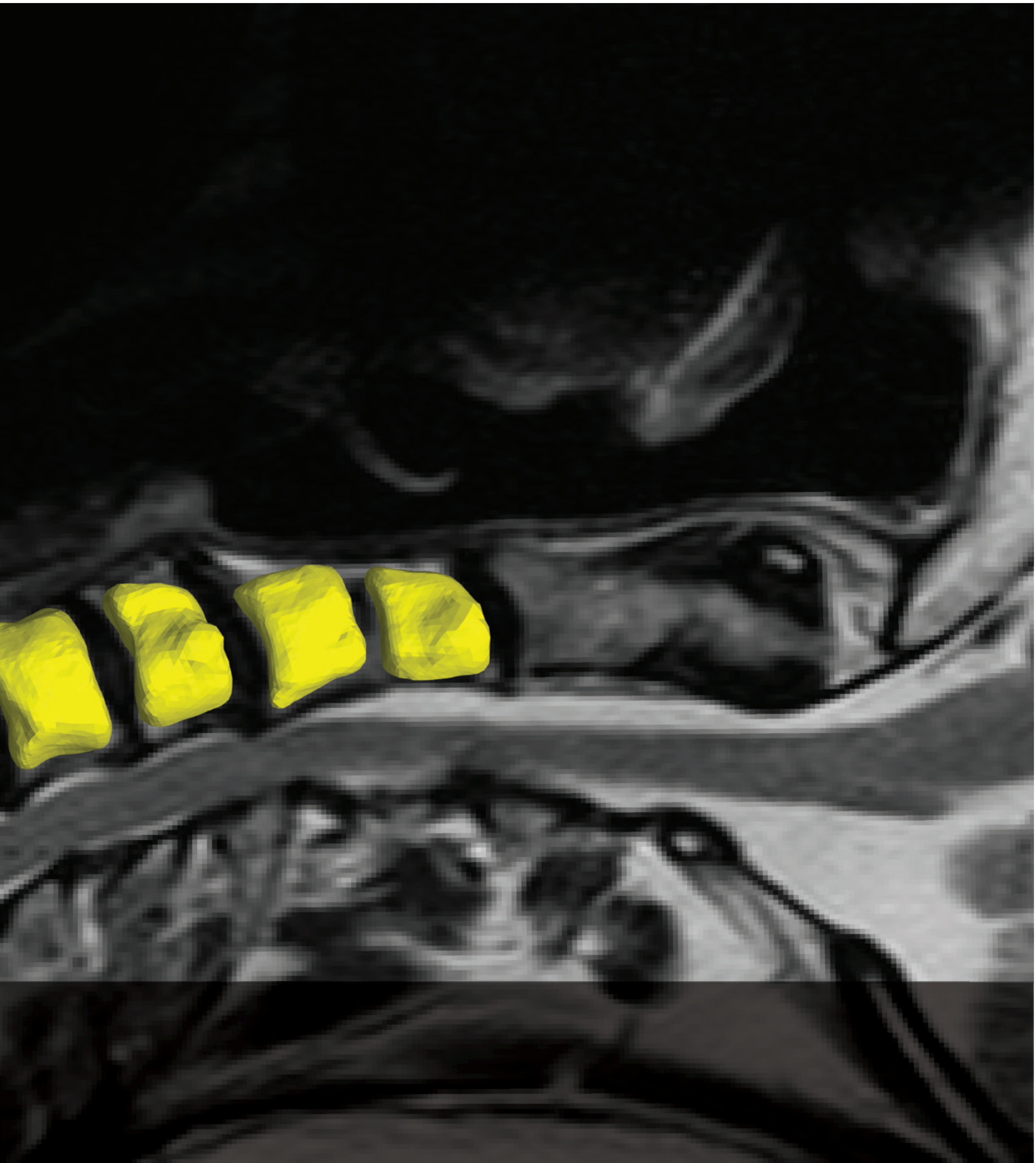


STRUCTURAL DEFECT CLASSIFICATION OF CERCIVAL SPINE



RESEARCH VISION

Development of a diagnostic and decision-support model for optimal treatment of classified cervical spine stenoses.

STRUCTURAL MECHANICAL DEFECT CLASSIFICATION AND MODELING OF THE CERVICAL SPINE

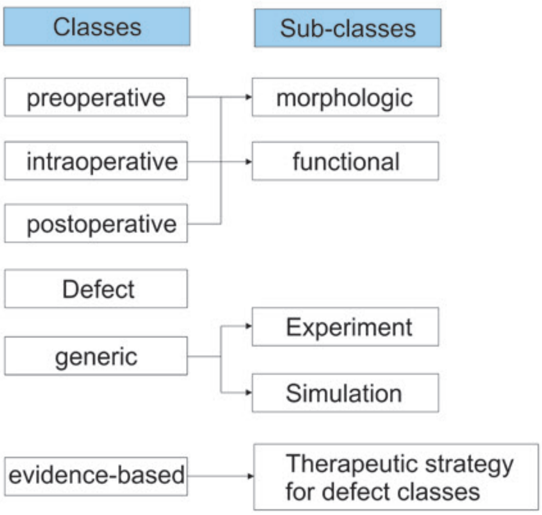


Fig. 1 – Metastructure digital patient model for treatment of spinal canal stenosis

Abstract:

An interdisciplinary research association is developing a defect-specific planning model of the middle and lower cervical spine in order to improve the quality of treatment of cervical spinal canal stenosis. Neurosurgeons, anatomists, computer scientists and engineers are working together on four sub-projects. The main goals of research are to define a defect classification for the degenerative modified cervical spine, the development of a method for the model-based segmentation of defect vertebrae, and experimental work to examine the structural mechanics of vertebrae and ligaments.

Defect classification

There is no uniform agreement concerning therapy strategies for the treatment of degenerative diseases of the cervical spine. In this respect, defining a classification scheme for a systematic description of defects and therapeutic strategies would be helpful. Therefore, a system of defect classification based on imaging methods (MRI, CT) is being elaborated by neurosurgeons and neuroradiologists at the university hospitals in Leipzig and Dresden as a key part of this research project. Based on over 150 MRI data sets, the defect position and five pathological features have been classified so far, namely the stenosis extension, the thickening of the ligamentum longitudinale posterius and the yellow ligament, as well as scoliosis and listhesis. An initial draft for a defect classification and associated therapeutic strategies has been evaluated by more than 50 neurosurgeons across Germany, who have tested its applicability.

Gefördert aus Mitteln der Europäischen Union

Europa fördert Sachsen.
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Fig. 2 – Application of HOG algorithm for cervical vertebrae detection and identification in MRI images

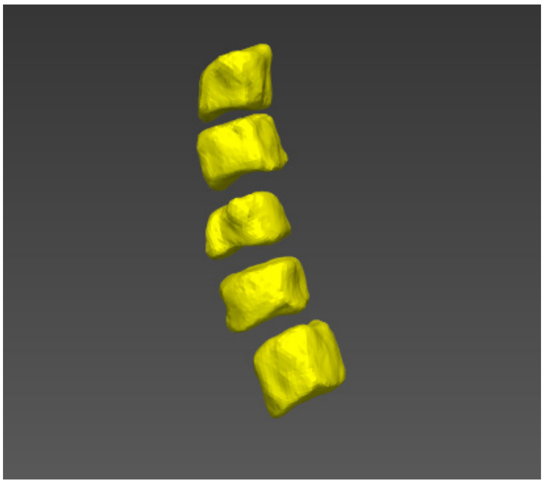

Fig. 3 – Segmentation of cervical vertebrae C3-C7 in MRI images based on Statistical Shape Models (SSM)

Model-based therapy planning

For the central provision of surgically related data, the digital patient model is enhanced with defect classification and new findings of experimental works to determine vertebral stress and the influence of ligaments. Accordingly, the therapy decision is based not only on patient-specific data but also on patient-specific data but also on intervention-related results of experimental studies.

Fig. 4 – Discussion of generated 3D model of cervical vertebrae with a clinical project partner

Furthermore, 3D defect models will be generated using sheet plastination and micro-CTs. These models should provide sample data for classified cases. To integrate the data into the planning process, a meta-structure for ventral interventions of spinal canal stenosis treatment has been defined using six classes and five sub-classes (see Figure 1). Furthermore, suitable interaction and visualization methods will be provided for explicit data access. A process chain for the fully automated segmentation of the C3-C7 vertebrae has been developed to help surgeons identify defect-specific features (e.g. scoliosis, listhesis). As a result, 3D surface models of the spinal segment of interest are available. For this purpose, the method Histogram of Oriented Gradients (HOG) for the automated detection and identification of vertebrae in MRI slices has been combined with the method of Statistical Shape Models (SSM) for the segmentation of the structure (see Figures 2 and 3).
For a needs-based development of an intervention-specific patient model, close cooperation is underway with neurosurgeons who acquire clinical sample data and evaluate developed methods in terms of their practical relevance (see figure 4).

Structural mechanics of the cervical spine

Suitable therapeutic strategies have to be worked out to treat classified defects. Struc-

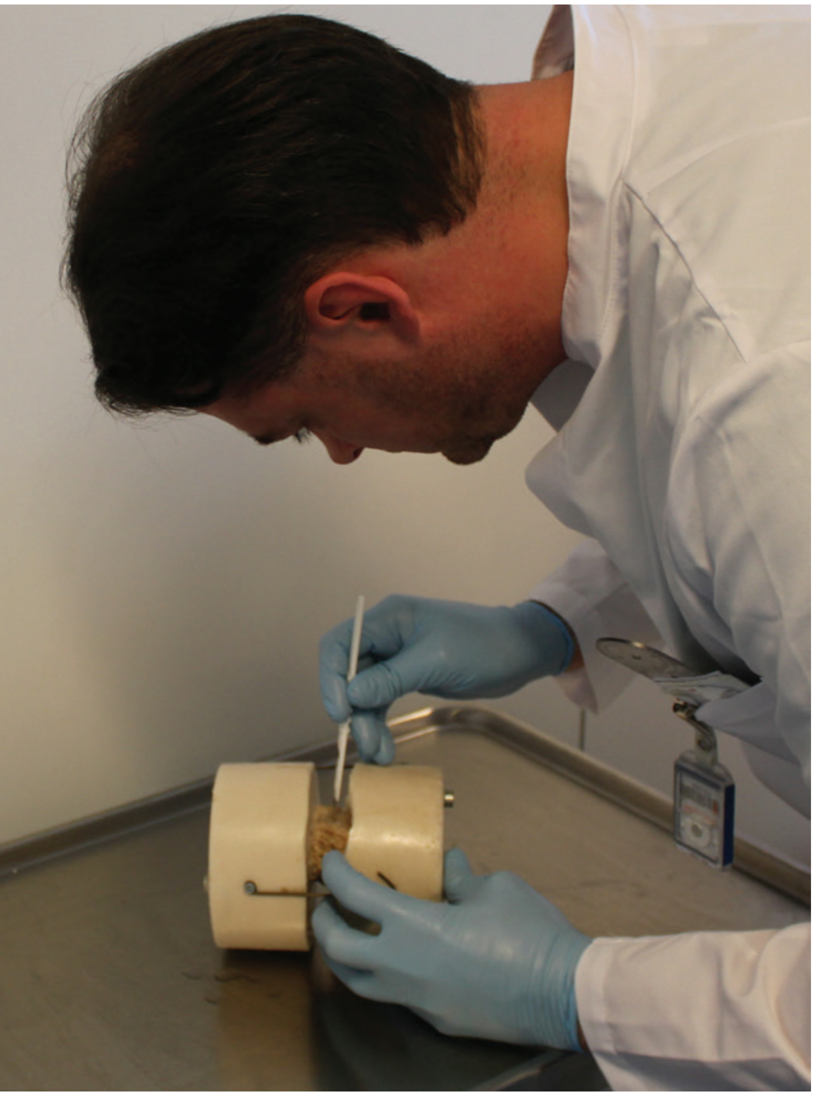

Fig. 5 – Cutting of ligaments for examining their effect on cervical spine stabilization

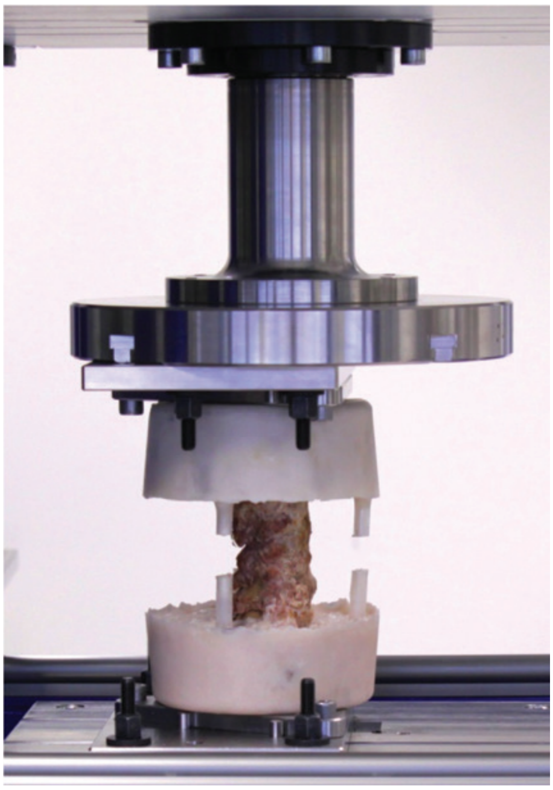

Fig. 6 – Supporting device for cervical spine plastinates for simple positioning and coupling of the embedded preparations with the testing machine

tural properties of the cervical spine are hence being considered during the research project. Experimental work is being conducted at the Fraunhofer IWU Institute for Machine Tools and Forming Technology in Dresden and Leipzig Institute of Anatomy. Tensile, pressure and torsion tests are being executed for human donations using a testing machine. The tests are expected to provide information about the vertebral stresses before and after the implantation of instrumentation and the occurrence of classified defects. Furthermore, the influence of ligaments on spine stabilization is being examined with the aim of optimizing access planning. For this purpose, specified ligaments are cut by a neurosurgeon after every measurement cycle (see Figure 5).

Twenty-five alcohol-fixed human specimens have been produced so far to provide the plastinates needed for experimental and morphological examinations. To produce measuring objects, the C3–C5 and C4–C6 cervical vertebrae are partially sublimated. They were embedded in a fast-curing polyurethane system suitable for pretesting. To adjust the spine segment's orientation in space, a line laser (see Figure 7) is used. The spine segment itself is placed in a tripod with an embedding device produced by Fraunhofer IWU.
An aid for the test series has been developed by Fraunhofer IWU which enables the simple positioning and coupling of the embedded preparations with the testing machine and realizes a mechanical connection (see Figure 6).

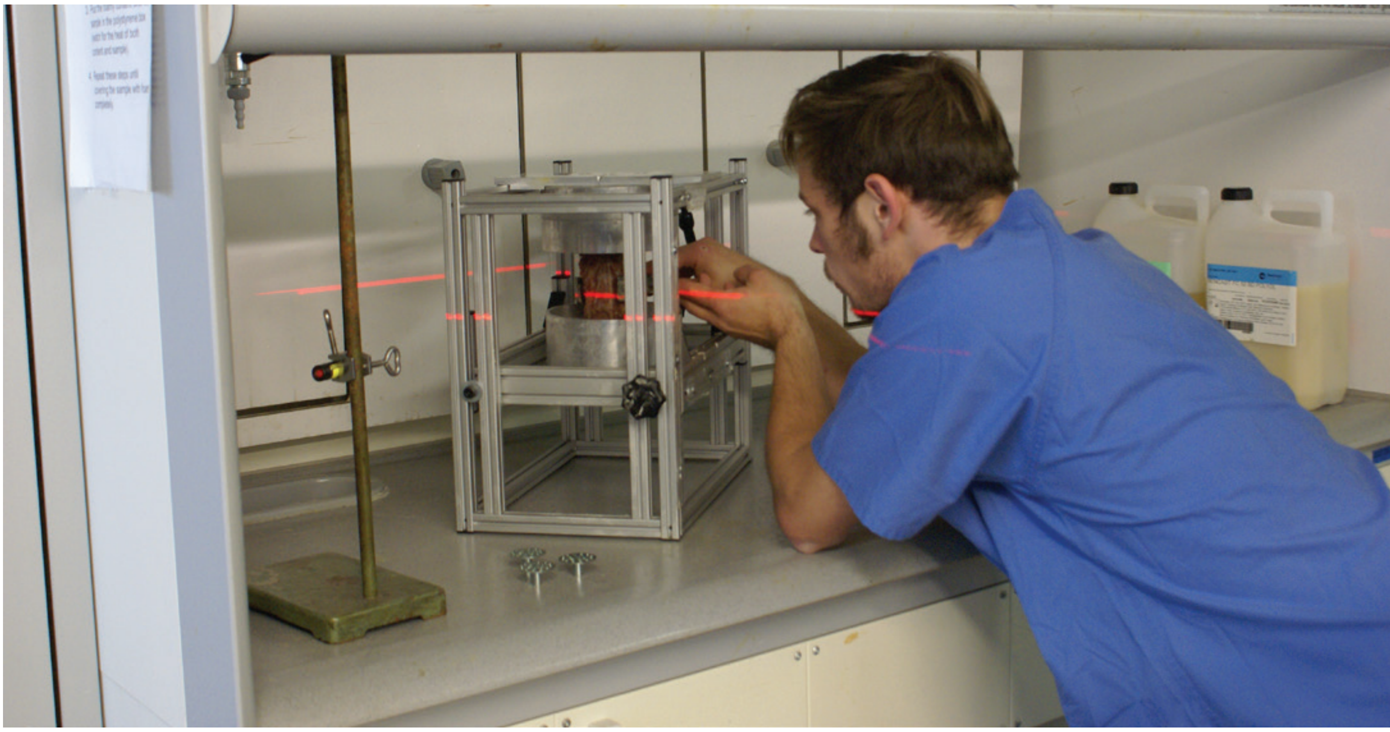

Fig. 7 – Adjustment of the spine segment´s orientation in space using a line laser

During the research project, measurements of defective and healthy cervical spines will be performed and jointly evaluated by engineers, neurosurgeons and anatomists.

Further work

In future it is planned to extract information automatically from radiology reports relevant to the therapeutic decision by using the methods of natural language processing and text mining. Work will also assess whether displaying items of information from the radiology report directly on the radiological image helps the indication of problems. ■

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Fraunhofer IWU Dresden

STD

STANDARDS FOR MODULAR SYSTEM ARCHITECTURES FOR COMPUTER ASSISTED SURGERY

RESEARCH VISION

Usage and development of international standards are required to connect surgical assistance systems from different vendors to provide the surgeon with all relevant data intra-operatively.

Standards for Modular System Architectures for Computer Assisted Surgery

Prof. Dr. Heinz U. Lemke
Group Leader STD

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Selected Publications

Meier J, Liebmann P, Neumuth T, Lemke HU. IHE/XDS-based infrastructure for information management of model guided therapy. Int J of Comput Assist Radiol Surg. 2012; 7 (1): 469–482.

Burgert O, Liebmann P, Treichel T. IHE in surgery – proposal for a new domain within the integrating the healthcare enterprise initiative. Int J of Comput Assist Radiol Surg. 2011; 6 (1): 156.

Bohn S, Franke S, Burgert O, Meixensberger J, Lindner D. First clinical application of an open standards based OR integration system. J Biomed Tech. 2011, 56 (1).

Dressler C, Rockstroh M, Liebmann P, Burgert O. Anforderungsanalyse und Entwurf zur Integration von optischen Oberflächenscannern als neue Modalität im DICOM-Standard. 10. Jahrestagung der Deutschen Gesellschaft für Computer- und Roboterassistierte Chirurgie e.V.; 2011 Sep; Magdeburg, pp. 157–160.

ICCAS aims to complement image based surgery, as it is practiced today, with additional information towards a model based surgery. In a model based surgical workflow the patient is presented not only by images but also by other relevant patient specific information acquired from a large variety of sources.

As there is a wide spectrum of manufacturers providing devices to collect and process this information, a common standard to interconnect these devices is needed. One of the generally accepted standard, very well established in radiology, but a candidate to fulfill this need also for surgery, is the Digital Imaging and Communication in Medicine (DICOM) standard.

With the establishment of the DICOM Working Group 24 (DICOM in Surgery) and through the development of four novel DICOM supplements for surgery from 2010 to 2012, the ICCAS Standards Group, as the driving partner for this activity, has established itself as an internationally recognized group for standards in surgery. Current activities on work items are focusing on:

» "Reference Coordinate System" in close collaboration with Prof. Dr. L. Berliner, New York Methodist Hosp.,
» "Angiography Video" in close collaboration with Prof. Dr. L. Berliner, New York Methodist Hosp.,
» "DTI in DICOM" in close collaboration with Brainlab,
» "Frame of Reference" in close collaboration with Brainlab.

In addition to the work on the DICOM standard, the ICCAS Standards Group has succeeded in its efforts to establish a new Integrating the Healthcare Enterprise (IHE) domain "Surgery". By means of integration profiles, IHE gives explicit guidelines for using well established standards to harmonize industry-wide efforts in order to connect devices across vendor specific systems. In partnership with ISCAS and IFCARS, ICCAS was one of the driving forces behind the efforts of establishing the domain "IHE Surgery". This IHE domain provides the possibility to create integration profiles as guidelines for the proper implementation of existing standards for surgical use cases. These integration profiles will improve clinical workflows as they allow for an effective interoperability of various technologies in clinical settings.

ICCAS will make use of its standardization expertise to support several IHE profile proposals. In 2013, based on 7 years of successful work within the DICOM WG 24, the first IHE integration profile proposals were made on the themes of implant templates (ITD), Patient Identification Distribution (PID), and Cross enterprise model sharing (XMS).

Also in 2013, the ICCAS Standards group increased its efforts, for example through focused activities in special workshops, of bringing the new IHE domain "Surgery" to the attention of various vendors and consortia in order to start a cooperation for developing new integration profiles for surgery.

ESTABLISHMENT OF A NEW IHE DOMAIN FOR SURGERY

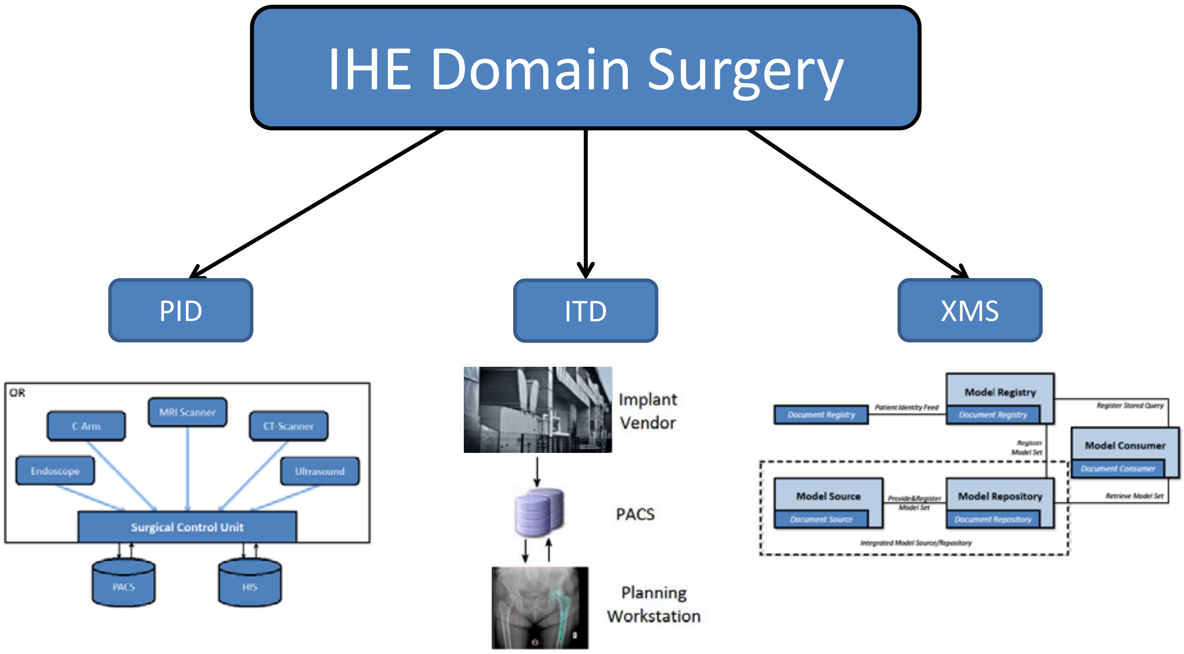

Fig. 1 – Image of the distinguished characteristics of the surgical domain. IHE Surgery is helpful for a great variety of persons and use cases of which some are shown in the figure

Abstract:

ICCAS's successful work within DICOM and IHE has led to the creation of the new IHE Surgery domain. ICCAS will massively introduce integration profiles that will significantly improve interoperability in everyday surgery.

One of the most important institutions in the standardization of clinical tasks is the Integrating the Healthcare Enterprise (IHE) initiative. IHE identifies existing standards for specific clinical tasks (use cases) in close collaboration with clinicians, researchers and industry partners so that they can be implemented consistently and correctly. IHE is divided into domains which cover specific clinical areas such as radiology, dentistry and pharmacy. Given the outstanding position of ICCAS, the new Surgery domain was founded in December 2012 in Chicago during the annual meeting of IHE. This allows the creation of integration profiles as rules for the proper implementation of existing standards for surgical use cases. These will improve clinical practice by allowing the widespread interoperability of technology in the clinic.

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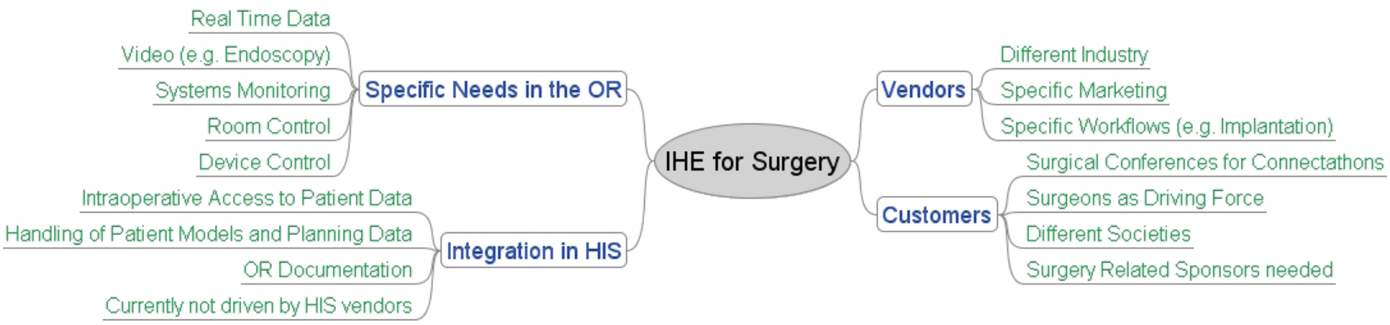

Fig. 2 – Some of the very first work areas in IHE Surgery are Integration Profiles for patient identity distribution (PID), implant template distribution (ITD) and cross-enterprise model share (XMS)

ICCAS will make use of its standardization expertise for several profile proposals. Based on years of successful work within DICOM, one of the first IHE integration profiles will involve implant templates (ITD). While implementation within DICOM refers primarily to the communication and storage of implant data and implant planning data, IHE integration will lead to an improvement of the entire life cycle of an implant from manufacturer to patient. Previous standardization work within DICOM in this field has been fully harnessed yet also substantially expanded.

Other integration profiles such as patient identity distribution (PID) result from manufacturers' support in mapping specific use cases. The aim is to find an integrated generalized solution to distribute patients' demographic data in the OR. This approach will cover surgical use cases and allow interoperability between different disciplines.

The issue of cross-enterprise model sharing (XMS) is a necessary extension of existing structures in the IHE standard. It involves the storage, communication and use of data which is not patient-centred within and among clinics. This may be digital patient models or models for workflow support or teaching, etc. Concurrent patient-centric data must be supported in the same way as it is currently supported to allow smooth transition and interoperability.

This broad-based approach highlights the importance of the Surgery domain and the role of ICCAS in this context. Such integration profiles undergo a strictly defined process and will soon have to be implemented in a 'trial implementation'. Manufacturers can then declare their conformity with one or more profiles at a so-called Connectathon, where many meet to demonstrate their implementations of IHE integration Profiles. Successfully passing this practice test with other manufacturers guarantees that users will easily be able to implement the use case in an IHE-compliant heterogeneous environment in terms of interoperability. ■

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International Symposium on Circuits and Systems (ISCAS)

DEVELOPMENT OF AN IHE SURGERY PROFILE FOR IMPLANT TEMPLATE DISTRIBUTION

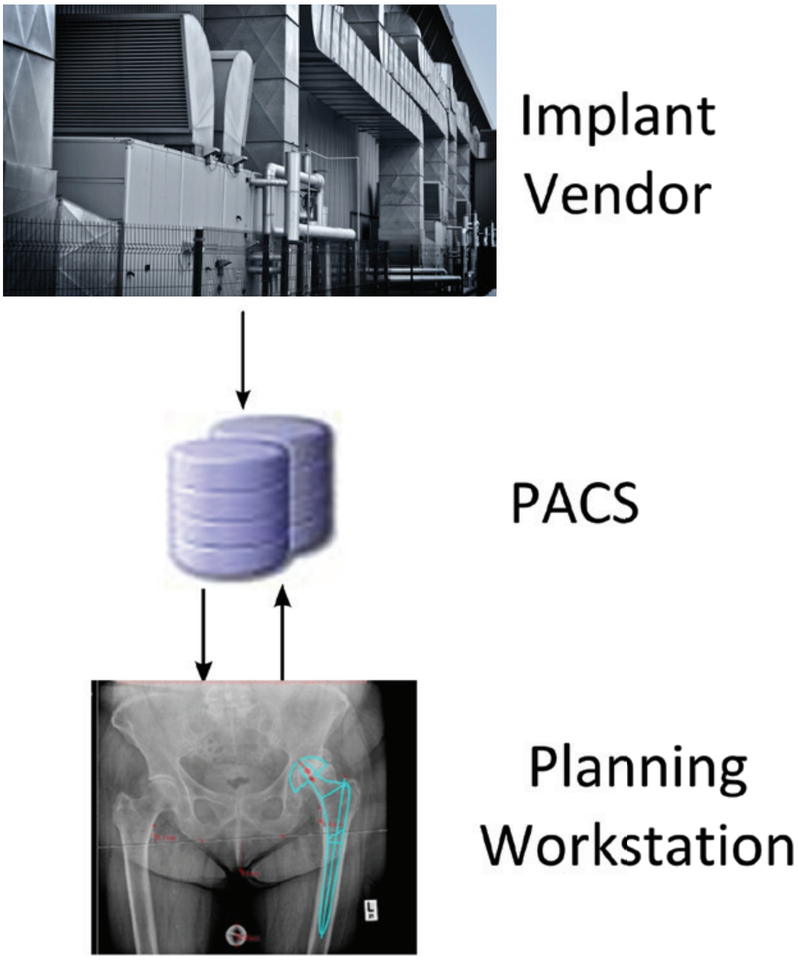

Fig. 1 – Implant Vendors are offering digital implant data for PACS which can be used e.g. within the implantation planning workflow. There is no need to convert different data formats at any point

Abstract:

Rigid implants are widely used in everyday clinical practice for several purposes such as restoring mobility. With standards regarding implant templates having been established within DICOM, a new integration profile is planned under the more wide-ranging Integrating the Healthcare Enterprise (IHE) initiative.

The foremost standardization organization for medical issues is the Integrating the Healthcare Enterprise (IHE) initiative. IHE was set up by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively.

IHE is organized internally by clinical and operational domains, where experienced users

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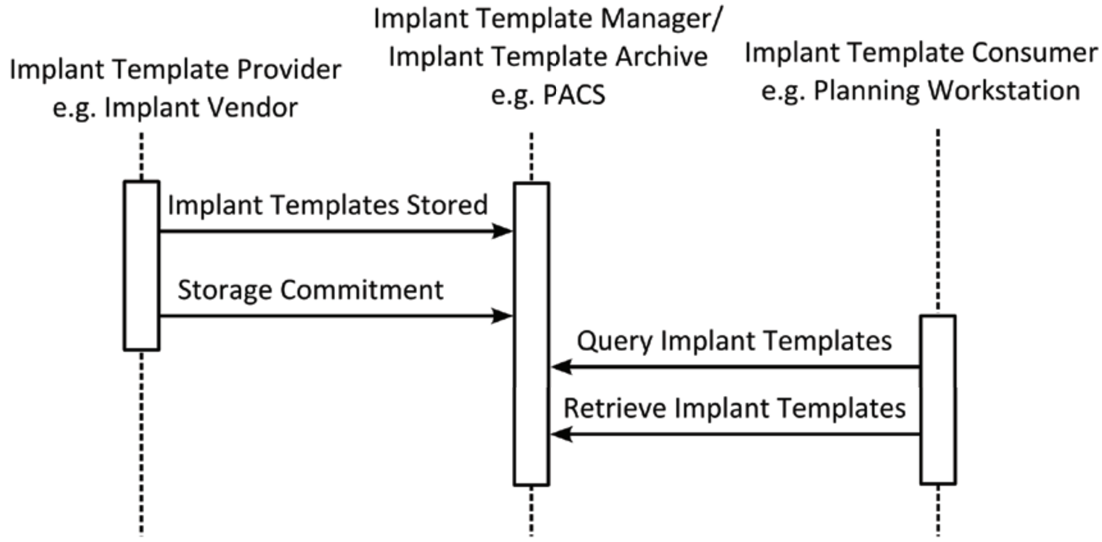

Fig. 2 – Basic process flow in the Implant Template Distribution Profile shows communication from and to the implant template archive (e.g. PACS). The same data can be used conveniently for different purposes

develop consensus with vendors to address specific integration and information, sharing priorities with standards-based solutions.

The leading role of ICCAS in establishing the new IHE Domain Surgery will also lead to new integration profiles regarding the lifecycle of implant templates from manufacturer through clinic to patient. These profiles will be based on previous work by ICCAS within the DICOM standards committee.

Rigid implants like plates, nails and pins are widely used in everyday clinical practice for several aims such as restoring mobility (e.g. prostheses for fractures of the femur, tibia, radius, ulna, spine, knee and shoulder as well as total hip replacements) and dental implants.

The Digital Imaging and Communications in Medicine (DICOM) standard supports such implant templates by offering a standardized way of storing, accessing and sharing implant templates through supplement 131.

However, DICOM only works in specific environments and does not operate between different clinics or between manufacturers and customers. The IHE initiative can close this gap because it offers standardized descriptions on how to use certain well-known, widely used standards such as DICOM or HL7. The coordinated use of established standards improves specific clinical processes and hence overall patient care. It defines how the new DICOM standards for implant templates are to be communicated between IHE-conform devices, improving interoperability.

As a result, implant manufacturers will have a new standardized way to offer digital data about their products, while medical engineers and vendors of relevant medical devices can ensure the broader use of consistent implant template data throughout the clinic. The overall handling of implant templates from acquisition through planning software to intraoperative assistance systems will be substantially improved and contribute to overall patient care. ■

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DISTRIBUTION OF PATIENT IDENTIFICATION INFORMATION TO SURGICAL OR EQUIPMENT – IHE PID

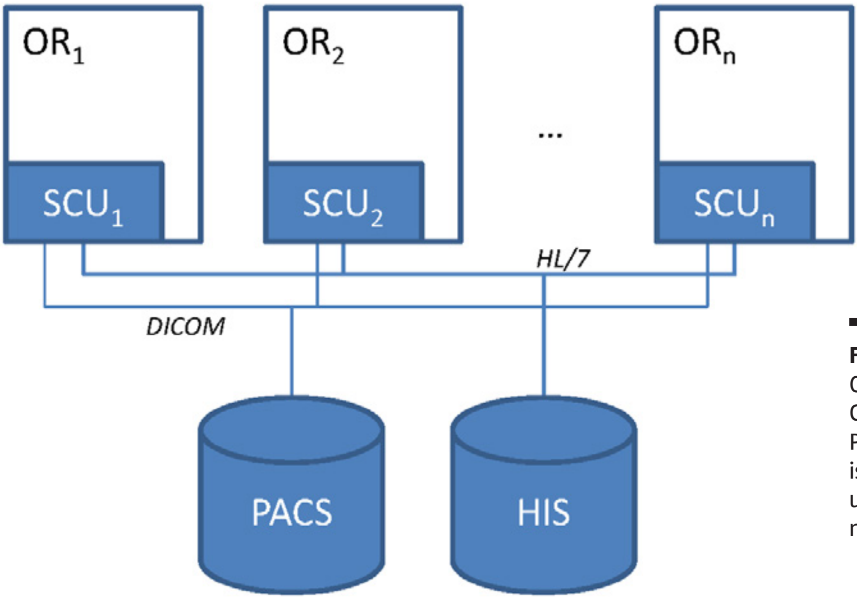

Fig. 1 – In a typical hospital several ORs are operated simultaneously. Communication to and from the HIS, PACS and other information systems is managed through surgical control units (SCU), one for each operating room (OR)

Abstract:

A new integration profile for Patient Identity Distribution among all devices in an OR is being developed in close cooperation with clinicians, industry partners and the newly founded IHE Surgery domain under the internationally recognized IHE initiative.

Computer-assisted surgery aims to reduce effort and redundancy as well as to avoid errors in the transmission of patient demographic data. To do so, all devices creating patient-specific data during surgery first have to receive patient demographics such as a unique patient ID, date of birth, gender, etc.
Ideally, all the equipment used on a specific patient in a specific OR during surgery is automatically initialized with the correct unique patient ID so that it can store and communicate the data and diagnosis together with this information to the PACS.
In the radiological environment, the DICOM Modality Worklist Standard has proven very useful. However, other difficulties are caused in the OR by modalities which are called in on demand. At this point, the patient's data has to be entered or chosen from a list of possible patients on every device that will be used on this patient. A good solution would be to have a central system that distributes the neces-

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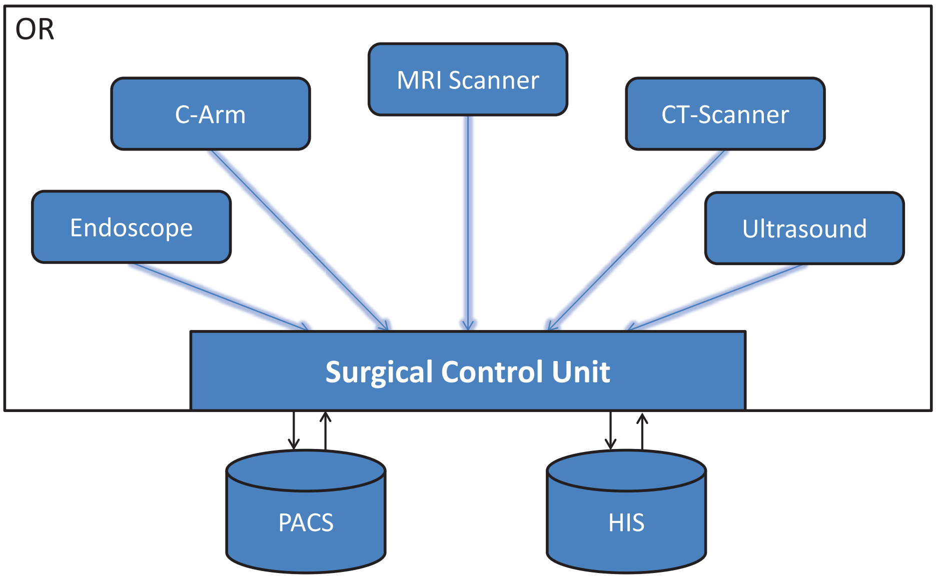

Fig. 2 – Each modality in the OR communicates through its associated SCU, reducing the effort for initializing devices for the patient and also reducing the likeliness of errors due to redundancy

sary patient information to all the devices in the OR that require it at some point during surgery. Such a system is possible because the information only changes when a patient is carried into or out of the OR, whereas devices may change more frequently.
Existing standards such as DICOM and HL/7 solve the problem of patient identity distribution for specific limited use cases by means of a Modality Worklist, which was originally designed for a radiological environment.
To find a unified solution which also works for surgical environments, all the existing approaches are to be combined within the Integrating the Healthcare Enterprise (IHE) initiative in a new Integration Profile PID. This will provide a generalized way to cover more aspects of clinical practice and will lead to the improved homogeneity of standards, thus enhancing interoperability and interdisciplinary communication.
ICCAS is therefore cooperating with healthcare professionals and industry partners through IHE Surgery to design the best strategy for standardization. The importance of the new Surgery domain will grow as the confidence of clinicians and manufacturers in the IHE standard is strengthened. Henceforth, when purchasing new equipment, clinicians need only look for a declaration of conformity with the IHE Integration Profile PID because IHE-compliant devices can easily and reliably communicate with each other, even in today's heterogeneous environments.
In order to prove compliance, manufacturers have to demonstrate under independently controlled conditions at a Connectathon that their devices can communicate with any other PID-compliant equipment. ICCAS supports manufacturers and clinicians throughout the process with expertise and advice. ■

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TOWARDS A GENERALIZED IHE STANDARD TO SHARE DATA ACROSS ENTERPRISES

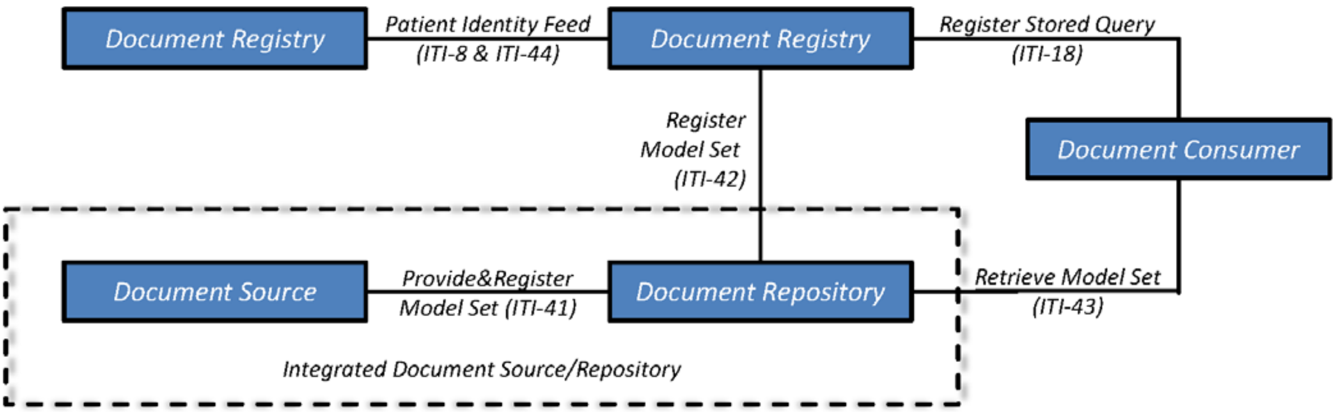

Fig. 1 – Documents in a cross-enterprise environment are handled through IHE „cross-enterprise document share“ (XMS). An "integrated document source/repository" stores the actual data that is accessed through a repository by queries from document consumer actors. Patient-specific documents have to be registered in the repository, but can be stored elsewhere

Abstract:

While patient-specific data can be handled in a standardized fashion by using the IHE integration profile Cross Enterprise Document Share (XDS), there is still no uniform standard for all clinical data. ICCAS aims to find a generalized data model within a new integration profile named Cross Enterprise Model Share (XMS) to cover both previous and other clinical data such as workflow models, teaching data and scientific research data.

In the hospital, most data arises from treating patients on the basis of medical reports, imaging modalities, laboratory analysis, etc. and is therefore patient-specific. In Germany and many other countries, data sovereignty lies with the patient and patient data must be treated confidentially by hospital staff. Accordingly, patients must be allowed to view their data, to order deletions at any time, and to approve any planned disclosures, although differences exist from one country to the next. Other national differences concern rules about the medication of patients in unconscious and/or life-threatening emergency situations. As a result, all patient-specific data such as personal information as well as consent forms and advance directives has to be stored and communicated in accordance with the country-specific data protection legislation. For the purpose of successful medical treatment, it must be possible for authorized persons to find such data quickly.

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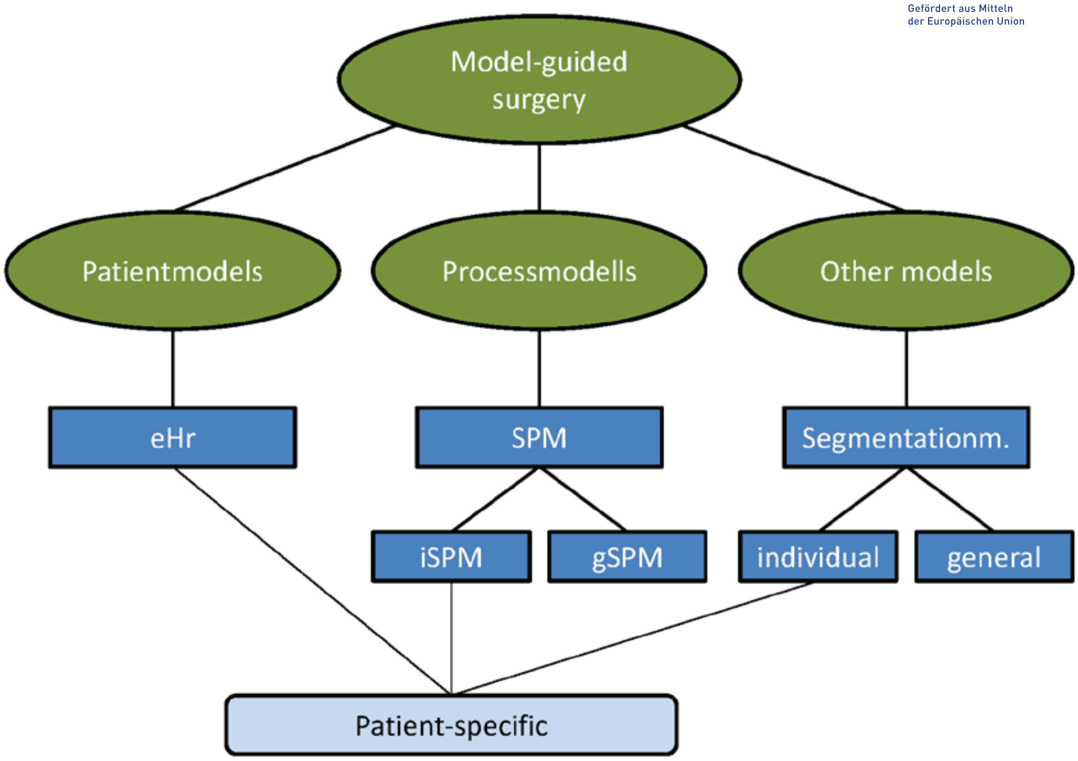

Fig. 2 – There are numerous types of models used in model-guided surgery. This sketch shows an overview (green) as well as some specific examples of commonly used models like electronic health records (eHr), surgical process models (SPM, individual iSPM or generalized gSPM) and segmentation models (for an individual patient or general model). Some of those are patient-specific and thus covered by IHE XDS

Furthermore, such data needs to be efficiently structured.

Many of these aspects find their way into the clinic through the IHE standard Cross Enterprise Document Share (XDS) profile. However, additional data incur in clinical practice that are not necessarily linked to actual patients, such as models for workflow analysis, teaching material, research data and so on. At the moment this non-patient-specific data is either communicated and stored on systems separated from the clinical system and standard, or labelled semantically incorrectly regarding the standards used.

To achieve a unified integrated solution, ICCAS is exploring ways of generalizing clinical data to include both patient-specific data and abstract models. This solution will be an Integration Profile entitled IHE Cross Enterprise Model Share (XMS). To ensure the standards are used by different companies and organizations, it should be possible to easily communicate patient-specific data to XDS-compliant systems. It is essential to find a fundamental model for clinical data that covers XDS-compliant patient-specific data, currently used models and teaching data as well as future models. ■


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ACTIVITIES IN TEACHING

ICCAS is the leading research institution in Saxony which is committed to the interdisciplinary education in the field of computer assisted surgery for medicine and computer science studies at the Leipzig University. At the Faculty of Medicine ICCAS manages the elective subject Computer Assisted Surgery and offers a comprehensive course on this topic to medical students in the fifth year of study.

The lectures provide an interdisciplinary view on computer assisted surgery from the clinical perspective of various surgical departments as well as on engineering aspects that will be relevant to future surgeons. Additionally, within the Masters of Medical Computer Science a number of lectures and seminars in the field of computer assisted surgery are offered to computer science students at the Leipzig University.

ICCAS opens up numerous opportunities to students to get acquainted with the highly innovative research topic Computer Assisted Surgery, including bachelor and master theses as well as medical doctor’s theses and research internships.

Regular courses at the Leipzig University:

Study course “Computer-assisted Surgery” (Master, Computer Science)

» Lecture “Medical Planning- and Simulation Systems”
» Lecture “Surgical Navigation, Mechatronics and Robotics”
» Practical course “Computer Assisted Surgery”

Study course “Structured System Innovation for Medicine” (Master, Computer Science)

» Lecture “Structured System Innovation”
» Seminar “Applied Development of Medical Technology Systems”

Courses in Human Medicine

» Lecture “Computer Assisted Surgery”
» Practical course “Introduction to Careers in Medicine – Computer Assisted Surgery”

SCIENTIFIC EVENTS

Kick-off-Meeting, subprojects 2 and 3 of main project OR.Net
Heidelberg, Germany, January 2013

1st public status symposium on collaborative project OR.Net within the framework of Connecting
Healthcare IT 2013 (ConhIT 2013)
Berlin, Germany, April 2013

EFMI Special Topic Conference Data and Knowledge for Medical Decision Support
Prague, Czech Republic, April 2013
» Presentation: Dr. Kerstin Denecke "Knowledge-based systems to support personalized medicine"

Graduierten Seminar ICCAS – IMISE
Leipzig, Germany, May 2013
» Organiziation: Prof. Dr. Thomas Neumuth, Prof. Dr. Alfred Winter (IMISE)

Research Period at Image Processing and Informatics Laboratory (IPILab), University of Southern California
Los Angeles, USA, May 2013
» Presentation: Dipl.-Ing. Jens Meier "oncoflow"

DICOM Meeting
Mainz, Germany, June 2013

1st workshop on programming cyber physical systems at Eötvös Loránd University Budapest
Budapest, Hungary, June 2013
» Presentation: Dipl.-Inf. Stefan Franke "The surgical workflow management for the digital operating room"

27th Int. Congress for Computer Assisted Radiology and Surgery (CARS)
Heidelberg, Germany, June 2013
» Presentation: Dipl.-Inf. Max Rockstroh "A workflow-driven surgical information source management"
» Presentation: Dipl.-Ing. Jens Meier "Towards a digital patient model for head and neck tumor treatment: information integration from distributed information systems".
» Presentation: M.Sc. Computer Science Philipp Liebmann "IHE in Surgery"
» Session Chair: M.Sc. Computer Science Philipp Liebmann "DICOM Working Group 24 – Meeting"

14th World Congress on Medical and Health Informatics (Medinfo)
Copenhagen, Denmark, August 2013
» Presentation: Dr. Kerstin Denecke "New trends in health social media: Hype or evidence-based medicine"
» Poster Presentation: Dr. Kerstin Denecke, Poster Session "Ontologies, knowledge representation, data models"

58th Annual Conference German Association for Medical Informatics, Biometry and Epidemiology (GMDS)
Lübeck, Germany, September 2013
» Presentation: Dipl.-Inf. Max Rockstroh "Concept of a data recorder for the recording of intraoperative device data"
» Presentation: Matthäus Stöhr (physician) "Modeling and support of decision-making regarding the treatment of laryngeal carcinoma in the head and neck tumor board"

25th International Conference of the Society for Medical Innovation and Technology (SMIT)
Baden Baden, Germany, September 2013
» Presentation: Master en Multimédia Sandra von Sachsen "Stent graft configurator for assisting implant planning in aortic aneurysm repair"

3. Dreiländertagung der Deutschen, Schweizerischen und Österreichischen Gesellschaft für Biomedizinische Technik (BMT)
Graz, Austria, September 2013
» Presentation: Dr. Kerstin Denecke "Model-based decision support: Requirements and future for its application in surgery"
» Presentation: M. Sc. Michael Unger "Automatic gesture recognition based on thermography"
» Poster Presentation: Prof. Dr. Thomas Neumuth, Dipl.-Inf. Stefan Franke "A framework for multi-model surgical workflow management"

16th International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI)
Nagoya, Japan, September 2013
» Presentation: Dr.-Ing. Stefan Bohn "System monitoring and diagnostics architecture for networked medical devices"
» Presentation: M.Sc. Computer Science Philipp Liebmann at M2CAI workshop "Validation of a surgical process model regarding the robustness of missing sensor information"
» Presentation: Dipl.-Ing. Christian Meißner at M2CAI workshop "Hierarchical approach for low-level surgical activity recognition"

Dresdner Aortensymposium
Dresden, Germany, October 2013
» Invited lecture: Master en Multimédia Sandra von Sachsen "Simulation-supported planning of EVARs"

Gemeinsame Jahrestagung von HL7 und IHE Deutschland
Göttingen, Germany, October 2013
» Presentation: Prof. Dr. Heinz U. Lemke, M.Sc. Computer Science Philipp Liebmann "IHE Surgery"

12th Annual Conference German Society for Computer and Roboter-Assisted Surgery (CURAC)
Innsbruck, Austria, November 2013
» Presentation: Dr. Claire Chalopin "Method for the evaluation of US perfusion for brain tumor surgery"
» Poster Presentation: Dipl.-Inf. Stefan Franke "A Surgical Assistance System for Transcatheter Aortic Valve Implantation Based on a Magic Lens Concept"

3rd Munich Aortic & Carotid Conference (MAC)
Munich, Germany, November 2013

» Invited lecture: Master en Multimédia Sandra von Sachsen “Medical Postprocessor for stent graft comparison“

99th Scientific Assembly and Annual Meeting Radiological Society of North America (RSNA)
Chicago, IL, USA, December 2013
» M.Sc. Computer Science Philipp Liebmann “DICOM WG24 Meeting”

15th International Conference on Biomedical Engineering (ICBME)
Singapore, December 2013
» Presentation: Dr.-Ing. Stefan Bohn “An interoperability architecture for networked medical devices and its application to neurosurgery”

12th Leipzig Research Festival for Life Sciences
Leipzig, Germany, December 2013

ICCAS Colloquium Leipzig 2013

» Presentation: Prof. Dr. Andreas Melzer, Institute for Medical Science and Technology, University of Dundee, Scotland
“Multimodale bildgebende Diagnose und bildgesteuerte Therapie”

» Presentation: Dipl.-Ing. Mathias Neugebauer, Department of Simulation und Graphics, Otto von Guericke University Magdeburg, Germany
“Visuelle Exploration von Blutfluss in zerebralen Aneurysmen auf Basis digitaler Patientenmodelle“

» Presentation: Feng Li, Robarts Institute London, ON/ Canada
“Navigation system for off-pump beating heart mitralvalve repair”

» Presentation: Dipl.-Inf. Frank Heckel, Fraunhofer MEVIS, Bremen, Germany
“Vortrag zum Institut Fraunhofer MEVIS Bremen und zur wissenschaftlichen Arbeit im Bereich onkologische Therapieverlaufskontrolle“

» Presentation: Dr. med. Patrick Dubach, ENT clinic, Bern University Hospital, Switzerland
“Speziellere Bildgebungsanwendungen in der HNO-Chirurgie. Von der Strahlendosisreduktion in CAS NNH bis zur CEUS Fistulographie.“

» Presentation: Dr.-Ing. Klaus-Hendrik Wolf, Peter L. Reichertz Institute for Medical Informatics, University of Braunschweig and Hannover Medical School
“Assistierende Gesundheitstechnologien für neue Lebensweisen und neue Versorgungsformen“

» Presentation: Dr. Robyn Whittaker, Malcolm Pollok, National Institute for Health Innovation (Nihi), University of Auckland, New Zealand
Frienz Study Group Tour 2013

» Presentation: Dr. Nicolas Gerber, ARTORG Center for Biomedical Engineering Research, Bern University Hospital, Switzerland
“Computer Assisted Planning and Image Guided Surgery Systems for Implantable Hearing Systems”

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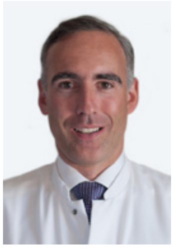

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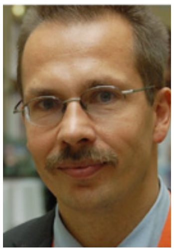

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INVITED LECTURES

49th Annual Meeting & Exhibition The Society of Thoracis Surgeons (STS)
27.01.2013, Los Angeles, California, USA
» Lecture: Prof. Dr. med. Friedrich W. Mohr "Will Robotic MVR Make it to Mainstream?"

SPIE Medical Imaging 2013
14.02.2013, Orlando, FL, USA
» Lecture: Prof. Dr. Heinz U. Lemke "The digital operating room: towards intelligent infrastructures and processes"

ECR – European Congress of Radiology 2013
07.03.2013, Vienna, Austria
» Lecture: Prof. Dr. Heinz U. Lemke "New PACS architecture: decoupling image management from image navigation"

9th International Congress of Update in Cardiology and Cardiovascular Surgery (UCCVS)
22.03.2013, Antalya, Turkey
» Lecture: Prof. Dr. med. Friedrich W. Mohr "Types of Mitral Annulo and Valvuloplasty Available for FMR: A Critical Appraisal"

79th Annual Meeting German Cardiac Society (DGK)
04.04.2013, Mannheim, Germany
» Lecture: Prof. Dr. med. Friedrich W. Mohr "Modern Surgery" in Session: "The Mitral Valve Revolution"

Jubiläumssymposium „10 Jahre Medizinische Visualisierung"
23.04.2013, Magdeburg, Germany
» Lecture: Prof. Dr. Thomas Neumuth "Prozessgestützte Mensch-Technik-Interaktion im Operationssaal"

Annual Scientific Congress 2013 (ASC) – Royal Australasian College of Surgeons
08.05.2013, Auckland, New Zealand
» Keynote Lecture: Prof. Dr. med. Friedrich W. Mohr "Transcatheter therapies for surgeons – TAVI and beyond"

18th Conference of the Spanish Neurosurgery Society (SENEC) 2013, German – Spanish Joint Meeting
15.05.2013, San Sebastian, Spain
» Lecture: Prof. Dr. med. Jürgen Meixensberger "Advanced intraoperative ultrasound – Impact for glioma imaging and resection control"

International Mastercourse on Endoscopic Sinus Surgery (iMESS) 2013
22.–25.05.2013, Brussels, Belgium
» Lecture: Prof. Dr. med. Gero Strauß "Surgical management and guidance functionalities for the transnasal surgery cockpit"

DIN 2013
03.06.2013, Berlin, Germany
» Lecture: Prof. Dr. Heinz U. Lemke "The Digital Operating Room: Intelligent Infrastructures, Surgical Processes and Standards"

Hauptstadtkongress Medizin und Gesundheit – Fachkongress KRANKENHAUS, KLINIK, REHABILITATION
05. – 07.06.2013, Berlin, Germany
» Lecture: Prof. Dr. med. Gero Strauß "Automatisierung im chirurgischen Cockpit. Chancen und Grenzen aus chirurgischer Sicht"

13th Annual Meeting Norddeutsche Gesellschaft für Otorhinolaryngologie und zervikofaziale Chirurgie
14. – 15.06.2013, Magdeburg, Germany
» Lecture: Prof. Dr. med. Gero Strauß "Einsatz von Assistenzfunktionen (SMGS) in der endoskopischen HNO-Chirurgie"

27th Int. Conress for Computer Assisted Radiology and Surgery (CARS)
26. – 29.06.2013, Heidelberg, Germany
» Expert forum: Prof. Dr. med. Andreas Dietz "IFCARS Think Tank on Model Guided Therapy"
» Session chair: Prof. Dr. med. Jürgen Meixensberger "Computer Assisted Neurosurgery"
» Tutorial: Prof. Dr. Heinz U. Lemke "Medical Workstations and Model-Guided Medicine"
» Tutorial: Prof. Dr. Thomas Neumuth "Surgical Process Modeling and Surgical Workflows"

Eurasien Head and Neck Conference (EAFO)
25. – 28.06.2013, St. Petersburg, Russian Federation
» Lecture: Prof. Dr. med. Andreas Dietz "Tumor Therapy Manager, decision making in interdisciplinary tumor-board using different models"

Endoscopic Course for Paranasal Sinus and Skull Base Surgery (PSSB) 2013
05. – 07.09.2013, Bern, Switzerland
» Lecture: Prof. Dr. med. Gero Strauß "Automation and assistance systems for transnasal surgery"

Graduiertenkolleg des Sonderforschungsbereiches "Cognition-guided Surgery"
01.08.2013, Karlsruhe, Germany
» Lecture: Prof. Dr. Thomas Neumuth "Intelligente Geräteintegration im Operationsaal der Zukunft"

XVII International Congress of Polish Cardiac Society
27.09.2013, Warsaw, Poland
» Lecture: Prof. Dr. med. Friedrich W. Mohr "Modern surgery"

IHE 2013
24.10.2013, Göttingen, Germany
» Lecture: Prof. Dr. Heinz U. Lemke "The Digital Operating Room and IHE Surgery"

Wissenschaftliches Symposium anlässlich des 60-jährigen Bestehens der universitären Neurochirurgie in Gießen
25.10.2013, Gießen, Germany
» Lecture: Prof. Dr. med. Jürgen Meixensberger "Individualisierte operative Therapie – Helfen Computer und Roboter im neurochirurgischen Operationssaal ?"

HONORS AND AWARDS

Dr.-Ing. Stefan Bohn successfully defended his dissertation in computer science. For his doctoral work he received the grade magna cum laude.

Prof. Dr. Andreas Dietz has been elected to the executive board of the German Society of Oto-Rhino-Laryngology, Head and Neck Surgery.

Stefan Franke won the poster award of the 12th Annual Conference German Society for Computer and Roboter-Assisted Surgery (CURAC) for his contribution „A Surgical Assistance System for Transcatheter Aortic Valve Implantation Based on a Magic Lens Concept“

Prof. Dr. Jürgen Meixensberger has been appointed 2nd Vice President of the German Society of Neuro-Intensive Care.

Prof. Dr. Jürgen Meixensberger has been elected Vice Dean of Medical Education at the Faculty of Medicine of Leipzig University.

Prof. Dr. Thomas Neumuth has been appointed honorary professor of Biomedical Information Systems at HTWK Leipzig University of Applied Sciences.

Prof. Dr. Thomas Neumuth has been elected to the committee of the German Association for Medical Informatics, Biometry and Epidemiology (GMDS).

Sandra von Sachsen received a poster award for outstanding scientific achievements in the field of Medicine and Life Sciences at the 11th Leipzig Research Festival for Life Sciences in December 2012.

Prof. Dr. Gero Strauß has been appointed to the scientific advisory board of the Interuniversity Centre for Medical Technologies Stuttgart-Tübingen (IZST) at Eberhard Karls Universität Tübingen.

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IFCARS – International Foundation for Computer Assisted Radiology and Surgery

IHE International – Integrating the Healthcare Enterprise

ISCAS – International Society for Computer Aided Surgery

Industry

3dMD, Atlanta, Georgia, USA
MedPlan Engineering AG, Schaffhausen, Switzerland
Sirona Dental GmbH, Wals bei Salzburg

PUBLICATIONS

Articles

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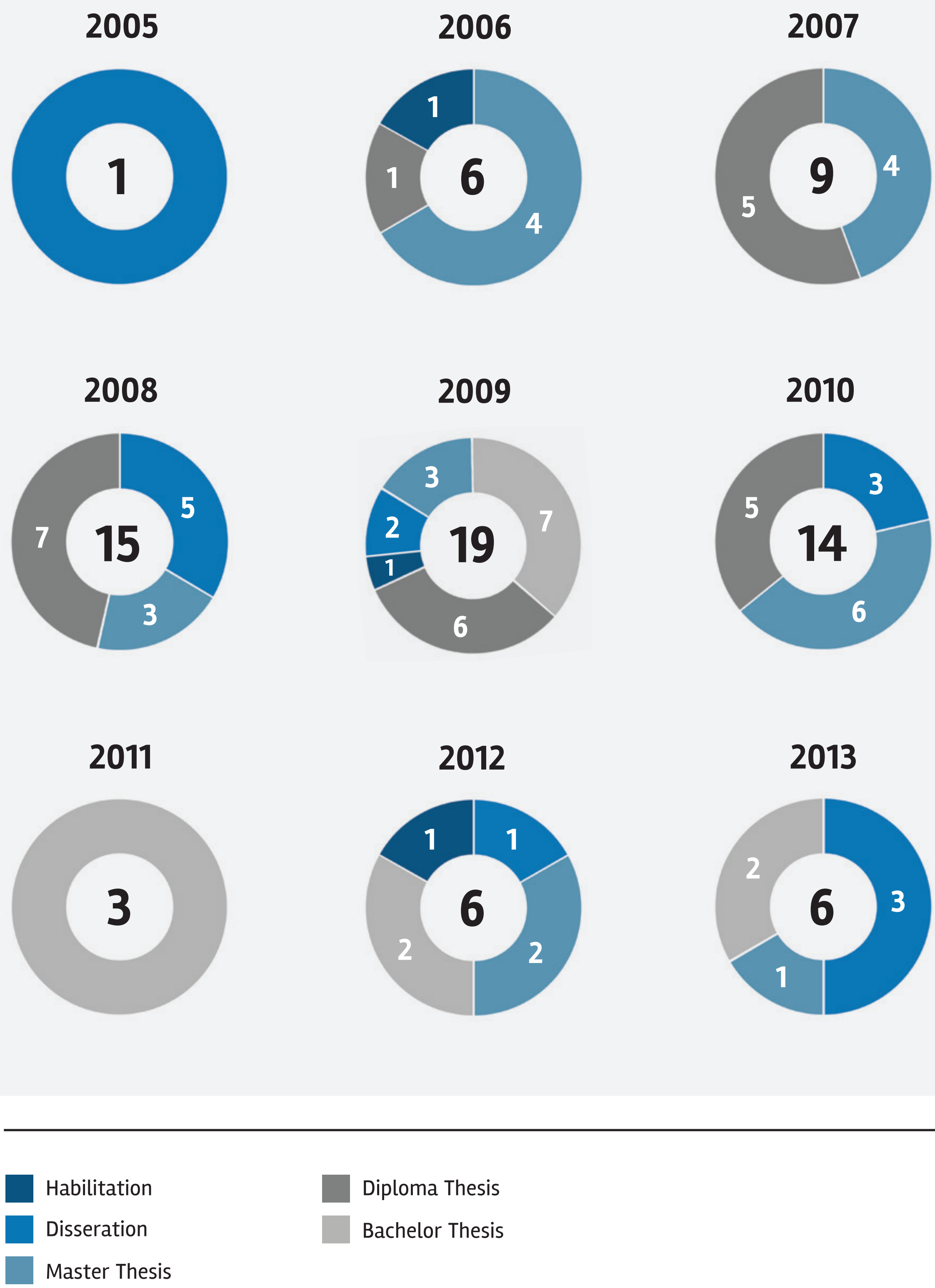
GRADUATIONS



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