



Chair of Medical Engineering
Faculty of Mechanical Engineering

Innovative Technology for Smart Therapy

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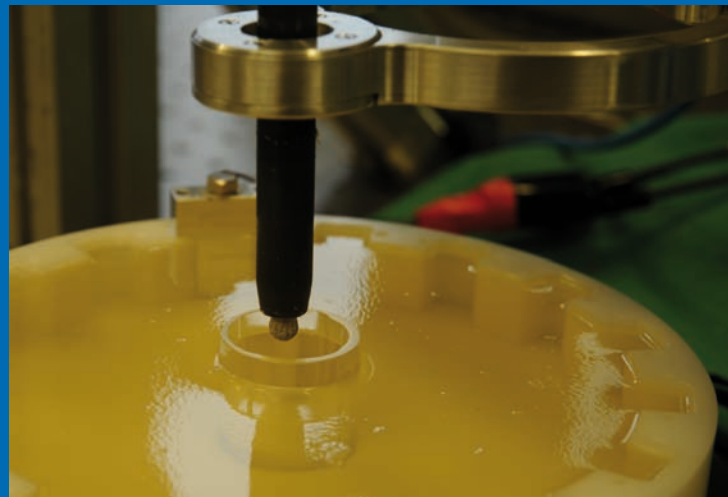
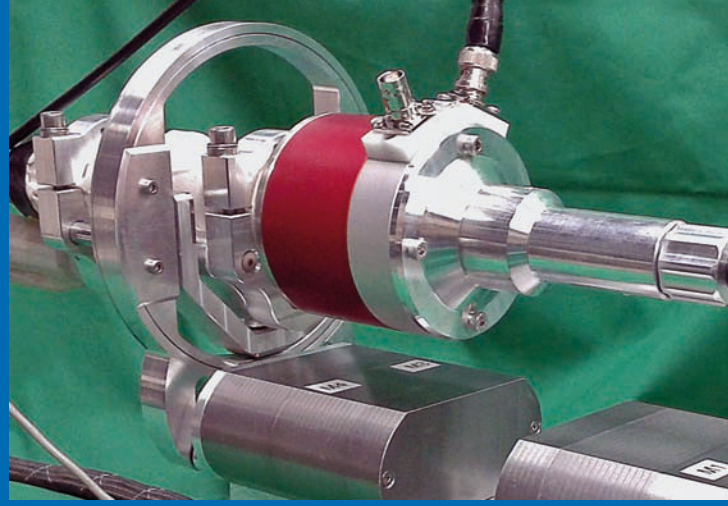
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Introduction

The team of the Chair of Medical Engineering of the Faculty of Mechanical Engineering of the RWTH Aachen University (mediTEC) is engaged in basic research issues as well as in application-oriented aspects of computer assisted diagnosis and model-guided therapy systems engineering. For more than two decades our work has been focused especially on computer assisted therapy with activities ranging from image, signal and information processing (with a special focus on ultrasound apart from other modalities) to biomechanical modeling and simulation for computer assisted personalization of model-based therapy planning and surgical navigation, smart mechatronic instruments and surgical robotics. Moreover, computer assisted diagnostics and non-surgical therapy complemented the spectrum of activities. Since 2007 we established a medical shock wave lab and related research activities. Considering the increasing technical complexity of medical work systems, the integration, risk management and usability engineering of medical work systems represent another focus area of our activities.

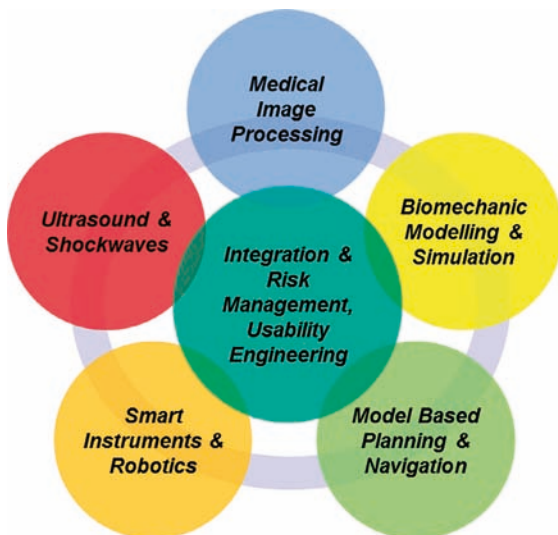


Fig. 1: Focus research areas and teams at mediTEC

Actual projects in the domain of Orthopedic and Trauma Surgery, Neurosurgery, General Endoscopic Surgery, Cardiology, Interventional Radiology, Maxillofacial Surgery, Dental Therapy and Psychiatry are ranging from feasibility studies (proof of concept) and system development to usability analysis and clinical field tests. The development of integrated surgical systems in the context of the smartOR project (smart medical IT networks for modular integrated OR systems; 4/2010 -3/2013; 2.8 M€ overall funding by the German Federal Ministry of Economics and Technology (BMWi); Coordination: mediTEC) exemplifies our continuing efforts for the optimization of surgical work systems and is another very successful example of our actual research activities. In 2012 the German Ministry for Education and Research (BMBF) approved further funding of about 15 M€ for 3 years for the project OR.NET (54 partners, co-coordination: mediTEC) essentially based on the achievements of the smartOR-project, which will enable us to continue our work on a broader and sustainable basis. The BMBF project IDA (development of an intraoral ultrasound base micro-scanner; Medical Technology Innovation Award 2008, 4

Partners, 1,2 M€, Coordination: mediTEC) represents another highlight of our activities with successful proof of concept studies in 2012. Apart from other projects funded by the state of North-Rhine Westphalia and by the European Union as part of the European Regional Development Fund, the RapidGEN project on personalized modeling and rapid manufacturing of individual knee implants (2,3 M€; 7 Partners, Coordination: mediTEC) started in 2012. Additionally, various new research grants related to basic research issues as well as industrial co-operations have been acquired by our team. The continuing successful market application of several products originally developed in our lab as well as the approval of international patent applications confirm our general concept of combining basic as well as problem oriented medical engineering research and application development, being also an essential basis for the sound education of our students. In 2012 Prof. Radermacher received the M.E. Müller Award for Excellence in Computer Assisted Surgery of the International Society for Computer Assisted Orthopaedic Surgery. Last but not least, we congratulate Prof. Dr.-Ing. Stefan Heger who accepted his appointment as Lecturer for Ultrasound Imaging of the Faculty for Information Technology of the University of Mannheim. We greatly appreciate, that Prof. Heger will continue his research at our institute as the head of our ultrasound team.

Selected Projects

OrthoMIT – Follow-up

In 2012 the German Ministry for Education and Research (BMBF) reported on the OrthoMIT project on technical innovations for minimal invasive orthopaedic therapy (2005 - 2011, BMBF funding ca. 15 M€, 25 partners, technical coordination: mediTEC) as a prominent example of success in medical engineering (www.bmbf.de/pub/erfolge_der_medizintechnik.pdf). Whereas US patent US 8308730B2 on genALIGN knee navigation, filed by RWTH/mediTEC in the framework of OrthoMIT, has been approved, several other patent applications are still pending. The OrthoMIT project substantially fostered the development of many products actually on the market and has been a substantial basis for ongoing research activities and projects.

Apart from the very comprehensive official final report, major results of the OrthoMIT-project have been published in a special issue of the Journal for Biomedical Engineering (DeGruyter, Vol. 4 (Aug 2012), pp. 207 – 306) edited by Prof. Radermacher / mediTEC and Prof. Tingart / Clinic for Orthopaedic Surgery, RWTH Aachen University.



Model Guided Intravascular Navigation

Endovascular procedures allow for minimal-invasive interventions especially in case of patients in a critical general state of health. In the project in.nrw:HyTher® we develop

an approach towards navigated personalized in-situ fenestration of aortic prostheses making use of image based 3D data and smart catheters, equipped with distortion corrected electromagnetic position tracking and ultrasound probe for intravascular navigation.

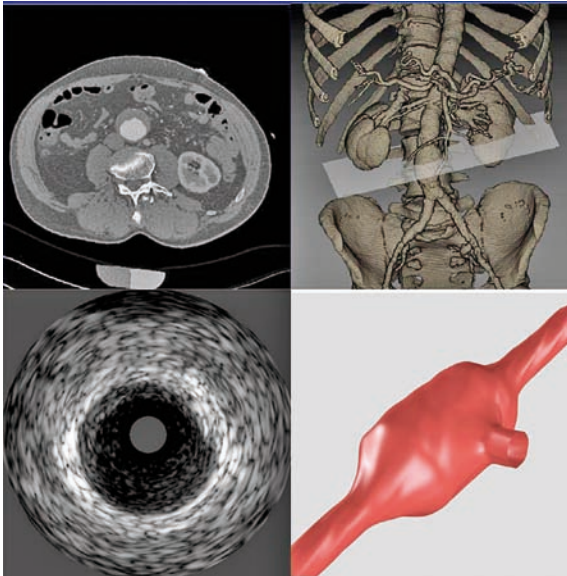


Fig. 2: Model based intravascular navigation based on CT imaging (upper row) and tracked US probe (lower row)

In-vivo trials with domestic pigs already showed the feasibility of the concept. Ongoing work is related to the reduction of x-ray exposure by incorporating the registration of a-priori 3D model data and intravascular ultrasound for 3D dataset acquisition as well as the transfer to other applications such as the placement of an intrahepatic stent shunt.

Image-based Musculoskeletal Modeling of the Knee Joint for Model Guided Surgery Planning

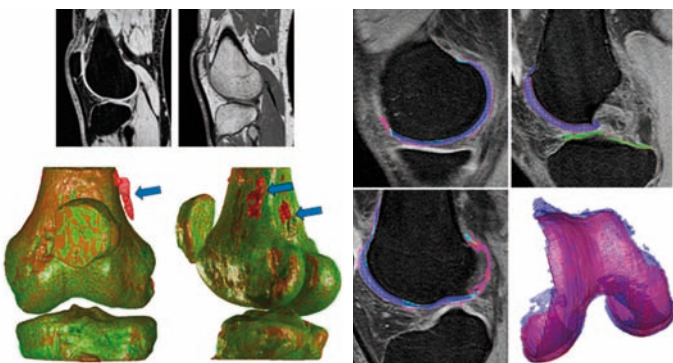


Fig. 3: Patient-specific morphological modeling of the knee joint from MR images. (left): Study on optimized MR-sequences for automatic level-set segmentation. (right): Model-based classification approach for the automatic segmentation of femoral cartilage.

Customized knee morphological and functional models provide valuable feedback on joint deformity and how it influences the joint functionality in the individual case. These models are essential for the optimization of the surgical

treatment in case of severe knee arthritis and related functional limitations. One of the research focuses of the project RapidGEN* is the development of model-based approaches for the segmentation and biomechanical modeling of the knee joint based on MRT image data for patient specific implant design and manufacturing. (Fig.3).

Biomechanics of the Wrist

In cooperation with the Department of Plastic Surgery, Hand and Burns Surgery (University Hospital Aachen) we develop enhanced biomechanical multi body simulation models of the wrist joint. For experimental model validation US, CT and MRT image data as well as motion analysis with miniaturized magnetic tracking sensors are used. The identification of appropriate parameters and strategies for surgical therapy planning are major objectives of our work.

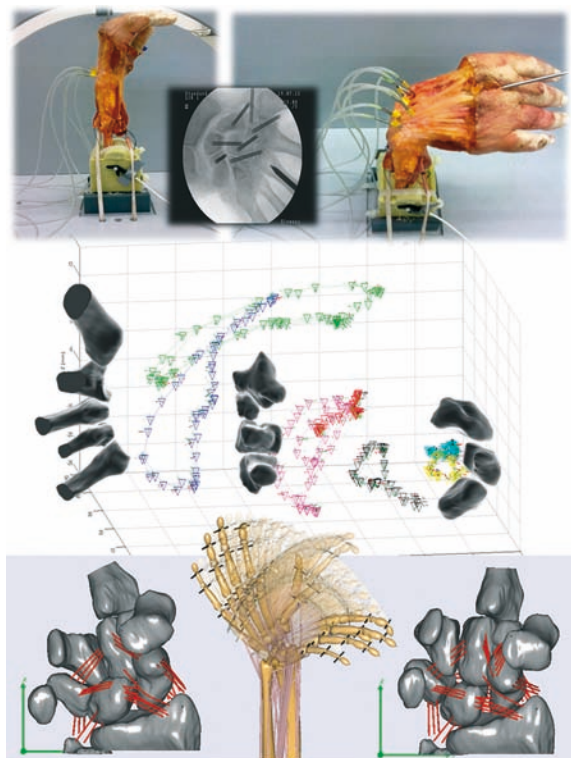


Fig. 4: Results of model based simulation and motion analysis of wrist joint biomechanics.

Impedance Controlled Surgical Instrumentation

Revision total hip replacement surgery is one of the standard procedures in orthopedic surgery. In case of a cemented prosthesis stem the bone cement removal out of the femoral cavity is important for the success of the surgical intervention. The project ICOS* investigates the approach of using the variation of electrical impedance during bone cement removal for an intraoperative robot assisted real-time control of the remaining bone cement. A milling tool and the MINARO mini-robot system were adapted for impedance measurement. Furthermore, a strategy for real-time milling path generation using only local information from impedance measurement was developed and actually undergoes experimental evaluation.

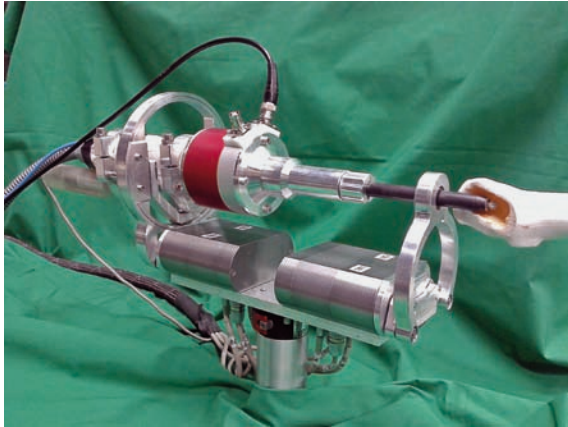


Fig. 5: Experimental set-up for the impedance controlled robotic milling with the MINARO system

Robot Assisted Endoscopic Brain Surgery

Treatment of hydrocephalus occlusus disease can be done through fenestration of the bottom of the third ventricle. This surgical intervention is carried out endoscopically. Problems can occur at finding the best trajectory through the brain and at fine-positioning of the endoscope, which is done freehand by the surgeon. To address these problems in the context of the INKA* project, we developed a robotic manipulator system on the basis of the MINARO mini robot architecture, leading the surgeon moving the endoscope within a predefined tunnel to the target, and on the other hand allows a precise intraoperative motion and repositioning.



Fig. 6: CAD Study of the INKA manipulator system

Hydrocephalus - Biomechanics and Instrumentation

In the context of the iShunt* project, an intelligent shunt system is developed in cooperation with the Chair of Medical Information Technology (RWTH Aachen University) controlling the intracranial pressure by adapting the opening pressure according to the body posture and various vital signs of the patient. Due to a disturbed liquor balance pathologically high intracranial pressure can occur, resulting in severe brain damage. In 2012 the focus in hydrocephalus research was brought to formation of Normal Pressure Hydrocephalus (NPH) the biomechanics of the brain parenchyma during this disease. Particularly the influence of an oscillating blood pulse in the brain parenchyma and the resulting stresses and strains are investigated.

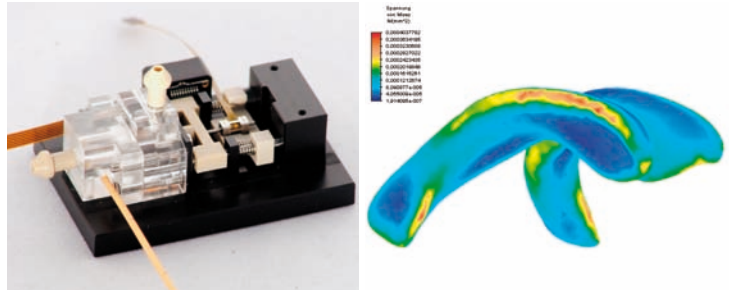


Fig.7: Mechatronic shunt valve (left); FEM-analysis of the stress distribution in the lateral ventricular walls (right)

IDA – Intraoral Data Acquisition Using Ultrasound Micro-Scanning

Computer-integrated manufacturing of dental prosthesis such as crowns, bridges and inlays gains more and more importance due to its high accuracy and its time efficiency. One crucial step of the CAD/CAM process is the precise intraoral surface digitization of the tooth preparation with an accuracy of better than 50 μm . The objective of the interdisciplinary IDA-project* is the development of an US based intraoral micro-scanner replacing the conventional casting process without the drawbacks of current optical scanners.

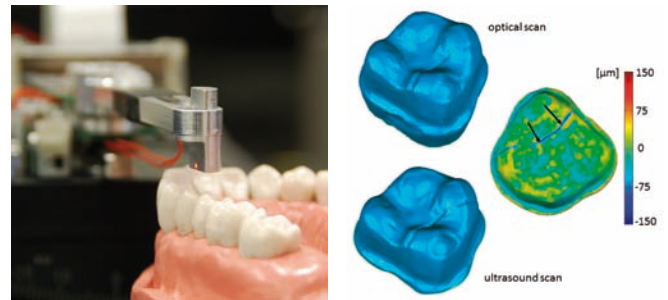


Fig. 8: Evaluation of ultrasound micro-scanning with the IDA Sonic prototype: lab set-up (left), results (right)

The first lab-type of the IDA micro-scanner integrating a focused high frequency US transducer has been successfully implemented and tested (Fig. 7). The high accuracy of the 2-axis ultrasonic scanner prototype has been confirmed by in-vitro laser measurements and a conventional dental optical scanner.

Ultrasound in Dental Implantology

Dental implants are well-established in modern dentistry. However, progressive peri-implant bone loss may lead to failing implants. Conventionally, the particularly relevant vestibular jawbone thickness is monitored using x-ray based 3D imaging methods. Radiation as well as metal artifacts caused by metallic implants and superstructures are major drawbacks of those imaging modalities. Diagnostic ultrasound, as a patient friendly and cost effective technology may be used to overcome this problem. Because bone is an inhomogeneous and highly attenuating medium surrounded by soft tissue, the interaction between ultrasound and bone is complex. Therefore, new model based signal processing strategies and scanning concepts are currently developed

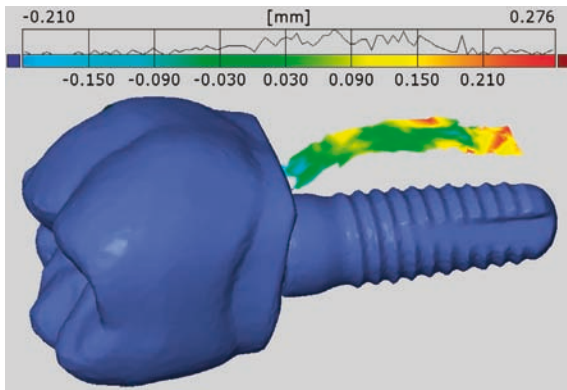


Fig 9: Reconstructed jawbone surface by high frequency ultrasound micro-scanning and visualization of the reconstruction error.

in order to accurately measure the vestibular jawbone thickness.

Medical Shockwaves Lab

Shockwave Therapy is being used clinically since the 1980's to support the regeneration of different tissues. However, the physical effect parameters of the waves are still neither known nor understood. In order to gain knowledge about the biological effects of shockwaves, cell and animal experiments are being conducted additionally to physical measurements and FEM-Simulations of the experiments. To ensure realistic computer simulations of the acoustic field, the start signal which is the vibration of the transducers surface and the material parameters are measured. Thereby, resulting acoustic fields can be computed and their variation due to different geometries or interfaces can be evaluated.

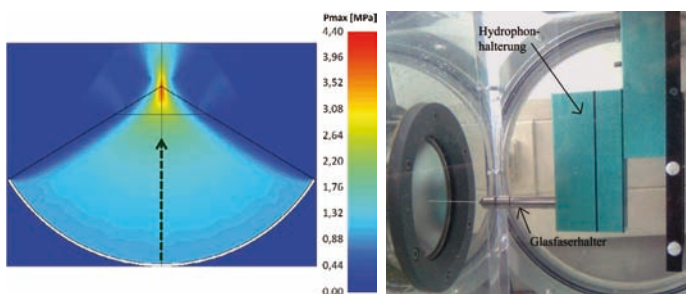


Fig.10: Simulation (left) and experimental set-up for the evaluation of a transducer for focused shockwave therapy

Knowledge Based Risk Management in Medicine

Based on our long-standing research activities on ergonomics in medicine, we have established a portfolio of tools and methods for usability engineering of medical products. The HiFEM method and the related software tool mAIXuse for human error risk analysis (Walter Masing Award 2010 of the German Association for Quality (DGQ)) has been successfully applied with a very positive response in cooperation with an increasing number of industrial partners. In the framework of the FQS/AIF/BMWi-Project sysRISK*, mAIX-control - a new method for risk control of technical and human induced risks - has been developed and



Fig. 11: Typical team situation in a risk analysis workshop

evaluated. First results show, that mAIXcontrol outperforms classical methods for a systematic reduction of risks in man-machine systems.

smartOR.NET – Plug & Play in the OR

Over the last three years, the smartOR* project created an innovative solution for the integration of medical devices and IT systems in operating rooms. The development of an open surgical communication bus and interfaces for a platform and vendor independent solution on the basis of a service oriented architecture (SOA) are key elements of the concept.



Fig. 12: smartOR demonstrator (top) and smart-OR educational workshop introducing external partners from clinics, academia and industry in the smartOR architecture and implementation (bottom)

The smartOR partners were able to demonstrate a plug-&-play implementation and integration of several IT systems of different vendors at the conhIT 2012 trade fair and on an official status symposium and work shop in November 2012. The results of the smartOR project are one essential basis for the BMBF project OR.NET* aiming to take the medical IT integration to the next level by migrating from an OR-only system to a clinic-wide integrated platform.

Man-Machine Interaction for Neurofeedback Systems in Psychotherapy

The EEG-based neurofeedback training in combination with medication poses an alternative treatment opportunity for attention deficit hyperactivity disorder (ADHD). Due to the number of sessions needed and to optimize the training, it is the main object of this project to transfer the training into the living environment of the patient. Therefore, the main objective of the BMWi project NF-Home^{1*} is to develop an innovative neurofeedback system for home application. Usability engineering and the design of adequate man-machine-interfaces are main aspects of this activity and mediTEC.



Fig.13: Experimental set-up for user interactive evaluation

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- the German Research Foundation (DFG)
- the European Union, the Ministry of Innovation, Science, Research and Technology and the Ministry of Economic Affairs North-Rhine-Westphalia (EFRE/Ziel2.NRW)
- European Space Agency (ESA)

Team



Selected Publications

- [1] Belei, P.: Intraoperative biomechanische Modellierung für die patientenindividuelle funktionelle Planung, Simulation und Umsetzung von Korrekturosteotomien, Shaker-Verlag, Band: 15, Leonhardt, St., Radermacher, K., Schmitz-Rode, T. (Hrsg.): Aachener Beiträge zur Medizintechnik, 2012
- [2] Birkle, M., Benzko, J. & Shevchenko, N.: Das Projekt OR.NET - Sichere dynamische Vernetzung in OP und Klinik. Deutsche Zeitschrift für

Note: In this report we can only provide a short overview of selected activities. For further information on the related projects, our cooperating partners, funding agencies and sponsors, please visit our website www.meditec.rwth-aachen.de or contact us directly.

- klinische Forschung, Innovation und Praxis. November 2012, 11/12-2012(11/12), pp. 41-45
- [3] Elfring, R.: Störungskompensation und Optimierung des elektromagnetischen Trackings in der computerunterstützten Chirurgie, Band: 13, Leonhardt, St., Radermacher, K., Schmitz-Rode, T. (Hrsg.): Aachener Beiträge zur Medizintechnik, Shaker Verlag, 2012
- [4] Eschweiler, J., Allmendinger, F., Stromps, J.-P., Corves, B., Pallua, N. & Radermacher, K.: Kinematische Modellierung der menschlichen Handwurzel. Computer Aided Medical Engineering. 2012, 3(1), pp. 6-11
- [5] Eschweiler, J., Fieten, L., Anna, J.D., Kabir, K., Gravius, S., Tingart, M. & Radermacher, K.: Application and evaluation of biomechanical models and scores for the planning of total hip arthroplasty. Journal of Engineering in Medicine. 2012, 226(12), pp. 955-967
- [6] Fieten, L., Dupraz, I., Reising, K., Helwig, P., Heger, S., Blömer, W. & Radermacher, K.: Ultrasound-based registration of the pelvic coordinate system in the lateral position using symmetry for total hip replacement. Biomed Tech (Berl). 2012, 57(4), pp. 239-248
- [7] Follmann, A.: Ein mechatronisches System zur semiaktiven Schädel-trepanation, Band: 12, Leonhardt, St., Radermacher, K., Schmitz-Rode, T. (Hrsg.): Aachener Beiträge zur Medizintechnik, Shaker-Verlag 2012
- [8] Follmann, A., Korff, A., Fuertjes, T., Kunze, S.C., Schmieder, K. & Radermacher, K.: A Novel Concept for Smart Trepanation. Journal of Craniofacial Surgery. 2012, 23(1), pp. 309-314
- [9] Ibach, B., Benzko, J., Schlichting, S., Zimolong, A. & Radermacher, K.: Integrating medical devices in the operating room using service-oriented architectures. Biomed Tech (Berl). 2012, 57(4), pp. 221-228
- [10] Köny, M., Benzko, J., Czaplík, M., Rossaint, R., Radermacher, K. & Leonhardt, S.: Getting Anesthesia Online: The smartOR Network. International Journal On Advances in Internet Technology. 2012, 5(3&4)
- [11] Müller, M.C., Belei, P., Pennekamp, P.H., Kabir, K., Wirtz, D.C., Burger, C. & Weber, O.: Three-dimensional computer-assisted navigation for the placement of cannulated hip screws. A pilot study. Int Orthop., 2012, 36(7), pp. 1463-9
- [12] Müller, M.C., Kabir, K., Gravius, S., de la Fuente, M., Belei, P., Strake, M. & Wirtz, D.C.: Fluoroscopy-based computer-assisted navigation for implant placement and hip resurfacing arthroplasty in the proximal femur: the zero-dose C-arm navigation approach. Biomed Tech (Berl). 2012, 57(4), pp. 209-219
- [13] Niggemeyer, M., Müller, M., Niesche, A., de la Fuente, M., Komadinic, A. & Radermacher, K.: Modular design of a miniaturized surgical robot system. Biomed Tech (Berl). 2012, 57(4), pp. 261-268
- [14] Reich, S., Vollborn, T. & Wolfart, S.: Die optische intraorale Abformung - vier Systeme im Überblick. Dtsch Zahnärztl Z. 2012, 67, pp. 177-189
- [15] Zimmermann, F., Schwenninger, Ch., Nolten, U., Firmbach, F.P., Elfring, R., Radermacher, K.: A new approach to implant alignment and ligament balancing in total knee arthroplasty focussing on joint loads. Biomed Tech (Berl). 2012, 57(4), pp. 283-91 [13] Niggemeyer, M., Müller, M., Niesche, A., de la Fuente, M., Komadinic, A. & Radermacher, K.: Modular design of a miniaturized surgical robot system. Biomed Tech (Berl). 2012, 57(4), pp. 261-268