APRnews

Newsletter of the KIT Center Information, Systems, Technologies –
Anthropomatics and Robotics

Issue 1|2015

EDITORIAL

The deployment of theoretical methods and techniques from the disciplines of computer science, engineering and mathematics to the solutions of medical problems has grown rapidly over the past years. Today the resulting range of applications in health care is very wide, spanning from intelligent systems which support diagnosis and therapy with model-based prognoses, medical imaging, neural engineering, advanced prosthetics, physiological signal processing, biomaterials up to tools for the training of medical professionals.
This newsletter provides a glimpse into some of the activities in this area carried out at the KIT Center Information, System, Technologies. The first two contributions bring the reader into the operating room. The former article presents a technique to compensate soft-tissue deformations for navigation during surgical interventions, while the latter describes a robotic solution to cope with the movement of a beating heart during heart surgery. The newsletter concludes by giving an overview of the FET-Flagship "Human Brain Project", which paves the way for a deep understanding of the human brain.

Prof. Rüdiger Dillmann
Spokesperson
KIT Center Information, Systems, Technologies

NEWS

Prof. Heinz Wörn awarded honorary doctorate degree
Prof. Heinz Wörn, Institute for Anthropomatics and Robotics, received on March 18, 2015 from the Ufa State Aviation Technical University, Russia, the honorary doctorate degree, for his long-standing commitment to the German-Russian cooperation in the area of robotics and automation.

Successful grant application for InterACT
The German Academic Exchange Service (DAAD) approved the proposal "Continuous Learning in International Collaborative Studies" (CLICS), which provides the International Center for Advanced Communication Technologies (InterACT) with a four years support. CLICS will develop three international Massive Open Online Courses (MOOC) in the areas of automatic speech recognition, machine translation and robotics. To facilitate international access to the MOOCs automatic transcription and translation technology will be used. InterACT is a network of leading research universities and institutes of the main economies of the world, directed by Prof. Alexander Waibel, Institute for Anthropomatics and Robotics, with the mission of facilitating scientists exchange and education at international level.

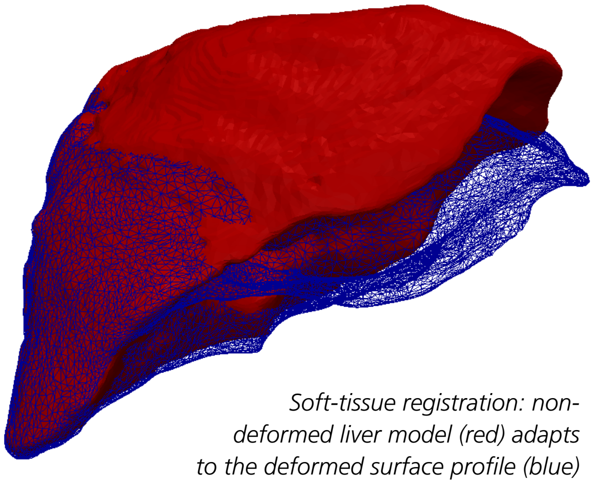
Prof. Dorothea Wagner in the German Council of Science and Humanities
In January 2015 Federal President Joachim Gauck appointed Prof. Dorothea Wagner (Institute of Theoretical Informatics) to serve for three years in the German Council of Science and Humanities (Wissenschaftsrat). The German Council of Science and Humanities provides advice to the German Federal Government and the State (Länder) Governments on the structure and development of higher education and research.

30 Years FZI
On January 28-29, 2015 the FZI Research Center for Information Technology celebrated its 30th anniversary by organizing the congress "30 Years of Knowledge Transfer" with presentations on key topics like security, mobility, health care, industry 4.0, logistics, robotics, and energy. An Open House event rounded the program.

Prof. Henkel and Prof. Waibel elevated to IEEE Fellows
Prof. Jörg Henkel, Chair for Embedded Systems, and Prof. Alexander Waibel, Institute for Anthropomatics and Robotics, have been elevated by the Institute of Electrical and Electronics Engineers (IEEE) to IEEE Fellows, effective January 1, 2015, for their contributions respectively "to hardware/software codesign of embedded computing systems" and "to neural network based speech recognition and translation and multimodal interfaces". IEEE Fellow is a distinction reserved for select IEEE members whose extraordinary accomplishments in any of the IEEE fields of interest are deemed fitting of this prestigious grade elevation.

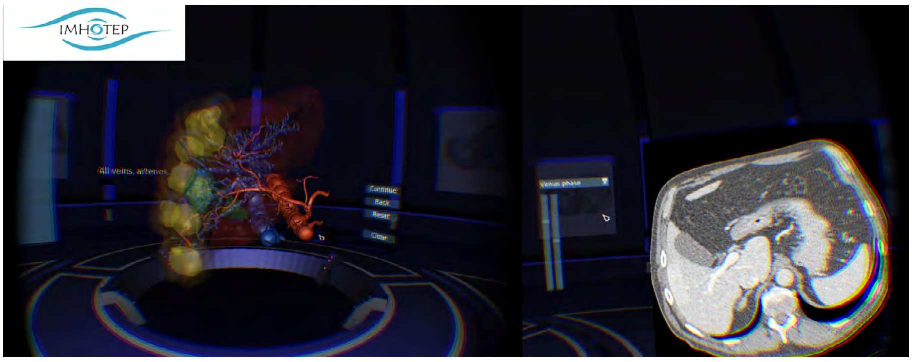
KASTEL Team wins the 5th German IT-Security Prize
A joint cooperation between KASTEL and the Wibu-Systems AG was awarded on October 23, 2014, with the first prize of the 5th German IT Security Prize of the Horst Görtz Foundation. The team, lead at KIT by Prof. Jörn Müller-Quade, received the prize for developing the Blurry Box® method for software protection.

Computer-assisted Surgery



Soft-tissue registration: non-deformed liver model (red) adapts to the deformed surface profile (blue)

With advances in image-guided surgery and therapy, there is an increasing amount of valuable data which can be used intraoperatively to help surgeons treat patients and improve outcome. Computer-assisted surgery refers to systems which provide useful information during the intervention, e.g. the visualization of navigation information or the prediction of complications. However, soft-tissue deformations as well as information overload and poor integration into the clinical workflow reduce the validity and usefulness of an assistance system. A context-aware assistance adapts automatically to the situation in the operation room, thus relieving surgeons from the burden of managing computer assisted surgery devices manually.
The goal of the junior research group "Computer-assisted surgery" at the Institute of Anthropomatics and Robotics is a context-aware assistance system for minimally-invasive soft-tissue surgery. The vision is a system that acts like a filter and visualizes information context-aware, e.g. preoperative planning data like the position of a tumor or risk structures, based on the recognized phases in the operating room. To recognize the current phase, methods for analysis and interpretation of intraoperative sensor data, e.g. the endoscopic images, medical device data or tracking information are developed.
Soft-tissue deformations can severely degrade the validity of preoperative planning data and require an intraoperative registration. In order to accurately register planning data to the patient (and thus provide a meaningful guidance), these deformations have to be compensated. Intraoperative imaging such as stereoendoscopes are used to obtain information about the surface of the moving tissue in real-time. The group developed a real-time stereoendoscopic reconstruction and a biomechanical registration method to adapt the virtual organ to the deformed surface profile. Furthermore, for preoperative planning, an operation planning and teaching system is proposed. It allows surgeons to view segmented patient organs, tumors and vessels in an immersive virtual 3D scene using a head-mounted display (Oculus Rift). In this way, the surgeons will know exactly where to cut and how to reach the tumors with the smallest possible risk for the patient.
The projects are supported by the German Research Foundation (DFG) within the setting of the Transregional Collaborative Research Centre (TCRC) 'Cognition-Guided Surgery', a collaboration between KIT, the University Hospital of Heidelberg and the German Cancer Research Center. The aim is to create a technical, cognitive system to support the surgeon. It will act in a similar way to a human assistant while permanently retaining vital knowledge to be transferred, accumulated and reused for future operations. It is furthermore sponsored by the Klaus Tschira Foundation and the European Social Fund of the State Baden-Wuerttemberg.



Operation planning and teaching system IMHOTEP

Dr.-Ing. Stefanie Speidel
Prof. Dr.-Ing. Rüdiger Dillmann

Further information:
http://his.anthropomatik.kit.edu/829.php

Robotic Beating Heart Surgery

Heart disease is the leading cause of death in the world. The major reason for this is a narrowing of the coronary arteries by plaque, which inhibits the blood flow to the heart muscles. One of the treatments for this condition is the surgical creation of a bypass around the narrow arteries.

During this procedure, the heart is usually stopped to avoid the difficulty of performing surgery on the beating heart. However, stopping the heart leads to increased medical risks for the patient. For this reason, in a research project at the Intelligent Sensor-Actuator-Systems laboratory (ISAS) in cooperation with the Heidelberg University Hospital, a system for robotic beating heart surgery is being developed.
The idea behind robotic beating heart surgery can be summarized as follows. The surgeon does not operate on the patient directly anymore, but remotely controls a robot instead. In traditional robotic surgery, the robot would exactly follow the movements of the surgeon. For the purpose of beating heart surgery, however, the robot not only follows the movements of the surgeon, but also automatically compensates for the movement of the beating heart. The surgeon in turn is presented a stabilized image of

the intervention area. Thus, the illusion of operating on a still heart is created and the surgeon can operate as though the heart were not moving at all.

In order to make the vision of robotic beating heart surgery with automatic motion compensation a reality, several of the key components of this system are investigated at the ISAS laboratory.

First, the problem of reconstructing the three-dimensional heart surface is considered. Accurate information about the current three-dimensional shape of the surface is required to automatically compensate its motion. To obtain three-dimensional measurements from the heart surface, a stereo vision system consisting of multiple color cameras can be used. Alternatively, a depth camera such as the Microsoft Kinect can be employed. As both types of systems have strengths and weaknesses, an approach based on information fusion is considered, i.e., information from both types of sensors is combined to obtain more accurate and more robust information about the heart surface.

Heart phantom with trinocular stero camera system

Second, it is important to estimate the phase of the beating heart, i.e., to answer the question how many percent of the current heartbeat are already over and how many percent are yet to come. This allows, for example, predicting when the next contraction of the heart is going to occur. Because phase is a periodic property, i.e., the end of one heartbeat directly connects to the beginning of the next heartbeat, nonlinear estimation methods based on directional statistics have been developed at the ISAS lab. These techniques allow explicit consideration of the periodicity involved and produce superior results to standard methods.

Third, image stabilization algorithms have been developed and evaluated at the ISAS laboratory. These algorithms allow to create a stabilized image of the beating heart that could be shown to the surgeon in order to complete the illusion of surgery on a stopped heart. Image stabilization is not limited to two-dimensional images, however. The techniques developed at ISAS also allow the computation of a stabilized three-dimensional surface, which can then be rendered from an arbitrary perspective.

Dipl.-Inform. Gerhard Kurz,
Prof. Dr.-Ing. Uwe D. Hanebeck

Further information:
http://isas.uka.de/

PhD Graduations at the Institute for Anthropomatics and Robotics July – December 2014

IES Prof. Beyerer, Michael Teutsch
Moving Object Detection and Segmentation for Remote Aerial Video Surveillance

HIS Prof. Dillmann, Michael Delles
Bestimmung zeitabhängiger Blutdruckfelder aus Strömungsdaten der Magnetresonanztomographie

Tobias Gindele
Learning Behavior Models for Interpreting and Predicting Traffic Situations

Stefan Suwelack
Real-time Biomechanical Modeling for Intraoperative Soft Tissue Registration

ISAS Prof. Hanebeck, Jörg Fischer
Optimal Sequence-based Control of Networked Linear Systems

Marc Reinhardt
Linear Estimation in Interconnected Sensor Systems with Information Constraints

CSL Prof. Schultz, Felix Putze
Adaptive Cognitive Interaction Systems

Tim Schlippe
Rapid Generation of Pronunciation Dictionaries for new Domains and Languages

cv:hci Prof. Stiefelhagen, Martin Bäuml
Contextual Person Identification in Multimedia Data

Joris Ijsselmuiden
Interaction Analysis in Smart Work Environments through Fuzzy Temporal Logic

Hildegard Kühne
Analysis and Recognition of Human Actions with Flow Features and Temporal Modals

IPR Prof. Wörn, Jens Liedke
Entwicklung einer heterogenen Roboter-Plattform für Modular- und Schwarmrobotik

Stephan Puls
Situationsverstehen für die Mensch-Roboter-Kooperation

Lutz Winkler
Vom Roboterschwarm zum Organismus – Steuerung modularer Schwarmroboter

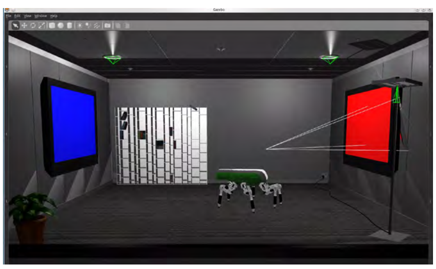
The Human Brain Project

Gaining fundamental insights about how the human brain works and, ultimately, what "makes us human" remains one of the greatest challenges of the 21st century. This understanding is exactly the main goal of the large-scale "Human Brain Project" (HBP), a Future and Emerging Technologies (FET) flagship project funded by the European Commission. In this project, over 120 institutions out of 24 countries cooperate in integrating neuro-scientific data using methods from many different disciplines such as medicine, Information and Computer Technologies (ICT), and neuroscience, to achieve a deeper understanding of the human brain. Eventually, these results will pave the way to new treatments for brain diseases and the development of new biologically inspired technologies like neuromorphic hardware and human-like robots.

In the scope of the HBP, the FZI Research Center for Information Technology at the Karlsruhe Institute of Technology is one of the partners of the Neuro-Robotics subproject which, in the first phase of the project, focuses on the development of a software infrastructure for scientists and developers alike for the creation and execution of reproducible neurorobotic experiments. In later phases of the project, this subproject will dedicate its efforts to the development of new robot technologies inspired by theoretical neuroscience.

The Neuro-Robotics subproject

The Neuro-Robotics subproject pursues the goal of providing the scientific community with a common unified platform for the collaborative design of experiments that links principles and data from theoretical neuroscience

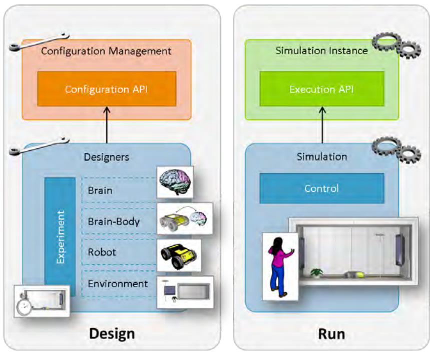


Virtual Room with the six-legged walking robot LAURON V

to realistic simulations of robots and interactive environments. That way, the resulting neuro-robotic systems can be investigated and be evaluated easily in silicio such that they can contribute to the development of novel robotic technologies. The platform will also offer access to the computational resources of high-performance computing centers and the specialized neuromorphic hardware architectures that are developed in different subprojects of the human brain project. This will enable researchers to simulate even entire brain models at a very realistic and high level of detail and connect them to simulated robot platforms for control in real-time.
With a team of robotics specialists and years of experience in the creation of simulation environments, the FZI contributes to the development of this Virtual Neuro-Robotic Simulation Platform (Project VINERO). Ultimately, this project will provide the software necessary to run closed-loop simulations with brain models connected to both simulated and real robotic platforms capable of interacting with their environments.
The software consists of the following core components: the Robot and Environment Designers allow creating virtual robots and environments based on detailed specifications. The Brain and Body designers offer researchers the possibility to model neural circuits and their connection to a robot platform. Complex experiments can be defined by the Experiment designer. Finally, the brain mo-dels and robot platforms are connected and simulated by the Closed-Loop Engine.

Future research

In later phases of the project, the FZI will focus its scientific efforts on sensorimotor representations and learning, and higher-level reasoning. Therefore, the transfer of established and well understood concepts of traditional machine learning to representations based on realistic spiking neural models will be investigated. The goal of this research is, on the one hand, the creation of a system that creates a bridge between classical machine learning and neural computing in order to provide a realistic model of human



Virtual Neuro-Robotic Simulation Platform architecture

sensorimotor coordination. On the other hand, it will be evaluated how the field of robotics can benefit from such systems with respect to the expected increase in flexibility and fault tolerance. Ranging from robots that model simple systems, such as the inspection robot KAIRO and the six-legged walking machine LAURON, up to complex robots driven by artificial muscles, the involved robotic platforms will reflect the increasing complexity of the required neural control systems. In addition to that, the application on industrial robots and dedicated neuromorphic hardware will be considered.

Dr.-Ing. Stefan Ulbrich
Prof. Dr.-Ing. Rüdiger Dillmann
Prof. Dr. Paul Levi

Further Information:
https://www.fzi.de/de/forschung/projekt-details/human-brain-project/

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