modiCAS®

Universal Surgical Assistance System

www.zess.uni-siegen.de/modicas

OBJECTIVE

As a result of medical progress and the use of new technologies which are based on computer aided procedures, novel sensor components, and innovative mechatronic systems, conventional surgical methods are increasingly amended or replaced by new approaches. Physicians and engineers are challenged to derive the optimum benefits from the potential and the advantages of these approaches.

A research team working in the field of medical technology at the Center for Sensor Systems (ZESS) is focusing on this subject. In close cooperation with physicians and industrial partners, the components of the universal surgical assistance system modiCAS® are designed, implemented and tested. The system represents an integral solution for computer and robot assisted surgery, supporting all steps from planning to operating.

OVERVIEW

The modiCAS® system is characterized by the following key features.

- **Modular structure**
  The consistent modularisation of all hardware and software components makes modiCAS® an adaptable generic system for various surgical disciplines.

- **Support for all steps of an operation**
  modiCAS® offers a continuous support from pre-operative planning to robot-assisted surgery. Users can take advantage of this integral solution in various configurations and progressively add additional modules to an existing basic system.

Pre-operative planning → Intra-operative registration and navigation → Mechatronic arm and surgical tools

mod i CAS Research Projects

ZESS

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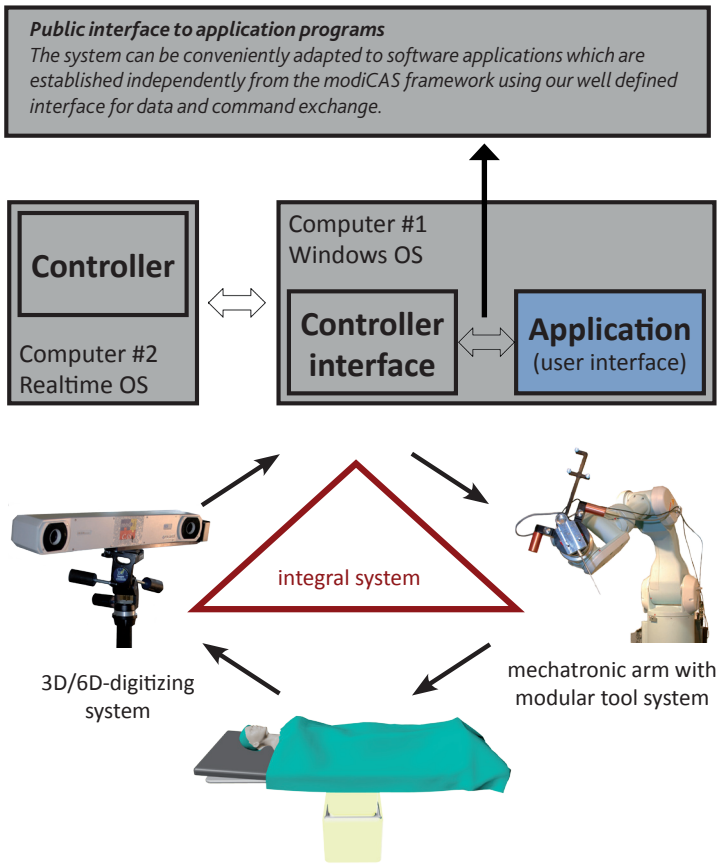
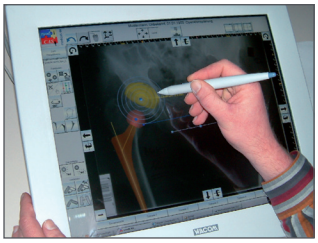
- **Unique system concept**
  The concept is based on a patented approach to integrate a navigation system and a robotic arm. 3D digitizing devices are used to register the patient's anatomy, while the robotic arm is applied as a mechatronic extension of the navigation system for guiding and positioning the surgical instruments. During system initialisation, the coordinate systems of the 3D digitizing system and the robotic arm are combined to one integral world after a short calibration movement of the arm.



- **Manufacturer-independent and open**
  The modularity and flexibility of modiCAS® permits its adaptation to existing hardware and software products, e.g. by interfacing with PACS-systems for electronic image distribution in hospitals, by including implant data of most manufacturers, and by interfaces to different image modalities (ultrasound systems, C-arms, ...) and different 3D digitizing devices (optical and electromagnetical).



Optionally specific hardware like pen displays can be used to provide an even more intuitive user interface.

PARTICULAR ADVANTAGES OF THE MODICAS® SYSTEM

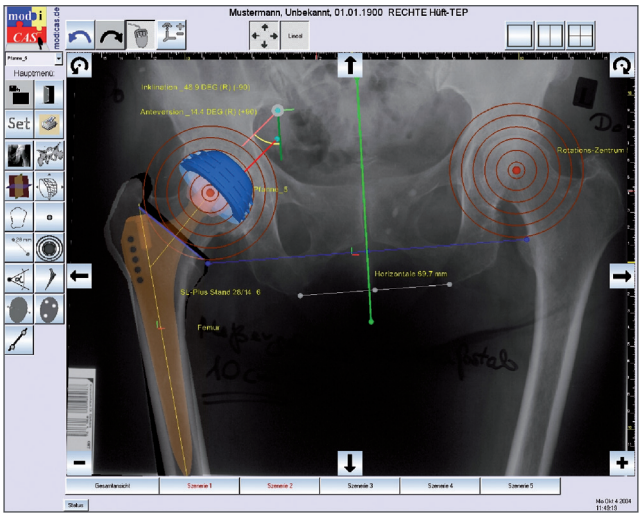
- Enhancement of accuracy, reproducibility and security in surgical interventions.
- Novel interactive concept for the mechatronic assistant - no fully automated operation.
- Intuitive control, no extended surgery time.
- The operator keeps full control with the option of intervention at any time.
- Multiple benefits for patients (best possible medical care), surgeons (reduction of stress burden), and hospitals (cost savings due to shorter stay in hospital and reduced after treatment needs).

PRE-OPERATIVE PLANNING

modiCAS® comprises a software package for computer-assisted preoperative planning of surgical operations based on X-ray-, CT-, MR-images or other image formats.

- Planning results can be transferred to the mechatronic assistant for intra-operative use.
- Image data can be imported and exported in DICOM format.
- Option for interfacing with PACS (Picture Archiving and Communication Systems) software for electronic image distribution and archiving.

A particular stand-alone version facilitates diligent planning for total joint replacement procedures on a personal computer. It is possible to compile user specific workflows out of all functions provided in the various menus of the software. All steps of such workflows can subsequently be controlled by clicking on just three buttons on the computer screen ("continue", "back", "abort"). Thus planning can be done very efficiently and does not demand more time than careful execution of conventional film-based planning procedures on a light-box.



INTERACTIVE MECHATRONIC ASSISTANT

The modiCAS® mechatronic assistant is based on a novel concept which on the one hand enables the surgeon to interactively control the robotic arm ("hands-on-robot"). On the other hand the system always knows the desired position and orientation of the surgical tool and can move it autonomously. The robotic arm may thus be regarded as a controlled machine actuator of a navigation system that substitutes for manual instrument guidance.

- **Intra-operative registration and navigation**

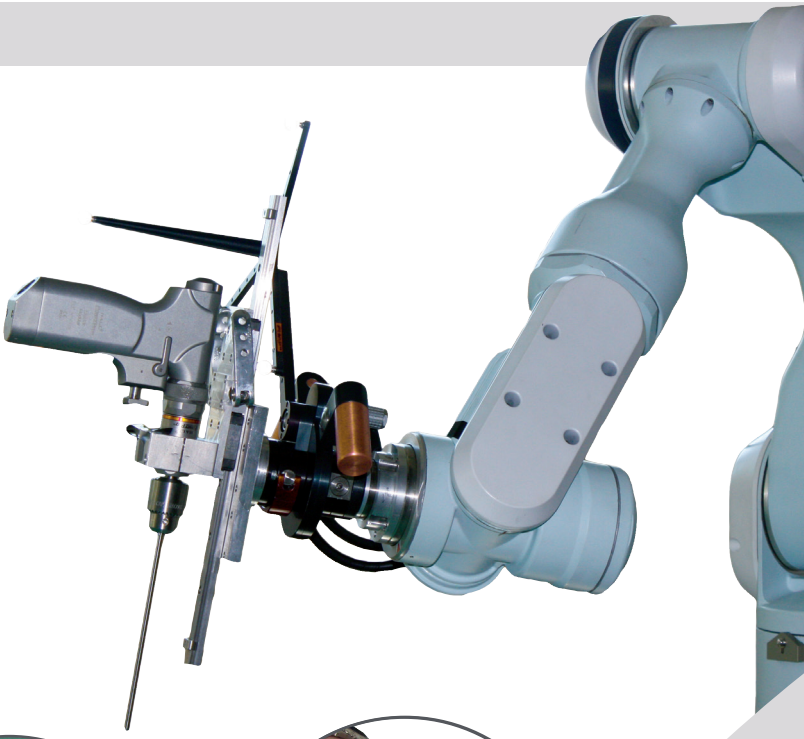
  The navigation component of modiCAS® is primarily used in combination with the mechatronic assistant. Its basic functionality comprises modules
  - to register the patients'anatomy,
  - to match pre-operative image data with intra-operative data,
  - to visualise the position of the instruments in pre-operative planning images.

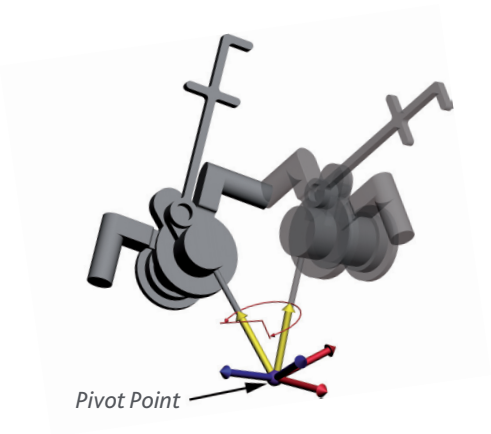
  Current research projects deal with the development of new methods and components to make the registration of patients easier, faster and more reliable.

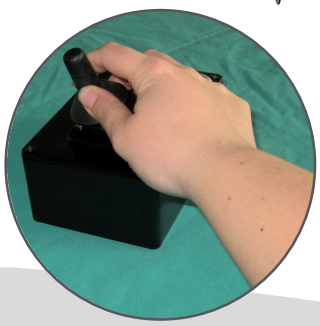
- **Interactive operation and haptic guidance of the robotic arm**

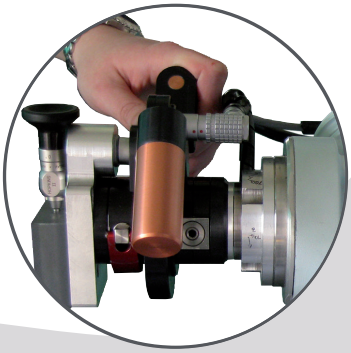
  The system does not work fully automatically. The surgeon can take full control at any time – he gets support for those parts of a procedure where human skills are limited. During surgery he can grab a handle at the wrist and move the arm as desired. Subsequently the system will move the tool exactly back to the position before interruption.

  The haptic operating mode is improved by methodologies to assure a robust and accurate motion through singular arm configurations. Furthermore the concept of "virtual fixtures" is used to restrict the range of motion of the robot according to pre- or intra-operatively defined constraints. For example, the arm can rotate the instrument precisely around a pivot point (see figure below).









- **Automatic monitoring of patient movements**
  The mechatronic assistant can track small patient movements in real time. The alignment between the surgical instrument and the bony structure thus remains constant all the time. A rigid fixation of the patient is not required.

- **Example applications**

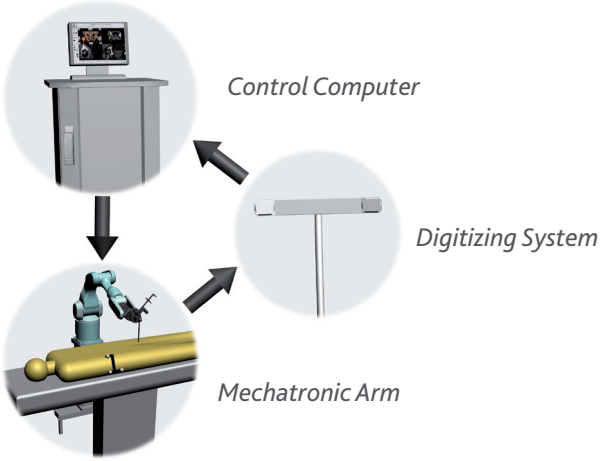
1. Instrument guidance

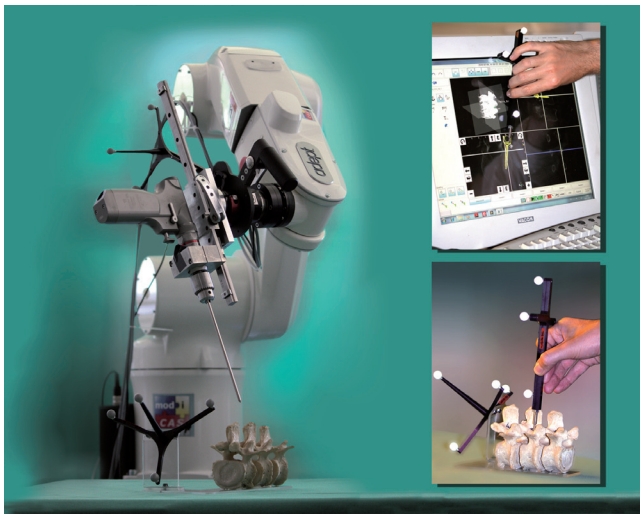
Conventional tools like a machine with drill or reamer can be fixed on a one-degree-of-freedom linear slider mounted at the wrist of the robot. Their operation is still manually controlled by the surgeon, giving him complete control over the operation while he can be certain that the instrument maintains its correct orientation. This approach has been successfully applied in clinical trials for total hip replacement surgery (see photo on previous page). Presently applications in spine surgery are investigated, like precise placement of pedicle screws. In combination with a 3D Iso C-arm for intraoperative imaging a very effective workflow can be achieved which does not require any matching procedures.

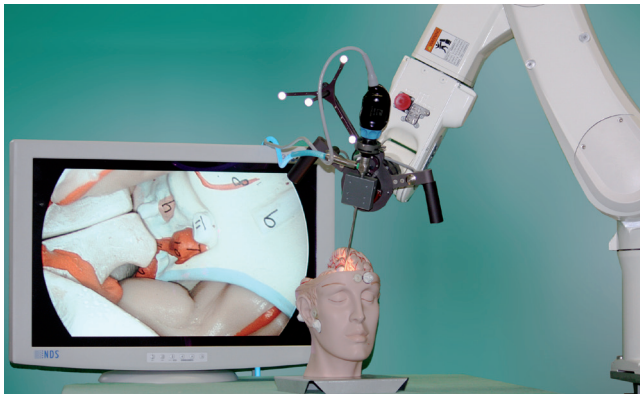
2. Endoscope guidance

The main objective is to give the surgeon a "third hand". He can thus guide two surgical instruments simultaneously. Using the concept of "virtual fixtures" it can be ensured that the endoscope does not unintentionally touch delicate structures. Interactive endoscope guidance by the robot facilitates tremor-free pictures, precise movements like pivoting, and positioning of the instrument in pre-defined locations.

- **Advantages in comparison with pure navigation systems**
  - No problems due to tremor or unintentional slipping of the tool.
  - Surgery will exactly achieve pre-operatively planned targets with very good reproducibility.
  - More precise drilling or reaming results, e.g. accurate hemispheric bed for the cup prosthesis.
  - Endoscope movements can be carried out exactly along pre-defined trajectories and with selectable velocity.
  - No ergonomic problems associated with manual tool guidance such as
  - difficult hand-eye-coordination,
  - frequent changes of the viewing direction.
  - Definition of "virtual fixtures" prevents that a surgical tool is moved into sensitive areas.
  - Use of novel tool systems which cannot be guided manually (e.g. laser systems).
  - One cannot imagine all advantages today!







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Acknowledgement
We appreciate funding of this research project by various institutions, including DFG (German research foundation), BMBF, BMWA (German ministries for research and economics), and Siegen University.