IROS 2011 Workshop on
Methods for Safer Surgical Robotics Procedures

Rainer Konietschke, Stefan Jörg, and Paolo Fiorini

Abstract

This full day workshop will present methods and future directions to increase safety and quality in prospective surgical robotics procedures. It is intended to cover current research on Simulation, Modelling, Haptics, Force Feedback, Human Robot Interaction, Operating Room Sensing and Reasoning.

I. Introduction

To the current state, surgical robotics systems rely exclusively on surgeons' decisions on safety critical aspects, whereas engineering support such as telepresence, planning, real time sensing, etc. are only used to carry out the intervention without any decision support function. We believe that those technologies can provide support also for higher level cognitive tasks, bringing additional benefits to surgery execution, as demonstrated e.g. in industrial applications. Introducing task sharing and partly autonomous task execution to robotic surgery, new procedures could exceed the manual capabilities of the surgeon. However, this would impose very strict safety conditions since the robotic tool naturally is in close contact with the patient. Furthermore, a common ground for communication and task evaluation must be established between the engineering and the surgical communities at large, so that possible misunderstanding between the two communities can be prevented.

The workshop will support an exchange of experiences in designing complex surgical procedures with a focus on methods to reduce the complexity seen by the surgical staff and to integrate various safety-relevant features. Transfer and comparison of methods from the industrial robotics and automotive fields will be supported by several dedicated talks. In addition to technically oriented talks, the workshop will feature talks from a surgical perspective by renowned surgeons with robotics expertise.

II. Workshop presentations

During the workshop, the following presentations will be given, structured according to the workshop subjects:

Simulation and Modelling:

- **Nikhil L. Shah DO, MPH** Director of Minimally-Invasive and Robotic Surgery, Department of Surgery, Saint Joseph's Hospital, Atlanta
  Robotic Surgery learning requirements: Simulation Based & Schoolhouse Training to Improve Safety
- **Stefan Jörg** Robotics and Mechatronics Center, German Aerospace Center (DLR), Germany
  Robotic System Simulation and Modelling
- **Prof. Allison Okamura** Mechanical Engineering Dept., Stanford University
  Tissue modeling for Safer Robotic Interventions
- **Ph.D. Louai Adhamï** SimQuest LLC, Silver Spring
  Balancing Safety and Cost in Robotically Assisted Surgery

Haptics, Force Feedback and Human Robot Interaction:

- **Dipl.-Ing., MSc. Sami Haddadin** German Aerospace Center (DLR), Robotics and Mechatronics Center
  Safe Human-Robot Interaction
- **Prof. Hannes Bleuler and Laura Santos-Carreras** École Polytechnique Fédérale de Lausanne (EPFL), Robotic Systems Laboratory
  Multimodal Haptics for Improved Safety in Robotic Surgery
- **Dr. Jessica Burgner** Vanderbilt University, Medical & Electromechanical Design Laboratory, Nashville
  Toward safe endonasal surgery using teleoperated continuum robots
- **Ph.D. Francois Conti** Force Dimension / Stanford University, Artificial Inteligence Laboratory, Department of Computer Science
  Hybrid Actuation Approaches for Robotic Systems and Haptic Interfaces

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Patient Safety Overview:

- **M.C. Fiazza and Prof. Paolo Fiorini** Department of Computer Science, University of Verona
  Safety Principles: the Safros Stance on Patient Safety

Operating Room Sensing and Reasoning:

- **Dipl.-Inform. Philip Nicolai and Dr.rer.nat. Jörg Raczkowsky** Karlsruhe Institute of Technology, Institute of Process Control and Robotics, Medical group (MeGI)
  Operation Room Supervision for Safe Robotic Surgery with a Multi 3D-Camera Setup
- **Prof. Darius Burschka and Oliver Ruepp** Technische Universität München, Machine Vision and Perception Group, Technische Universität München, Germany
  Vision-based Analysis of Conventional Surgical Procedures
- **Prof. Dr. Nassir Navab and Dipl.-Inf. (FH) Stefan Holzer, M.Sc.** Technische Universität München, Computer Aided Medical Procedures & Augmented Reality
  Real-time 3D reconstruction: applications to collision detection and surgical workflow monitoring
- **Prof. Greg Hager and Ph.D. Nicolas Padoy** The Johns Hopkins University, Department of Computer Science
  Human-machine Cooperation in the Operating Room
- **Dr. Marco A. Zenati, MD** Harvard Medical School, Boston, MA
  A Data Revolution for Robotic Surgical Safety

III. List of topics

The following topics lead towards safer surgical robotics procedures and will be presented during this workshop:

- *Sensing* Use e.g. force/torque sensors to detect faulty collisions and react on them. Thus the impact of the tools can be minimized (e.g. limiting excessive forces on the tip of a cutting knife or of grippers retracting tissue)
- *Modelling* A (constantly updated) model of the robot surroundings can help to detect dangerous situations. E.g., the patient can be tracked to react on repositioning, breathing etc.
- *User interface design* Transparence of the robot behaviour is a key feature for good usability and therefore safer operation: If the surgical staff can foresee and understand the robot motions, they can adapt themselves to these. Transparence can be achived through robot design and control or through user interface design.
- *Training* Training increases safety and quality of the robot/operator team. Training for surgical procedures can be performed in simulation, with phantoms, with animals, or directly with the patient. Naturally, the quality of the procedure directly affects the safety of the patient.
- *Safer human robot interaction* Safer operation by the surgical staff through concepts that handle constrained and unconstrained collisions with blunt, sharp, or active (laser, cautery devices, radiation) parts.

IV. Motivation and objectives

When dealing with surgical robotics, in general an invasive surgical intervention needs to be performed with robotic assistance to cure the patient. Here, Asimovs first law "A robot may not injure a human being or, through inaction, allow a human being to come to harm" is very difficult to fulfill for the surgical robot: In order to reach e.g. a tumor inside the patient, the robot needs to significantly injure the patient. How can the robot know that in this certain case injury is better than remaining inactive?

This question is very relevant in advanced telesurgery systems, since they provide a growing number of assistive functions. Among these are e.g. compensation for physiological motions, automatic performance of certain steps like suturing, accurate overlay of interior views of the organs, VR preview during the surgery, or feedback of haptic and tactile information to the surgeon.

Concepts that head towards these intelligent robotic assistance functions in surgical procedures are currently in the focus of many research groups. Those concepts with potential to increase patient safety will be presented during this workshop, grouped as follows:

- Patient-specific simulation of the surgery
- Sensing and modelling in the operating room
- User interface
- Training and simulation
- Force feedback and human-robot interaction

All of the aforementioned topics will be presented in separate sessions of the workshop. The integrating goal of the workshop is to bring together people and methods that will increase patient safety in tasks with close human-robot cooperation.

V. PRIMARY/SECONDARY AUDIENCE

Our goal is to promote concepts for safer medical robotics procedures as well as to encourage transfer of corresponding concepts from industrial robots available already today into the robotic surgery community. We envision to bring together researchers from various disciplines in robotics as well as surgeons to learn about the current state-of-the-art in designing safe surgical robotics procedures. As secondary audience, the workshop will be of high interest for people that develop human-robot cooperative applications as well as applications dealing with fragile or highly deformable workpieces in other robotic domains.

VI. Tentative schedule

8:30 - 8:45	**Welcome and Introduction** *Rainer Konietschke*
Session: Simulation and Modelling	
8:45 - 9:10	**Robotic Surgery learning requirements:** **Simulation Based & Schoolhouse Training to Improve Safety** *Nikhil L. Shah*
9:10 - 9:35	**Robotic System Simulation and Modelling** *Stefan Jörg*
9:35 - 10:00	**Tissue modeling for Safer Robotic Interventions** *Allison Okamura*
10:00 - 10:25	**Balancing Safety and Cost in Robotically Assisted Surgery** *Louai Adhamï*
10:25 - 11:05	**Morning Coffee Break**
Session: Haptics, Force Feedback and Human Robot Interaction	
11:05 - 11:30	**Safe Human-Robot Interaction** *Sami Haddadin*
11:30 - 11:55	**Multimodal Haptics for Improved Safety in Robotic Surgery** *Hannes Bleuler and Laura Santos-Carreras*
11:55 - 12:20	**Toward safe endonasal surgery using teleoperated continuum robots** *Jessica Burgner*
12:20 - 12:45	**Hybrid Actuation Approaches for Robotic Systems and Haptic Interfaces** *Francois Conti*
12:45 - 14:30	**Lunch Break** Note that lunch is not included in the registration. The participants should make their own lunch arrangements.
14:30 - 14:55	**Safety Principles: the Safros Stance on Patient Safety** *Paolo Fiorini*
Session: Operating Room Sensing and Reasoning	
14:55 - 15:20	**Operation Room Supervision for Safe Robotic Surgery with a Multi 3D-Camera Setup** *Jörg Raczkowsky and Phillip Nicolai*
15:20 - 15:45	**Vision-based Analysis of Conventional Surgical Procedures** *Darius Burschka and Oliver Ruepp*
15:45 - 16:15	**Afternoon Coffee Break**
16:15 - 16:40	**Real-time 3D reconstruction: applications to collision detection and surgical workflow monitoring** *Nassir Navab and Stefan Holzer*
16:40 - 17:05	**Human-machine Cooperation in the Operating Room** *Greg Hager and Nicolas Padoy*
17:05 - 17:30	**A Data Revolution for Robotic Surgical Safety** *Marco A. Zenati*
17:30	**End of Workshop**

VII. Presentation outlines

In the following pages, each presentation is briefly described.

ROBOTIC SURGERY LEARNING REQUIREMENTS:
SIMULATION BASED & SCHOOLHOUSE TRAINING TO IMPROVE SAFETY

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Abstract:
Historically, surgeons learn new surgical procedures through observation, practicing skills, techniques, and then performing the procedure on patients under the supervision of an experienced surgeon. Successful implementation of robotic programs requires development of a dedicated team and training using a structured approach. Today, training continues to be a serious safety issue for surgeons, hospitals, credentialing departments, surgical Associations and perhaps most importantly, the patients. If a surgeon expresses interest in robotic surgery, training is often conducted by a one-day basic training course involving simple tasks but no emphasis on technique or in-depth knowledge of the individual steps required. Although this is sufficient to gain familiarity with the controls of the robotic system, it is inadequate to perform a complex and technically demanding techniques in operations such as radical prostatectomy with any degree of precision and expertise. In order for a fighter pilot to fly a jet, he or she must complete technique and task oriented flight simulation to gain sufficient skills captured through metrics. Simulators for open surgery have never really been practical and surgical residencies are a graded and structured environment for surgeons to develop their skills under constant supervision and guidance. The advent of laparoscopic and robotic surgery, which depends on imaging using videoscopes inserted into the body, allow for the very real possibility of simulation. Inadequate or suboptimal training is a serious safety concern and has yet to be adequately addressed via current day simulators. In addition, current robotic training lacks any objective metrics with which to gauge a surgeon's skills. Development of task and technique driven simulation training programs will address serious safety concerns in the Operating Theater.

TISSUE MODELING FOR SAFER ROBOTIC INTERVENTIONS

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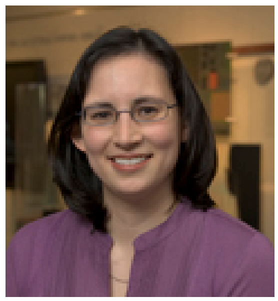

Abstract:
Robotic systems for medical interventions have great potential for enhancing patient care because of their ability to couple information to precisely controlled action in the operating room or interventional suite. However, the use of medical robots (and minimally invasive procedures in general) introduces additional risks by moving the clinician far away from the actual site of the instrument-tissue interaction, which is often located deep within the body. We propose that soft tissue injury during robot-assisted medical interventions can be minimized by predicting the mechanical forces and deformations acting at the instrument/tissue interface and applying this information to control the robot appropriately and/or provide feedback to the human operator. This talk will explore two robotic intervention scenarios: teleoperated robot-assisted minimally invasive surgery (RMIS) and needle steering. For RMIS, we describe a real-time tissue property estimation technique that allows an operator to detect hard lumps in soft tissue. The acquired information can be used to present graphical displays, direct haptic feedback, or provide virtual fixtures to guide the operator. For needle steering, we evaluate various mechanisms of soft tissue damage produced as needles with asymmetric tips are inserted and rotated inside the body. Through histological studies with ex vivo and in vivo tissue, we find that potential damage mechanisms include: cutting of the tissue by the sharp needle tip, tearing of the tissue as a bent needle tip is inserted, and slicing of the tissue as the thin shaft slides along the needle track. Our long-term goal is to understand of the mechanics of soft tissue damage as relevant to RMIS, and reduce the occurrence of surgical complications from new medical robotic techniques.

This work was performed in collaboration primarily with Tomonori Yamamoto and Steven Marra, as well as: Balazs Vagvolgyi, Niki Abolhassani, Sung Jung, Timothy Judkins, Ann Majewicz, Tom Wedlick, Kyle Reed, Vinutha Kallem, Ron Alterovitz, Ken Goldberg, and Noah Cowan.

Publications:

[1] T. Yamamoto, B. Vagvolgyi, K. Balaji, L. L. Whitcomb, A. M. Okamura. Tissue Property Estimation and Graphical Display for Teleoperated Robot-Assisted Surgery. Proc. of IEEE International Conference on Robotics and Automation (ICRA), 2009, pp. 4239-4245.

[2] K. B. Reed, A. Majewicz, V. Kallem, R. Alterovitz, K. Goldberg, N. J. Cowan, and A. M. Okamura. Robot-assisted needle steering. Robotics and Automation Magazine, 2011. In press.

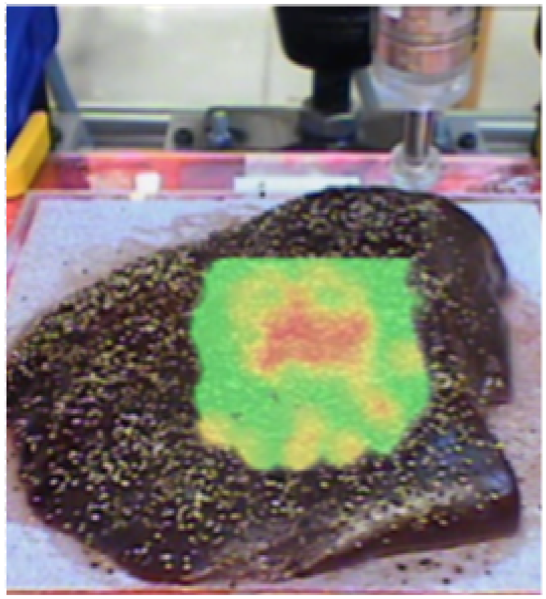

Fig. 1. Graphical overlay of estimated tissue stiffness on liver, displayed in real time during teleoperated palpation.

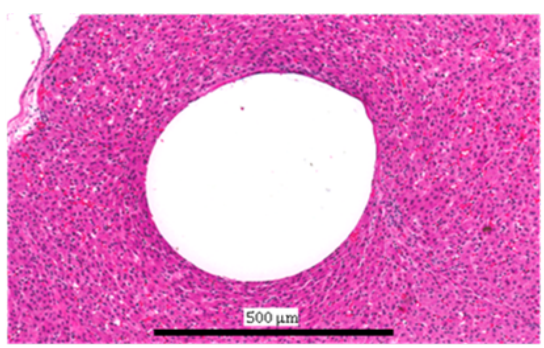

Fig. 2. Shape of bevel-tip needle hole in liver, captured in the configuration held while the needle is in place.

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Abstract:
This presentation will concentrate on an unexplored dilemma we are often faced with when working with surgical robotic procedures. Namely, that of balancing new techniques for increasing patient safety (and outcome in general), with the associate cost, and thus the final feasibility. The presentation will consist of two parts: the first will go through the experience of the ChIR medical robotics teams (INRIA) in developing an integrated system for robotically assisted surgical procedure, with a main goal of increasing patient outcome, and end with a year long feasibility study of turning the project into a spin-off where the delicate balance between cost and benefit will be most apparent. The second part will go through some recent industrial work that concentrated on a preferred technique for increasing safety, namely that of training. Training offers a high benefit-cost ratio and is gaining traction, though many challenges still have to be overcome before it is systematically adopted for robotic surgical procedures.

Publications:

[1] L. Adhami and È. Coste-Manière. Optimal planning for minimally invasive surgical robots. IEEE Transactions on Robotics and Automation: Special Issue on Medical Robotics, 19(5): 854- 863, 2003.

[2] Immersion Medical (now CAE Healthcare) Surgical Solutions: http://www.cae.com/en/healthcare/laparoscopy.asp

[3] SimQuest SurgSim Trainers: http://www.simquest.com/opensurgery.html

SAFE HUMAN-ROBOT INTERACTION

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Abstract:
Recently, robots have gained capabilities in both sensing and actuation, which enable operation in the proximity of humans. Even direct physical interaction has become possible without suffering from decrease in speed and payload. However, it is clear that these human-friendly robots will look very different from todayâs industrial ones. Rich sensory information, lightweight design, and soft-robotics features are required to reach the expected performance and safety during interaction with humans or in unknown environments. In this talk I will give an overview about the research topics at DLR that aim at solving these long-term challenges. The talk deals with the realization of sensor based co-workers that bring robots closer to humans and allow safe physical cooperation with both staff and patients. I will describe our design methodologies, exteroceptive sensing methods for surveillance, interaction control and real-time motion planning algorithms, as well as the developed behavior based HRI schemes that allow for distinct control strategies, depending on whom the robot interacts with.

Publications:
[1] Sami Haddadin, Michael Suppa, Stefan Fuchs, Tim Bodenmüller, Alin Albu-Schäffer, and Gerd Hirzinger: Towards the Robotic Co-Worker, Robotics Research: The 14th International Symposium ISRR2009, Eds. Cédric Pradalier, Roland Siegwart, Gerhard Hirzinger, pp. 261-280, 2011, Springer-Verlag Berlin Heidelberg.
[2] Sami Haddadin, Alin Albu-Schäffer and Gerd Hirzinger: Requirements for Safe Robots: Measurements, Analysis & New Insights, International Journal on Robotics Research (IJRR2009), Invited paper: Special issue of ISRR2007, Vol. 28, No. 11â12, November/December 2009, pp. 1507â1527

Multimodal Haptics for Improved Safety in Robotic Surgery

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Abstract:
The addition of haptic and tactile feedback in teleoperated robotic systems is a hot topic. Up to now, it has not been possible to prove any clinical benefits from haptics. However, it seems that in several situations the addition of haptics could improve performance and reduce the risk of accidents. Surgical experience allows a surgeon to estimate the magnitude of the applied forces by visual assessments of tissue deformation. Nevertheless, many situations are conceivable in which this estimate of tissue interaction force is not sufficient: when the surgeon is a novice, when the robotic tools are out of the field of view or when the surgeon is operating on a bone. We propose a concept based on multimodal feedback consisting of the integration of different kinds of audio, visual and tactile cues with force feedback that can potentially improve both the performance of the surgeon and the safety of the patient.

Publications:

[1] Santos-Carreras L, Beira R , Sengül A , Gassert R and Bleuler H. Influence of Force and Torque Feedback on Operator Performance in a VR-Based Suturing Task. Applied Bionics and Biomechanics 2010.

[2] Santos-Carreras L, Leuenberger K, Retornaz P, Gassert R and Bleuler H. Design and Psychophysical Evaluation of a Tactile Pulse Display for Teleoperated Artery Palpation. IROS 2010. Taiwan.

[3] Santos-Carreras L, Hagën M, Gassert R, Bleuler H. Survey on surgical instrument handle design: Ergonomics and acceptance. Surgical Innovation (Accepted waiting to be published)

[4] Beira R, Santos-Carreras L, Rognini G, Bleuler H and Clavel R. Dionis: A Novel Remote-Center-of-Motion Parallel Manipulator for Minimally Invasive Surgery. Applied Bionics and Biomechanics 2010. (Accepted waiting to be published)

[5] Beira R, Santos-Carreras L, Sengül A, Samur E, Bleuler H and Clavel R. An External Positioning Mechanism for Robotic Surgery. JSME Technical Journal 2011. (Accepted waiting to be published)

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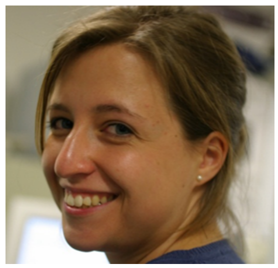

Abstract:
Endonasal surgery at the skull base is a challenging and delicate procedure, which has begun to offer a minimally invasive alternative to conventional transcranial and transfacial approaches. Despite its dramatic reduction in invasiveness, transnasal surgery remains dangerous due to lack of open access to the surgical site, and to the proximity of sensitive nerves and blood vessels to surgical targets. To increase the number of patients who are candidates for the endonasal approach, better, safer, more intelligent robotic surgical instruments and algorithms are needed. Current manual instruments are straight and rigid, which limits the complexity of procedures achievable through the nose, and disqualifies all but the truly expert surgeons and optimal patients from transnasal surgery. The constraints imposed by the small nostril opening and the curved trajectories required to bypass important structures in complex cases make continuum robots, and particularly concentric tube robots, ideal for endonasal surgery.

I will present recent results from the Vanderbilt Medical & Electromechanical Design Laboratory, directed by Robert Webster, on model-based force sensing and control of concentric tube robots for endosnasal surgery. These âtentacle-likeâ, needle diameter manipulators provide dexterity in the confined space of the skull base. Their inherent flexibility also makes intrinsic force sensing possible, wherein the robot itself acts as a force sensor. We believe force feedback to physicians, combined with image-guided assistance will enhance the safety of endonasal operations, and thereby bring their benefits to many more patients.

Publications:

[1] J. Burgner, P.J. Swaney, D.C. Rucker, H.B. Gilbert, S.T. Nill, P.T. Russell III, K.D. Weaver, R.J. Webster III. A Bimanual Teleoperated System for Endonasal Skull Base Surgery. IEEE/RSJ International conference in Intelligent Robots and Systems, 2011.

[2] D.C. Rucker, B.A. Jones, R.J. Webster III. A Geometrically Exact Model for Externally Loaded Concentric Tube Continuum Robots. IEEE Transactions on Robotics, 26(5), 769-780, 2010.

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Abstract:
Traditional robotic and haptic interfaces available today typically use motors to generate forces and to constrain motion in desired directions. In this work we introduce a new hybrid actuation approach which combines the use of brakes, springs and small motors. The proposed actuation design is safer and more energy efficient compared to systems which only rely on motors for actuation, and also overcomes many of the force rendering limitations displayed by passive mechanisms. Applications of this new technology range from devices where safety and reliability are of prime concerns (e.g. large force-feedback interfaces in human environments) to devices which can only be powered by limited energy sources such as small batteries (e.g. portable haptic interfaces).

Publications:
[1] Francois Conti and Oussama Khatib: A New Actuation Approach for Haptic Interface Design. The international Journal of Robotics Research 2009;28 834-848

SAFETY PRINCIPLES: THE SAFROS STANCE ON PATIENT SAFETY

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Abstract:
Patient safety (PS) is an emergent discipline and research field; it has attracted considerable attention in the past few years after publication of influential reports detailing the size of the phenomenon of medical error. The economic weight is enormous. Patient safety has in the past been associated mostly to surgical skill; medical error has been blamed almost exclusively on the medical personnel involved (surgeon, doctor, nurse, etc). After patient safety was placed in the spotlight, it has become apparent that PS cannot be treated as resulting solely from technical or medical skill. There is universal consensus that this notion is intrinsically systemic. What this means is that the entirety of factors characterizing the patient's medical environment have non-negligible repercussions on the final outcome of healthcare. Surgical or medical skill is not the only factor. Improvement on PS will not come just from demanding that medical personnel have even greater levels of skill. In fact, it is certain that improvements in PS can be realized by addressing factors such as teamwork in the OR, communication protocols between medical personnel of different qualifications and roles, more efficient information retrieval, information integration and operational conditions in general. EU reports have identified ICT-based solutions as the key to bring forth progress in PS. In this talk we will describe how this complex concept is addressed within the European Project SAFROS (Patient Safety in Robotic Surgery), which studies specifically robotic surgery. In fact, robotic surgery can potentially implement the integrated and monitored data flow that is essential to the improvement of patient safety during surgical interventions. Robotic surgery can support more efficiently the introduction and validation of new safety protocols than traditional surgery, and it is the natural candidate for developing new safety-based technologies.

Operation Room Supervision for Safe Robotic Surgery with a Multi 3D-Camera Setup

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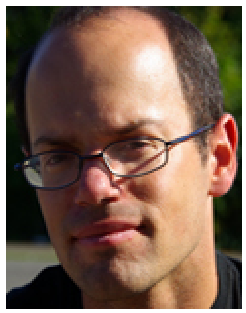


Abstract:
As concepts for completely active robotic surgery systems emerge and robots get smaller and smaller, new scenarios for robotic surgery unfold. The possibility of sharing a workspace between the surgeon and assisting robots is slowly coming to reality. Also, robots can execute side-tasks like approaching a pre-teached position autonomously. In order to take advantage of these developments and still guarantee safety for both the patient and the medical staff, there is need for a supervision system to capture the proceedings in the OR. As an approach to this task, a hybrid system is presented that acquires data in real-time using marker-based tracking as well as 3D imaging by time-of-flight cameras.

Publications:
[1] Holger Mönnich, Philip Nicolai, Jörg Raczkowsky and Heinz Wörn. A Semi-Autonomous Robotic Teleoperation Surgery Setup with Multi 3D Camera Supervision. In International Journal of Computer Assisted Radiology and Surgery, Volume 6, Supplement 1, page 132, Berlin, Germany, June 2011.

[2] Philip Nicolai, Holger Mönnich, Jörg Raczkowsky, Heinz Wörn and Jens Bernshausen. Überwachung eines Operationssaals für die kooperative robotergestützte Chirurgie mittels neuartiger Tiefenbildkameras. In Tagungsband der 9. Jahrestagung der Deutschen Gesellschaft für Computer- und Roboterassistierte Chirurgie, 2010.

VISION-BASED ANALYSIS OF CONVENTIONAL SURGICAL PROCEDURES

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Abstract:
Analysis tools for surgical procedures typically rely completely on motion data provided by a medical surgery robot, and thus are not able to work in absence of such data during conventional manual surgeries. Our aim is to extract essential information about the procedure itself (workflow-synchronization) and the motion constraints during the consecutive steps of the procedure from observations of standard procedures. This information can be used for several important safety features during the procedure. An important outcome of the work is a procedural data description for a better skill-assessment of a surgeon which allows to monitor the skill level and which may give suggestions for improvement in some steps of the surgery. The second safety relevant information derived from the processing is the information about fixtures and motion constraints during the surgery which may help to assess dangerous situation by a system monitoring the surgery and which also provides essential information to map a conventional surgery on a robotic system. We will present a system observing conventional surgery that provides the motion data and our approach for robust 3D reconstruction in poor textured environments which are common in many domains of surgical procedures.

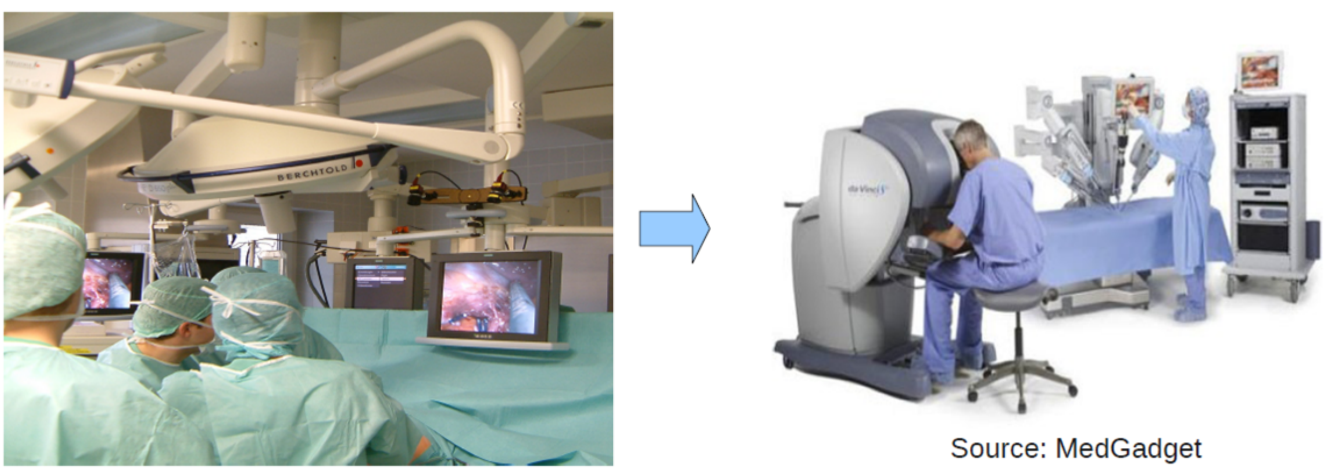

Fig. 3. Skill-Transfer from Conventional to Robotic Surgery [1].

Publications:
[1] Susanne Petsch and Darius Burschka. Estimation of Spatio-Temporal Object Properties for Manipulation Tasks from Observation of Humans. In Proceedings of the IEEE International Conference on Robotics and Automation, pages 192-198, Anchorage, Alaska, USA, May 2010. [2] Oliver Ruepp and Darius Burschka. Fast Recovery of Weakly Textured Surfaces from Monocular Image Sequences. Asian Conference on Computer Vision (ACCV) 2010

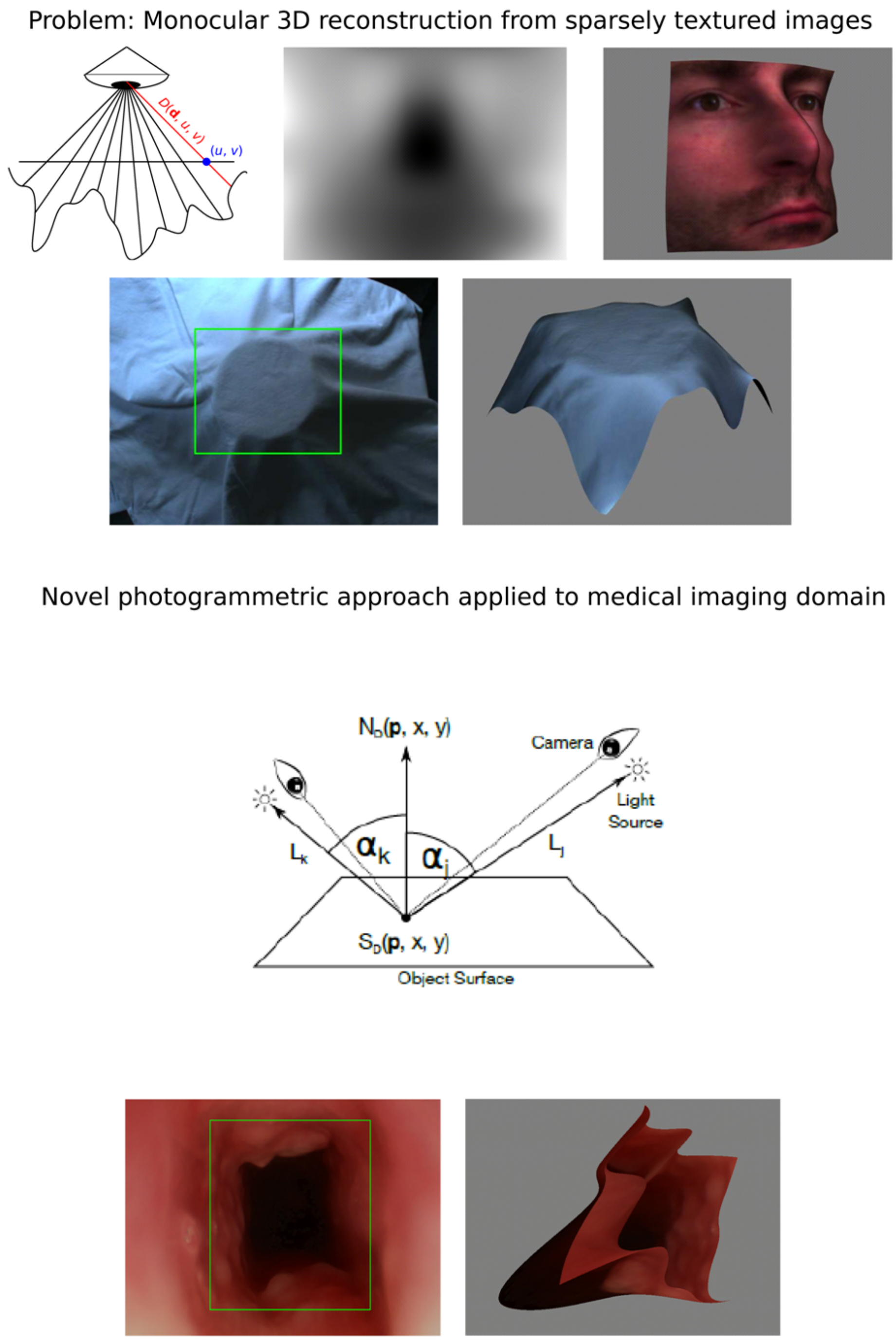

Fig. 4. Safety through robust monocular 3D reconstruction from endoscopic images.

Real-time 3D reconstruction: applications to collision detection and surgical workflow monitoring

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Abstract:
In the last decades robots have entered the operating rooms both to assist the surgeons in performing minimally invasive procedures and to improve intra-operative medical image acquisition. Most of these robots do not perform at full speed and are often required to be telemanipulated. One of the main reasons is the safety. It is therefore important for such systems to recognize their dynamic environment and thus predict and avoid collisions. This requires us to not only reconstruct and recognize the objects within these dynamic environments, but also recover, model and monitor the workflow of each interventional and/or surgical procedure.

In this talk we present the development of our multi-camera real-time 3D reconstruction system and its applications towards the enhancement of safety within interventional environment. Three applications of this system are discussed. The first two focus on the reconstruction of the environment within an angiographic suit equipped with a robotic angiographic C-arm, e.g. Zeego produced jointly by Siemens and Kuka. In the first application, we show within our laboratory setting that the system is able to perform collision detection in real-time. The second one allows us to track every visible patch on the staff working within interventional suit and estimate the accumulated X-ray radiation exposure to each of their body parts. Finally the third application of the real-time reconstruction, which could increase the safety of the usage of robots within any surgical environment, is focusing on the recovery, modeling and monitoring of surgical environment.

Publications:

[1] Ladikos, C. Cagniart, R. Ghotbi, M. Reiser, N. Navab, âEstimating Radiation Exposure in Interventional Environmentsâ, Medical Image Computing and Computer-Assisted Intervention MICCAI, September 2010.

[2] N. Padoy, D. Mateus, D. Weinland, M.O. Berger, N. Navab, âWorkflow Monitoring based on 3D Motion Featuresâ ICCV Workshop on Video-oriented Object and Event Classification, Kyoto, Japan, September 2009 (IBM Best Paper Award).

[3] A. Bigdelou, A. Ladikos, N. Navab, âIncremental Visual Hull Reconstructionâ, British Machine Vision Conference (BMVC), September 2009.

[4] A. Ladikos, S. Benhimane, N. Navab, âReal-time 3D Reconstruction for Collision Avoidance in Interventional Environmentsâ Medical Image Computing and Computer-Assisted Intervention, MICCAI, September 2008.

Human-machine Cooperation in the Operating Room

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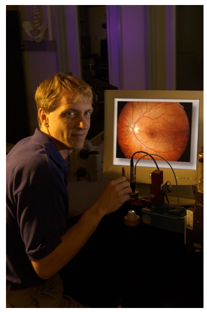


Abstract:
Modern surgery rooms are complex and equipped with a great deal of highly technological equipment. Our work on Human-Machine Collaboration Systems considers context awareness as a means to simplify the workflow in the OR by providing general context sensitive information and also by allowing the semi-automation of certain tasks. In this talk, we will highlight the usefulness of context recognition in the OR and present work that has been carried out in this area to recognize context during endoscopic surgeries and also to trade the control between the user and the system during simple tasks performed in tele-operated robotic surgery. We believe that, in the long term, such systems will simplify the operating room workflow, relieve the operating staff from simple tasks, and thereby increase the procedures' safety.

Publications:

[1] N. Padoy, G.D. Hager, 3D Thread Tracking for Robotic Assistance in Tele-surgery, Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), San Francisco, USA, September 2011 (To Appear)

[2] N. Padoy, G.D. Hager, Spatio-Temporal Registration of Multiple Trajectories, Proceedings of Medical Image Computing and Computer-Assisted Intervention (MICCAI), Toronto, Canada, September 2011 (To Appear)

[3] N. Padoy, G.D. Hager, Human-Machine Collaborative Surgery Using Learned Models, Proceedings of IEEE International Conference on Robotics and Automation (ICRA), Shanghai, China, Mai 2011, pp 5285-5292

[4] N. Padoy, T. Blum, A. Ahmadi, H. FeuÃner, M.O. Berger, N. Navab, Statistical Modeling and Recognition of Surgical Workflow, Medical Image Analysis, In Press, doi:10.1016/j.media.2010.10.001, 2010

A DATA REVOLUTION FOR ROBOTIC SURGICAL SAFETY

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Abstract:
We propose to enhance the safety of robotic surgery by introducing extensive peri-procedural data collection, analysis and interpretation. Currently, no data is being collected during robotic surgery, except when required for a specific trial. Given the number of "actors" involved, the myriad of tasks and the significant role played by "non-technical skills" of the surgeon and team members, we propose to develop a dedicated comprehensive peri-procedural data capture system and develop associated algorithms. We will build this application based on known industrial engineering principles and with the aid of a cognitive psychologist. In addition to procedural variables and steps, each team member will be associated with a code and verbal and non-verbal communication will be captured and analyzed. We believe that by introducing our systematic data capture system, a "data-driven revolution" in robotic surgical safety may be possible.

Publications:

[1] M.A. Zenati, T. Yokota, D. Schwartzman, T. Ota, B. Zubiate, C. Wright, C. Nikou,H. Choset: Model Guided Epicardial Interventions using a Novel âSnakeâ Robot (CARDIO ARM) through a Subxiphoid Port Access. Proceedings of The 14th International IASTED Conference on Robotics and Applications, 2009;242-246.

[2] M.A. Zenati, A.L. Shroyer, J.F. Collins, B. Hattler, T. Ota, G.H. Almassi, M. Amidi, D. Novitzky, F.L. Grover, A.F. Sonel: Impact of endoscopic versus open Saphenous vein harvest technique upon CABG patient late outcomes in the randomized ROOBY trial. JThoracCardiovascSurg 2011;141(2):338-44.