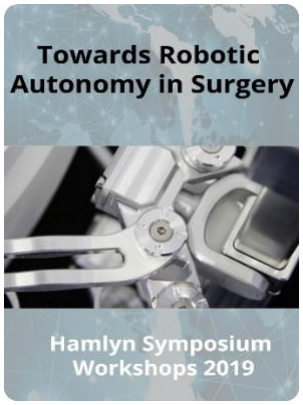

Workshop: Towards Robotic Autonomy in Surgery

Code: SAPM04 | Sunday, 23rd June

Royal Geographical Society

Co-Chairs and Organisers:

Paolo Fiorini, University of Verona, Italy
Riccardo Muradore, University of Verona, Italy
Francesco Setti, University of Verona, Italy

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08:30-09:00	**Registration and Coffee**
08:50	**Opening: Welcome & Introduction** *Riccardo Muradore, University of Verona, Italy*
09:00	**New Robots, Connectivity and AI in Robotic Surgery** *Prokar Dasgupta, King's College London, UK*
09:20	**Robot-assisted Surgery or Human-assisted Robot?** *Alessandro Larcher, Ospedale San Raffaele, Italy*
09:40	**Real-Time Assessment of Surgical Team Dynamics and Mental Workload with Computer Vision and Psycho-Physiological Data** *Marco Zenati, Harvard University, USA*
10:00	**Impact of the Increasing Level of Autonomy on the Industry** *Stephan Nowatschin, Medineering, Germany*
10:20	**Training and Evaluation of Autonomous Medical Robots** *Gernot Kronreif, ACMIT, Austria*
10:40-11:15	**Coffee Break**
11:15	**Robotic Solutions to Remote Trauma Care** *Juan Wachs, Purdue University, USA*
11:35	**Predicting Future Events in Laparoscopic Surgery** *Fabio Cuzzolin, Oxford Brookes University, UK*
11:55	**End-to-End Safe Reinforcement Learning for Autonomous Robotic Surgery** *Joel Burdick, Caltech, USA*

12:15	**Towards Autonomy in OR: Complementing Surgeons with Data-driven Situation Awareness** *Duygu Sarikaya, Université de Rennes, France*
12:35	**Technology Elements for Autonomy in Robotic Surgery** *Paolo Fiorini, University of Verona, Italy*
13:00-14:00	**Lunch Break**
14:00	**Perceptually-enabled Robotic Assistance in the Smart OR** *George Mylonas, Imperial College of London, UK*
14:15	**The Role of Human Robot Interaction for Autonomous Small-scale Surgical Robots** *Jessica Burgner-Kahrs, University of Toronto, Canada*
14:30	**Towards Increasing Autonomy in Surgical Robotics. Application Related Technical Issues** *Alicia Casals, Polytechnic University of Catalonia, Spain*
14:45	**Machine Learning for Deep Comprehension of the Surgical Site** *Elena de Momi, Politecnico di Milano, Italy*
15:00	**A Robust Teleoperation Architecture for Shared Control in Surgical Applications** *Federica Ferraguti, University of Modena & Reggio Emilia, Italy*
15:15	**Risk and Regulatory Burden: Building a Safety Assurance Case for Medical Robots** *Tim Phillips and Chris Wagner, Cambridge Consultants, UK*
15:30	**Closing Remarks**

Speaker:
Joel W. Burdick, California Institute of Technology, USA

Title:
End-to-End Safe Reinforcement Learning for Autonomous Robotic Surgery

Abstract:
Machine learning techniques are being considered as a means to automate portions of routine robotically-assisted surgical procedures. However, current Reinforcement Learning (RL) methods do not guarantee safety of the underlying physical system (in this case, the surgical robot and the patient's anatomy) during the process to learn a feedback control policy. Moreover, while some RL methods do encourage safety after the learning period, the safety guarantees are not complete.

In this talk, we introduce a new method, based on the coupling of Control Barrier Functions (CBFs) with any RL algorithm, to guarantee end-to-end safety during both the learning and deployment phases. The CBF coupled to the RL algorithm "filters" out any unsafe actions proposed by the RL process, both during the learning and deployment phases. Applications to robotic surgery will be discussed.

Speaker:
Jessica Burgner-Kahrs, University of Toronto, Canada

Title:
The Role of Human Robot Interaction for Autonomous Small-scale Surgical Robots

Abstract:
Thanks to their compliance, continuum robots are inherently safe in direct contact with or in proximity to patients. As their structure is continuously bending with many degrees of freedom, the control input to the robot and the resulting shape cannot necessarily be mentally related by the surgeon. In addition, surgical continuum robots are deployed in-situ such that the surgeon loses direct sight. This results in limited intuition about the current state of the robot.

To address these challenges, an immersive human robot interface for continuum robot systems which enables intuitive interaction and collaborative manipulation is needed. This talk elaborates on current developments and open questions in human robot interaction concerned with different levels of autonomy.

Speaker:
Alicia Casals, Polytechnic University of Catalonia, Spain

Title:
Towards Increasing Autonomy in Surgical Robotics. Application Related Technical Issues

Abstract:
Being far from achieving autonomous surgical robots the objective of new advances in surgical robotics is improving surgical procedures with better outcomes and safety by providing autonomy in some key points of the process. This talk will analyze, for the wide scope of surgical intervention types, the opportunities and challenges of robot autonomy in collaboration with the surgeon. Human and machine factors will be visualized specifically for the corresponding applications.

Speaker:
Fabio Cuzzolin, Oxford Brookes University, UK

Title:
Predicting Future Events in Laparoscopic Surgery

Abstract:
Predicting from the available streaming video future surgeon actions, as well as events outside the surgeon's control, is a crucial functionality for any assistive robotic system which aims to partially or completely replace the role of the assistant in surgery.
Current video-based action and event detection approaches build on deep learning architectures able to both detect where the events are located in the form of bounding boxes, and the class(es) of the observed events.

In this talk we propose two alternative approaches to predicting future events and actions by extending existing methods in two ways: a graph-based representation of surgical procedures, and a smoothing approach which builds on the notion of 'action tube'. We will also discuss the possible integration of control signals from the available hardware to help the prediction process.

Speaker:
Prokar Dasgupta, Professor and Chair of Urology at King's College London, Guy's Hospital, King's Health Partners, UK

Title:
New Robots, Connectivity and AI in Robotic Surgery

Abstract:
The amazing Da Vinci system, is about to face some market competition from other international companies with their own versions of next generation robots. In order to challenge the current gold standard, these systems will need to be at least as good if not better. The alternative is to be significantly cheaper thus attracting a wider variety of institutions who could currently not afford the Da Vinci. Open consoles, 3D enhanced vision, lighter instruments and greater portability will be recurring themes in these new systems.

There is even some renewed interest in automation that goes back to the days of John Wickham, who passed away just short of his 90th birthday. The STAR robot can suture bowel better than a human hand in an animal model. The water jet robot (Procept Biorobotics) takes inspiration from Wickham's PROBOT and may prove to be a viable alternative to TURP or HOLEP but without the steep learning curve.

Speaker:
Elena De Momi, Politecnico di Milano, Italy

Title:
Machine Learning for Deep Comprehension of the Surgical Site

Abstract:
As the black hole image was reconstructed fusing different source of visual information, computer vision methods applied to endoscopic images allow one to see more than one's sight. With this respect, machine learning and deep learning techniques applied to endoscopic images have allowed us to 1) tag soft tissue organs images; 2) identify informative frames; 3) segment vital structures in blurred or nosy images or vessels in 3D volumetric image stacks; 4) track surgical instruments pose in dynamic context. The talk will give the audience an overview of different techniques demonstrating the superiority of deep learning in providing accurate results in real-time for surgical application translation.

Speaker:
Federica Ferraguti, University of Modena and Reggio Emilia, Italy

Title:
A Robust Teleoperation Architecture for Shared Control in Surgical Applications

Abstract:
Shared-control telerobotic systems are designed to extend the reach of human beings allowing to interact with a remote unstructured environment while locally feeling the interaction force. Bilateral teleoperation has been used for many applications like manipulation of dangerous material, e.g. for bomb disposal, or surgical procedures. In this context, dealing with complex tasks could require the implementation of a multi-master-multi-slave teleoperation system that could provide the desired level of remote mobility and interaction capabilities. In this talk, recent advancements in the development of bilateral teleoperation architectures for shared control are presented to be applied, in particular, in a surgical context.

Speaker:
Paolo Fiorini, University of Verona, Italy

Title:
Technology Elements for Autonomy in Robotic Surgery

Abstract:
The future addition of autonomous functions to robotic devices is fueling an intense debate on their impact on work and daily activities. Two six-level classifications of autonomy have been proposed for the fields of self-driving cars and surgical robots, but the supporting technologies have not yet been classified in a precise way. In this talk I will briefly present the structure we are developing in the context of the ARS (Autonomous Robotic Surgery) project, from data analysis to cognitive models and control execution. I will also present some of the initial results of task learning and autonomous execution applied to the classical training task "peg and ring", first learned and demonstrated on a larger set up and then ported to the da Vinci Research kit.

Speaker:
Gernot Kronreif, ACMIT Gmbh, Austria

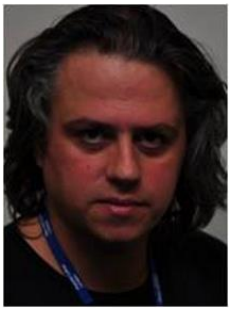
Title:
Training and Evaluation of Autonomous Medical Robots

Abstract:
Increased autonomy of medical robotic systems also requires more elaborated options for training and optimization of higher level robot control algorithms as well as for evaluation of such operating principles. In particular, the aspect of training calls for a setup which allows a high number of experiments in a well-controlled manner, especially considering repeatability of test scenarios. Artificial anatomical models seem to be a very appropriate solution, but aspects regarding degree of realism in different categories need to be carefully investigated. The presentation is highlighting different aspects for the design and realization of such phantoms, based on the example of a pelvic phantom for robot-assisted prostatectomy.

Speaker:
Alessandro Larcher, Ospedale San Raffaele, Italy

Title:
Robot-assisted Surgery or Human-assisted Robot?

Abstract:



Speaker:
George Mylonas, Imperial College of London, UK

Title:
Perceptually-enabled Robotic Assistance in the Smart OR

Abstract:
The talk will present a framework based on consumer level3D cameras, wearable interfaces, multi-sensor fusion and robotics, to allow seamless integration of human perception and cognition in the operating theatre. The ultimate goal is to keep the human in the loop of decision making and action, with robotic assistance and automation robustly achieved and seamlessly supervised. Exemplar studies will be presented.

Speaker:
Stephan Nowatschin, Medineering – Surgical Robotics, Munich, Germany

Title:
Impact of the Increasing Level of Autonomy on the Industry

Abstract:
The fast-growing numbers of surgical robots and new software tools in the OR lead to new challenges for the industry. The integration of devices from different manufacturers plays an important role in the integration of systems into a digital OR infrastructure. This already results in questions concerning the approval of the connected devices. In addition to these networks, intelligent software solutions will be added over the next few years that will enable an automated control of the existing systems. For this increasing level of autonomy, the main questions will be: How can a medical device manufacturer be responsible for a decision that has direct impact on a clinical situation and how could a regulatory approval process look like for different levels of autonomy?

Speakers:
Tim Phillips Senior Human Factors Engineer, Medical Technology, Cambridge Consultants, UK
Chris Wagner, Senior Consultant, Medical Technolog , Cambridge Consultants, UK

Title:
Risk and Regulatory Burden: Building a Safety Assurance Case for Medical Robots

As medical robotic systems become more advanced and incorporate aspects of autonomy and artificial intelligence, understanding and developing the safety logic of the system become increasingly

important. This safety understanding is critical to articulate early in the development process, both to guide architectural design mitigations and to carry out the appropriate regulatory activities to communicate the approach to safety. A particular challenge here is maintaining a safe design throughout development - where later design decisions invalidate earlier safety principles, causing costly delays to development.

In this presentation, Cambridge Consultants will share an overview of their technique for creating robot 'safety assurance cases'; combining top-down and bottom up approaches to risk management to demonstrate assurance of safety, effectiveness and performance. By incorporating a top-down safety logic, we have found that it is easier to maintain these safety principles throughout the development lifecycle, as well as communicate the risk management approach from a regulatory perspective.

The session will cover the approach for identifying and mitigating both design and human factors risks and crafting the accompanying safety logic. This rationale becomes more complex as autonomy is increased, therefore considerations for managing this will also be proposed.

Speaker:
Duygu Sarikaya, Université de Rennes, France

Title:
Towards Autonomy in OR: Complementing Surgeons with Data-driven Situation Awareness

Abstract:
Surgical robotic tools and digitally enhanced operating theaters have been giving surgeons a helping hand for years. While they provide great control, precision and flexibility to the surgeons, they don't yet address the cognitive assistance needs in the operating theater. We are on the verge of a new wave of innovations of artificial intelligence powered, situation-aware operating theaters, and surgery is increasingly becoming data driven.

We envision future operating theaters that are holistic and seamlessly integrated in the surgery process. They will monitor their environment by gathering multi-modal data from sources such as cameras, sensors, monitoring devices, patient profile and history, and will respond accordingly. Although this could be realized by following pre-established rules, a better and more holistic way would be to develop situation-aware systems that are able to perceive and reason; make sense of ongoing processes, project outcomes of a number of possible actions that could be taken within this context, provide quantitative support to aid the decision making process, evaluate the outcomes of the action taken, and then use this information to predict the next steps.

Surgical process models (SPM), and the advances in computer vision and machine learning, can answer these needs and complement the surgical team by assisting the surgical procedures, providing real-time guidance during complex tasks and unexpected events. Coupled with the maturity of robotics, these advances can make it possible to delegate certain tasks to robots by automation. In this talk, we will discuss situation-awareness in operating theaters, and talk about sample applications that use the advances of surgical process models, computer vision and machine learning towards achieving situation-awareness.

Speaker:
Juan P. Wachs, Purdue University, USA

Title:
Robotic Solutions to Remote Trauma Care

Abstract:
At the time, the only robots present in the operating room were those that acted instead of the surgeons, through tele-operation, such as the da-Vinci robot. Alternatively, a new type of robots is emerging that would understand natural language, and mainly non-verbal language, such as gestures, which is the main form of interaction in the operating room. But it also turns out that medics and first responders also use a combination of communication modalities to collaborate with robots outside the OR, in austere settings such as the battle field or in rural settings. Endowing robots with the capability of recognizing intention, predicting and informing the surgical team about the next steps is a key challenge in trauma care.

In this talk I will highlight two applications that showcase robots working with doctors in a semi-autonomous manner. Such work has applications to the DoD, and was made possible through collaborations with hospitals: Indiana University of Medicine, the Naval Medical Center Portsmouth at Norfolk, VA and Womack Army Medical Center at Fort Bragg, North Carolina. Significant breakthroughs in this research led to major publications, such as Annals of Surgery and Surgery. News releases covering this work appear at NPR “Surgical Technology Aims to Mimic 'Teleporting'”. NPR Inside Indiana Business. Sept. 28, 2015 and more recently featured in the WIRED magazine “How Technology is Helping Surgeons Collaborate from Across the World” (07/2018) and Inside Indiana Business with Gerry Dick. TV Show. October 4, 2018.

Speaker:
Marco Zenati, Professor of Surgery, Harvard Medical School
Associate in Cardiac Surgery, Brigham & Women’s Hospital
Chief, Department of Cardiothoracic Surgery, Veterans Affairs Boston Healthcare System Boston, Massachusetts, USA

Title:
Real-Time Assessment of Surgical Team Dynamics and Mental Workload with Computer Vision and Psycho-Physiological Data

Abstract:
New AI-enabled applications in surgery will be discussed including innovations aimed at expanding the availability of clinical expertise, availability of high-quality data (surgical data science), learning from undesirable past practices, computer vision, etc. In addition, new approaches for real-time cognitive workload monitoring of surgical team members will be discussed in context of increasing degrees of autonomy of surgical robotic systems.