Guest Editorial
Medical Robotics: Surgery and Beyond

I. Introduction

THE IEEE TRANSACTIONS ON MEDICAL ROBOTICS AND BIONICS (T-MRB) is an initiative shared by the two IEEE Societies of Robotics and Automation—RAS—and Engineering in Medicine and Biology—EMBS.

T-MRB is a multi-disciplinary journal aimed at publishing peer-reviewed papers and focused on innovative research ideas and medical application results, reporting significant theoretical findings and application case studies in the areas of medical robotics and bionics.

In particular, one of the six Journal Areas addressed in T-MRB concerns Surgical Robotics. Robots had a significant impact on the surgical practice, starting from primitive robotic tool holders in the early 1990s, up to the fully-fledged "smart assistants" available nowadays.

Digital surgery, defined as the convergence of surgical technology, real-time data and intelligence, is arguably the next frontier of surgery. Robotic surgery has seen a flow of improvements in surgical tools. This enabled smaller incisions, with consequent reduced patient recovery time, better access to hard-to-reach body parts, greater precision and 3D visualization. Besides, the power of linked data and advancements in Artificial Intelligence (AI) are producing a marked impact on the way surgeries are performed, with the goal of reducing the well-documented variability in surgical processes and outcomes.

The digitization of surgery has the potential to improve the lives of patients while reducing cost and inefficiencies, improving patient access, reducing inequities between citizens, improving quality and delivering more personalized and tailored surgical care. With increased funding pressures across global health systems and the introduction of value-based care in some markets, stakeholders in both the public and private sectors view digital surgery as the next apex in surgery.

Medical imaging technology focusing on acquiring real-time information and data visualization is one of the key recent advances in surgical robotics. Real-time access to 2D or 3D reconstructed images during surgery can be of critical importance and may be further enhanced by augmented reality (AR). Furthermore, the development of AR devices would allow clinicians to incorporate data visualization into diagnostic, rehabilitation and treatment procedures, thus improving work efficiency, safety and cost, as well as enhancing surgical training. However, the awareness of AR implementations and what they may offer remains generally low. In its current state, AR cannot fully replace most long-established surgical, diagnostic, training, and rehabilitation methods.

Robots performing partial automation could alleviate the cognitive load on the surgeon, allowing him/her to focus the attention on the most critical parts of the intervention. The partial and sequential introduction and uptake of autonomous capabilities could provide a safe passageway towards the next generation of surgical advances. This highly complex advancement involves developments and interactions between several fields in motion planning, perception, and human-machine interaction, along with the need to tackle outstanding limitations in task-level autonomy.

Another area of advancement is in the development of remote teleoperation. There have already been demonstrations on the potential of remote surgery, with surgeons conducting entire procedures on patients from thousands of kilometres away using remote robotic assistance over 5G networks. The routine and safe use of teleoperation is not established yet, but may be close. For example, the use of augmented reality (AR) images to transmit real-time information to a specialist surgeon at another location, to seek their guidance in completing a taxing procedure, is already a reality. The current pandemic also serves to highlight the importance of teleoperation; separating the clinician from the patient might be particularly desirable in these circumstances.

The editorial choice to link this issue (Volume 2, Issue 4, November 2020) of T-MRB to the 2020 Hamlyn Symposium on Medical Robotics (HSMR20) has been made to provide a cross-disciplinary platform to present the latest research in surgical robotics and allied technologies. Systems, devices and methods developed by teams of engineers, computer scientists, researchers and clinicians, are featured, which address significant technological challenges in surgical robotics, with the promise to positively impact clinical practice.

The 13th edition of the Hamlyn Symposium on Medical Robotics, unfortunately, was cancelled due to the ongoing threat posed by the Covid-19 pandemic. The symposium attracts around 600 international delegates each year, representing numerous countries around the world.

The theme of the symposium would have been "Surgery and Beyond" and intended to cover several topics, including Clinical highlights in Urology, Cardiac Surgery, Thoracic Surgery, General Surgery, Neurosurgery, Gynaecology, ENT, Orthopaedic, and Paediatric Surgery; Emerging, multi-speciality applications of robotic technology; Medical robotics for flexible access surgery, endoluminal, NOTES and micro-surgery; Mechatronic designs for medical robotics; and Surgical simulation, automation, training and skills assessment among many others.

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The event was supported by international and local programme committees who showed great enthusiasm and commitment in ensuring a timely and robust peer review process of all submissions. Authors of selected papers were invited to submit an extended version of their work; 42 papers (10 full-length, 8-page, articles and 32 short, 4-page, articles) were submitted for possible inclusion in this Special Section, and 16 papers (2 full-length, 8-page, articles and 14 short, 4-page, articles) have been accepted for publication in this Special Section of Volume 2 Issue 4 of T-MRB. Seven papers were rejected and the remaining 19 papers, which are still under review at the time of writing, will be considered as regular submissions and included in the next issue of T-MRB (Volume 3, Issue 1, February 2021).

All the papers have undergone full peer review, following a rigorous process coordinated by 4 Guest Editors: Prof. The Lord Darzi of Denham, Prof. Kevin Cleary, Prof. Ferdinando Rodriguez y Baena, and Prof. Dan Elson.

II. Special Section content

This Special Section includes 16 manuscripts that feature enhanced and extended versions of original abstracts submitted to the 2020 Hamlyn Symposium on Medical Robotics. The articles of this Special Section cover several areas of medical robotics, spanning the full breadth of healthcare technology.

Some of the articles describe complete systems, such as the work of Joonmyeong Choi featuring a novel soft robotic system for general surgery "Design of Continuum Robot With Variable Stiffness for Gastrointestinal Stenting Using Conformability Factor" and Jae-Hun So's manuscript describing a new micro-robot for middle ear surgery "Micro/Macro-Scale Robotic Approach for Middle Ear Surgery." Others focus on intriguing new sensing and image-based technologies to improve and/or augment the performance of existing systems, such as Stephen G. Laws' use of diffuse laser reflectivity for automatic soft tissue classification "Towards Automated Tissue Classification for Markerless Orthopaedic Robotic Assistance" and Alperen Acemoglu's proof-of-concept study involving teleoperation over a 5G network "5G Robotic Telesurgery: Remote Transoral Laser Microsurgeries on a Cadaver." Some of the authors within this Special Section also describe an array of new tools for smarter, less invasive, more effective, or otherwise better surgery. Examples include the improvement of robotic grippers through preferentially localized slip "Engineering Incipient Slip Into Surgical Graspers to Enhance Grasp Performance," new advances in the modeling of flexible needles for minimally invasive surgery "Analytical versus Data-Driven Approach of Modelling Brachytherapy Needle Deflection," and "three-handed" manipulations employing a novel smart foot interface "Tri-Manipulation: An Evaluation of Human Performance in 3-Handed Teleoperation." Finally, some of the papers showcase technologies to assist clinicians and patients outside of the operating theatre, such as Chloë Nicholson-Smith's insightful new method to increase engagement in VR-based patient rehabilitation "A Multi-Functional Lower- and Upper-Limb Stroke Rehabilitation Robot."

III. Conclusion

This issue highlights some of the critical progress made this year in the broad area of medical robotics, with evidence of innovation and impact across the full breadth of healthcare technologies. Contributions from academic teams in universities and hospitals across the world illustrate the importance of a sustained effort in this space and the timeliness of this Special Section.

We hope that these works will also draw a spotlight on the many unprecedented challenges and opportunities in medical robotics. While the field has made significant progress in the past decade, there continues to be a need for engineers and clinicians to work together with the aim of developing the next generation of robotic surgical technologies. In addition to the many advances mentioned above, a new generation of clinical engineers should be trained who are familiar with both the technology and clinical practice. Individuals such as these will be essential to move the technology to the operating theatre and complete the studies needed to validate these new developments. While the current pandemic will change the world in many ways, there will always be a need for scientific exchange in all fields, including surgical robotics. With this in mind, the Hamlyn Symposium will continue to adapt and innovate to ensure that it remains an international forum for clinicians and engineers who are passionate about the future of healthcare, for many years to come.

Acknowledgment

In closing, we would like to extend our appreciation to all reviewers who played a crucial role in the peer-review process for the manuscripts submitted to this issue, for their timely and professional comments.

Most importantly, thanks to all the authors who submitted their manuscripts for consideration.

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