# SMart weArable Robotic Teleoperated surgery

## Newsletter #4

Inside this issue:




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732515

# SMARTsurg Exoskeleton solution

## Rigid/soft hybrid exoskeleton

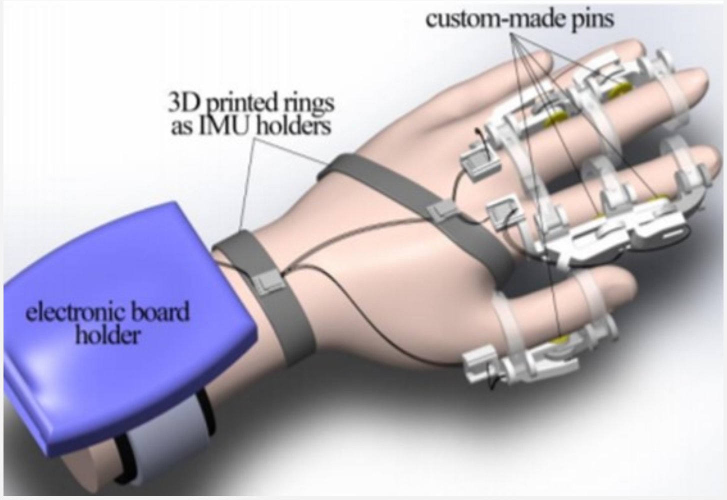
**Hand Exoskeleton** has been stated as the preferred master device for majority of the interviewed surgeons - (43%) for Orthopaedics, (40%) for Urology, Cardio surgery (45%). A spectrum of other devices like Omni Phantom, Leap motions, etc. scored much lower.

Specific features of the master exoskeleton are following:

- one hand exoskeleton integrated with Virtuose 6d Desktop for each hand
- lightweight
- adjustable for various hand sizes
- compact (including interface with Virtuose)
- fewer wires
- integrated with haptic feedback

The proposed improvement on the **pre-SMARTsurg exoskeleton design** is: "A hand exoskeleton for better tissue manipulation and grasping and an extended multi-DOF shaft for better dexterity inside the abdomen interfaced with Haption Virtuose 6D desktop, and Cybernetix Real Time 3D supervision software managing the haptic force-feedback between the slave and the master exoskeleton."

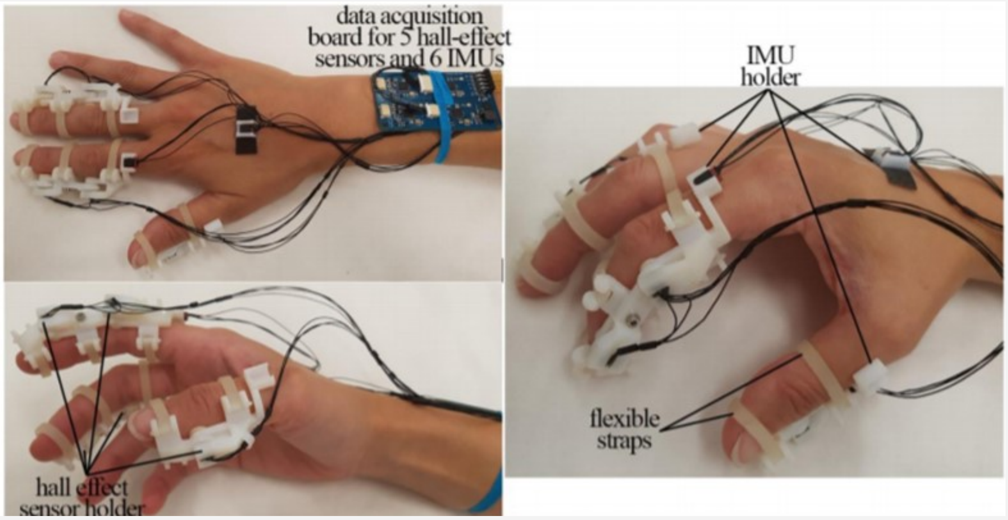
To reduce the exoskeleton weight and make it more compact and ergonomic, each of the 3-sensor mechanisms, shown in the figure below, were replaced by 2 IMUs (Inertial Measurement Units) (BNO552, Bosch), while an additional IMU is used for wrist tracking. This design comprises a total of 5 Hall-effect sensors and 5 IMUs to track 16 DOF of the user's hand and is shown in the pictures .




Envisioned concept with rigid parts and flexible straps comprising 2 types of sensors

# SMARTsurg Exoskeleton solution

A custom-made motherboard, as illustrated in the next figures, was designed for sensors data acquisition while it also has provision for a 6th IMU as a redundant sensor for the intricate CMC joint of the thumb. The rigid parts of the exoskeleton were printed in Verowhite (Stratasys, USA) and the soft straps in TangoPlus, TangoBlackPlus or Agilus30 (Stratasys, USA). In the current prototype, the electronics board is held on the forearm with hypo-allergenic flexible tape. The total weight of the exoskeleton including 5 Hall-effect sensors, 5 IMUs and the associated electronics is 40 gr, improved from the previous prototype at 200gr.




Prototype of the hybrid soft/rigid exoskeleton with 2 types of sensors

## Rigid exoskeleton

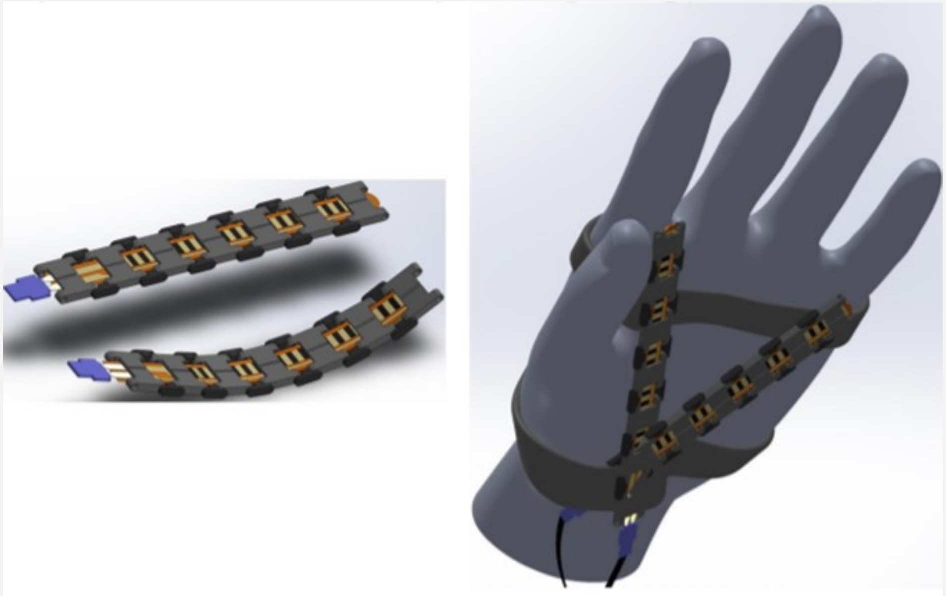
In parallel to the rigid/soft design of the previous section, a 2nd design is being developed for use exclusively with **Hall-effect sensors**, but with ergonomically improved design. This exoskeleton also benefits from the parametric design for different hand sizes custom fit and has the advantage of not requiring calibration before each use (due to lack of IMUs). The design includes two plates, one for the palm and one for the dorsal side of the hand. These are intended for holding a mechanism and are essentially replacing the hook-and-loop fasteners of the pre-SMARTsurg design. For a comfortable but snug fit, there are soft balancing stands between the top plate and the dorsal side of the hand. Instead of 3D printed flexible straps, the exoskeleton is held onto the digits via elastic fabric which is easily adjustable via a custom-made cam buckle (placed on the top of the hand).

Initial prototype of rigid exoskeleton for use with hall-effect sensors

# SMARTsurg Exoskeleton solution

## Thumb MCP Tracking using flex sensors on the palm

Further to the exoskeleton designs and to address potential problems with the CMC joint of the thumb, an alternative method for measuring change in the flexion of this joint is being developed. This includes flexible film sensors (Flexpoint, USA) that are placed inside the palm of the hand and measure change of resistance due to the change of curvature. These sensors are housed in a modular 3D printed chain, as shown in the next figure, which can be adjusted to various hand sizes by removing/ adding parts of the chain.



Flex sensor and modular 3D printed chain on the palm

# SMARTsurg 3F tool and hand tracking

The video presents the control of the da Vinci surgical instruments, using a novel wearable controller. The wearable controller, that contains inertial measurements units and hall effect sensors, is used to teleoperate a four-dof surgical instrument.

Click **here** to watch it and don't forget to subscribe to our YouTube channel!

# Dissemination Activities

## ICRA2020

SMARTsurg results participated at this year's Virtual IEEE International Conference on Robotics and Automation, with the video "Control of da Vinci surgical instrume4nts using a novel wearable controller", presented on the previous chapter. The 2020 Virtual edition featured world-class presentations by internationally renowned speakers cutting-edge session topics and provide a fantastic opportunity to network with like-minded professionals from around the world.



## SMARTsurg @DeviceMed Magazine

The work and the objectives of SMARTsurg project was presented on DeviceMed, a French magazine about medical devices manufacturing.

# Dissemination Activities

[SMARTsurg @Engineering Update Magazine]

A printed issue of the 'Engineering Update' Magazine featured the breakthrough and the expected impact that SMARTsurg is designed to have.


June 2019 ENGINEERING UPDATE

## Keyhole surgery using robots

**The Bristol Robotics Laboratory are incorporating maxon products as part of a project to develop Robot Assisted Minimally Invasive Surgery (RAMIS).**

ENGINEERING UPDATE June 2019



[SMARTsurg @Industrial Italiana Magazine]

Industria Italiana, an Italian magazine about Business and Technology referred to SMARTsurg's objectives, as Politecnico di Milano, a partner of SMARTsurg, moved with a new research collaboration about advanced robotics.

# MEDICON Conference


With special Session 110, Smart robotic assistant for minimally invasive surgery: the SMARTsurg project experience, held on 27 September 2019 afternoon at MEDICON conference 2019 Coimbra, Portugal, the consortium of SMARTsurg H2020 EU project, presented the advancement so far to the biomedical engineering community.

Papers Presented:

- **Towards Finger Motion Tracking and Analyses for Cardiac Surgery**, *Mohammad Fattahi Sani, Raimondo Ascione, Sajeeva Abeywardena, Efi Psomopoulou and Sanja Dogramadzi*
- **Surgeon Training with Haptic Devices for Computer and Robot Assisted Surgery: An Experimental Study**, *Salih Ertug Ovur, Marisa Cobanaj, Luca Vantadori, Elena De Momi and Giancarlo Ferrigno*
- **Augmented Reality Toolkit for a smart Robot-Assisted MIS platform**, *Georgios Zampokas, Konstantinos Tsiolis, Georgia Peleka, Angeliki Topalidou-Kyniazopoulou, Ioannis Mariolis, Sotiris Malasiotis and Dimitrios Tzovaras*
- **Control of a da Vinci EndoWrist surgical instrument using a novel master controller**, *Sajeeva Abeywardena, Efi Psomopoulou, Mohammad Fattahi Sani, Antonia Tzemanaki and Sanja Dogramadzi*
- **Toward a neural-symbolic framework for automated workflow analysis in surgery**, *Hirenkumar Nakawala, Elena De Momi, Roberto Bianchi, Michele Catellani, Ottavio De Cobelli, Pierre Jannin, Giancarlo Ferrigno and Paolo Fiorini*
- **Manipulation of a whole surgical tool within safe regions utilizing barrier artificial potentials**, *Theodora Kastritsi, Iason Sarantopoulos, Sotiris Stavridis, Dimitrios Papageorgiou and Zoe Doulgeri*
- **Evaluation of force feedback for palpation and application of active constraints on a teleoperated system**, *Efi Psomopoulou, Raj Persad, Anthony Koupparis, Sajeeva Abeywardena, Mohammad Fattahi Sani, Chris Melhuish and Sanja Dogramadzi*
- **A Knowledge-based Graphical Interface for Modeling Surgical Workflows in Robot-Assisted Minimally Invasive Surgery**, *Christos Papadopoulos, Angeliki Topalidou-Kyniazopoulou, Ioannis Mariolis, Aristotelis Sideridis, Emmanuel Papacostas and Dimitrios Tzovaras*
- **Augmented and Virtual Reality in Minimally Invasive Surgery, state of the art and future prospects**, *Michele Catellani, Giovanni Cordima, Ottavio de Cobelli, Efthymios Papasoulis, Emmanuel Papacostas, Aristotelis Sideridis, Georgia Peleka, Georgios Zampokas, Konstantinos Tsiolis, Angeliki Topalidou-Kyniazopoulou, Ioannis Mariolis, Sotiris Malasiotis and Dimitrios Tzovaras*


Check the above papers under Results section of our website here.

# SMARTsurg Publications

**Journal publications:**

**Skill-based human–robot cooperation in tele-operated path tracking**
*Enayati, N., Ferrigno, G. & De Momi, E.*
Autonomous robots , November 2017

This work proposes a shared-control tele-operation framework that adapts its cooperative properties to the estimated skill level of the operator. It is hypothesized that different aspects of an operator's performance in executing a tele-operated path tracking task can be assessed through conventional machine learning methods using motion-based and task-related features. To identify performance measures that capture motor skills linked to the studied task, an experiment is conducted where users new to tele-operation, practice towards motor skill proficiency in 7 training sessions. A set of classifiers are then learned from the acquired data and selected features, which can generate a skill profile that comprises estimations of user's various competences. Skill profiles are exploited to modify the behavior of the assistive robotic system accordingly with the objective of enhancing user experience by preventing unnecessary restriction for skilled users. A second experiment is implemented in which novice and expert users execute the path tracking on different pathways while being assisted by the robot according to their estimated skill profiles. Results validate the skill estimation method and hint at feasibility of shared-control customization in tele-operated path tracking.

To read the full journal please click here.

**An Uncontrolled Manifold Analysis of Arm Joint Variability in Virtual Planar Position and Orientation Telemanipulation**
*J. Buzzi, E. De Momi and I. Nisky*
IEEE Transactions on Biomedical Engineering, May 2018

In teleoperated robot-assisted tasks, the user interacts with manipulators to finely control remote tools. Manipulation of robotic devices, characterized by specific kinematic and dynamic proprieties, is a complex task for the human sensorimotor system due to the inherent biomechanical and neuronal redundancies that characterize the human arm and its control. We investigate how master devices with different kinematics structures and how different task constraints influence users capabilities in exploiting arm redundancy. Methods: A virtual teleoperation workbench was designed and the arm kinematics of seven users was acquired during the execution of two planar virtual tasks, involving either the control of position only or position-orientation of a tool. Using the uncontrolled manifold analysis of arm joint variability, we estimated the logarithmic ratio between the task irrelevant and the task relevant manifolds (R v ). Results: The R v values obtained in the position-orientation task were higher than in the position only task, while no differences were found between the master devices. A modulation of R v was found through the execution of the position task and a positive correlation was found between task performance and redundancy exploitation. Conclusion: Users exploited additional portions of arm redundancy when dealing with the tool orientation.

To read the full journal please click here.

# SMARTsurg Publications

**Journal publications:**

**Improved Human–Robot Collaborative Control of Redundant Robot for Teleoperated Minimally Invasive Surgery**
*Su H., Yang C., Ferrigno G., De Momi E.*
IEEE Robotics and Automation Letters , February 2019

An improved human-robot collaborative control scheme is proposed in a teleoperated minimally invasive surgery scenario, based on a hierarchical operational space formulation of a seven-degree-of-freedom redundant robot. Redundancy is exploited to guarantee a remote center of motion (RCM) constraint and to provide a compliant behavior for the medical staff. Based on the implemented hierarchical control framework, an RCM constraint and a safe constraint are applied to the nullspace motion to achieve the surgical tasks with human-robot interaction. Due to the physical interactions, safety and accuracy of the surgery may be affected. The control framework integrates an adaptive compensator to enhance the accuracy of the surgical tip and to maintain the RCM constraint in a decoupled way avoiding any physical interactions. The system performance is verified on a patient phantom. Compared with the methods proposed in the literature, results show that the accuracy of both the RCM constraint and the surgical tip is improved. The compliant swivel motion of the robot arm is also constrained in a defined area, and the interaction force on the abdominal wall becomes smaller.

To read the full journal please click here.

**Requirements elicitation for robotic and computer-assisted minimally invasive surgery**
*Nakawala H., De Momi E., Tzemanaki A, Dogramadzi S., Russo A., Catellani M., Bianchi R., de Cobelli O., Sideridis A., Papacostas E., Koupparis A., Rowe E., Persad R., Ascione R., Ferrigno G.*
International Journal of Advanced Robotic Systems, July 2019

The robotic surgical systems and computer-assisted technologies market has seen impressive growth over the last decades, but uptake by end-users is still scarce. The purpose of this article is to provide a comprehensive and informed list of the end-user requirements for the development of new generation robot- and computer-assisted surgical systems and the methodology for eliciting them. The requirements were elicited, in the frame of the EU project SMARTsurg, by conducting interviews on use cases of chosen urology, cardiovascular and orthopaedics procedures, tailored to provide clinical foundations for scientific and technical developments. The structured interviews resulted in detailed requirement specifications which are ranked according to their priorities. Paradigmatic surgical scenarios support the use cases.

To read the full journal please click here.

SMART surg

smartsurg-project.eu

info@smartsurg-project.eu

@SMARTsurg

www.linkedin.com/company/smartsurg-project

Prof. Sanja Dogramadzi
Bristol Robotics Laboratory
University of the West of England
Frenchay Campus, Coldharbour Lane
Bristol, BS16 1QY, United Kingdom

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732515