SMart weArable Robotic Teleoperated surgery

Newsletter #2

SMART surg

Inside this issue:

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Functional view of the SMARTsurg system

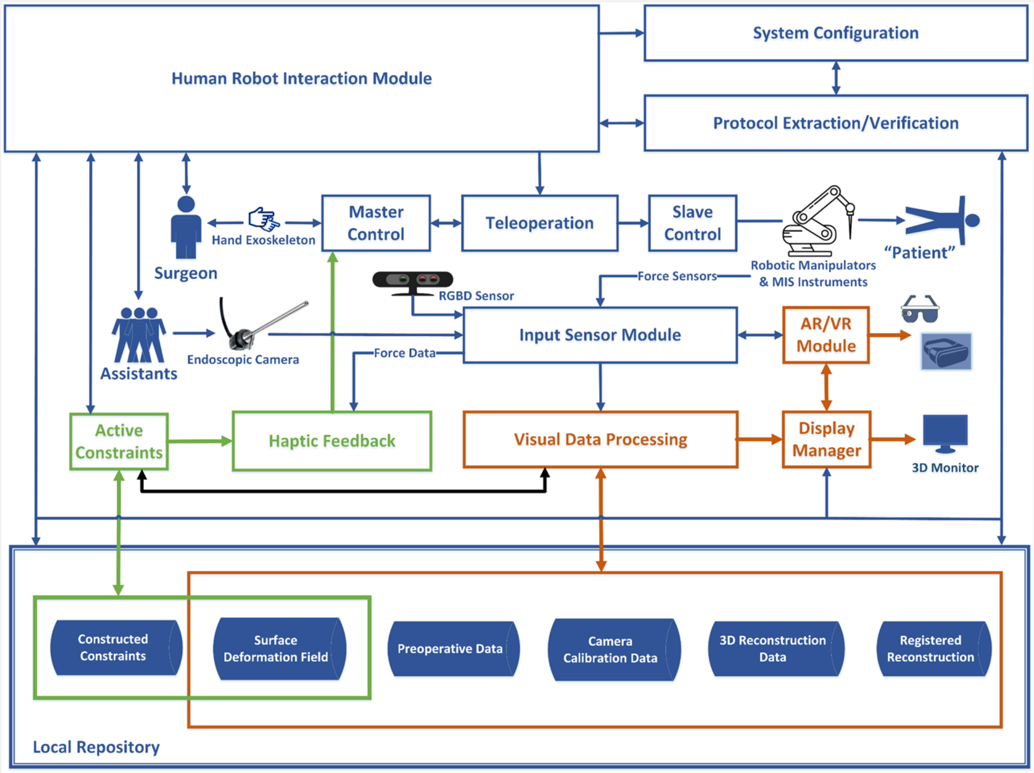
The functional view of a system's architecture defines the components that provide it's functionality. The view describes the functional structure of the system, demonstrating how the system performs the required functions. The functional structure of such view, as defined by Rozanski & Woods, typically contains functional elements, interfaces, connectors and external entities:

Functional Elements are well-defined components of the system that have particular functionalities and expose well-defined interfaces that allow them to be connected to other components. A functional component can be a software module, an application, a data collection, or even a sub-system.

Interfaces are specifications, defining how the functions of a component can be accessed by other components. An interface is defined by the inputs, outputs, the provided operation and the interaction needed for the operation.

External Entities are other systems, software programs, hardware devices, or any other entity the system interacts with. These are described as dependencies to other systems or components.

The following diagram provides a procedural view on the functional module dependencies of the SMARTsurg platform. It is a preliminary version that will evolve further during the project based on the corresponding developments. This figure translates SMARTsurg conceptual architecture into software modules and dependencies. The directed dependencies between the modules are denoted by arrowed lines.



Functional view of the SMARTsurg system

The SMARTsurg system consists of the following modules:

- Input Sensor Module
- Visual Data Processing Module
- Augmented/Virtual Reality Module
- Haptic Feedback Module
- Active Constraints Module
- Master Control Module
- Slave Control Module
- Teleoperation Module
- Protocol Extraction/Verification Module
- Data Display Manager
- HRI Module
- System Configuration Module

Use cases, requirements and specifications

As mentioned in the 1st SMARTsurg newsletter, we have chosen a total of seven use cases on urology, cardiovascular and orthopaedic surgery. The surgical workflow of these surgical use cases is represented in a graphical format with the components of the surgical activity, for example, "Phases" of the surgery. To obtain user-specific requirements in minimally invasive robotic surgery, a total of 29 surgeons, of urology, orthopaedic and cardiovascular specialties, are interviewed as shown in the following table:

Interviews	University of the West England (UWE)	Politecnico di Milano (POLIMI)	Total
Orthopaedic surgeons	0	6 (1 senior; 3 mid-career; 2 junior)	6
Urologists	7 (4 senior; 3 junior)	10 (3 senior; 3 mid-career; 4 junior)	17
Cardiac surgeons	0	6 (4 senior; 1 mid-career; 1 junior)	6
Total senior			12
Total mid-career			7
Total Junior			10

We used a questionnaire to conduct the interviews, whereby two types of questions have been considered. Surgeons expressed their opinions in the expressive form, provided answers in the form of Yes/ No or expressed their answers by selecting one or more options. We organised and structured recorded audio data of the interviews into verbatim transcripts for further analysis. The answers of different participant surgeons were then grouped together for each question in the questionnaire.

We analysed data within the specialties (i.e. interview data of orthopaedic surgeons, urologists and cardiac surgeons separately), referred to as the 'within-case' analysis. The 'within-case analysis' was used to identify common categories or a theme for the user requirements from each surgical use case; e.g. better 'image quality', as a defined by urologists. After the 'within-case' analysis, we analysed the specialties, i.e. common requirements between different specialties; the 'across-case' analysis. During the 'across-case' analysis, the identified requirements were prioritised, against a scoring scale of 1 to 5, during the SMARTsurg consortium meeting (Milan, Italy, 10-11 July 2017). Most of the end-users present, contributed in identifying and listing these priorities. In total we elicited a total of 33 mandatory user requirements out of which 4 requirements were mandatory:

- superimposed preoperative images,
- active constraints (an anatomical region which is defined preoperatively to stop the robot move outside of this region),
- articulated instruments,
- hand exoskeleton (as surgeon's side master system).

The elicited requirements have been put in correspondence with the system hardware and clinicians' feedback was taken into account when choosing the final application scenarios.

Use cases, requirements and specifications

SMARTsurg three application scenarios synopsis with user requirements:

1. Robot-assisted Partial Lateral Meniscectomy (RaPLM)

A meniscus tear is a common knee joint injury, RaPLM is performed to remove all or part of a torn meniscus. Smart glasses (for assistants) a hand exoskeleton, better image quality and articulated instruments are needed in all the phases of RaPLM. In the first phase of RaPLM surgeons need to overview the knee joint, where the three-fingered instrument could be used to see the knee compartments. In order to evaluate the position of the tear in the meniscus, this is damage is conventionally marked by the probe. However, the incorporation of haptic perception could be useful, as this will allow one to feel “a sense of touch”. During the RaPLM, pre-operative images could be superimposed to see the damaged meniscus enables the surgeon to cut it minimally. Finally, the three-fingered instrument could be used to cut the free cartilage pieces, where active constraints could also be implemented to prevent the injury to the meniscus rim and to cut the minimum amount of meniscus.

2. Robot-assisted Partial Nephrectomy (RAPN)

RAPN is performed to remove tumorous portions of the kidney. Hand exoskeleton, better image quality, smart glasses (for assistants) and 3D images (for visualization) are required in all the phases of RAPN. During the preparation of the kidney, active constraints could be used to prevent the injuries to vasculature such as, the aorta or vena cava as well as, organs such as the liver or spleen. After that, during the excision of the tumour, preoperative images are superimposed to view the renal artery, while incising the renal capsule before clamping the artery. After the preoperative images are superimposed, active constraints could be used to prevent the injury of renal arteries. Haptics could be used for the closure of renal breach during suturing and pulling of the thread while doing the suturing of the kidney.

3. Robot-assisted Coronary Artery Bypass Grafting (CABG)

CABG is advised in patients with significant narrowing or blockage of coronary artery. A hand exoskeleton, better image quality, smart glasses (for assistants), and 3D images are required in all the phases of CABG. Firstly, during the LIMA (Left Internal Mammary Artery) phase takedown, pre-operative images could be used to identify LIMA and the thymus gland. Then, active constraints could be used for preventing the injuries to LIMA while cauterising the sternal branches or using the diathermy. Before the LIMA takedown, haptics could be used to assess the calcium deposits, if any, in the coronary artery. Articulated instruments could then be used to take down LIMA and reach their posterior side of the heart, e.g. to assess the posterior branch of the coronary artery. During LIMA-LAD (Left Anterior Descending Artery), which is a branch of a coronary artery anastomosis, haptics could be incorporated during suturing and pulling of the thread, where the three-fingered instrument could be used to cut the sutures.

Design of HMD (Smart Glasses)

Optinvent engineers and delivers cutting edge wearable technology products. Optinvent's team has developed patented technologies, extensive knowledge and manufacturing expertise to create a disruptive new category of wearable devices that opens the door to a world of possibilities.

Optinvent has created revolutionary head worn products called "ORA". The ORA is a family of AR (Augmented Reality) devices which integrates the patented Clear-Vu display engine for see-through wearable computing AR products.

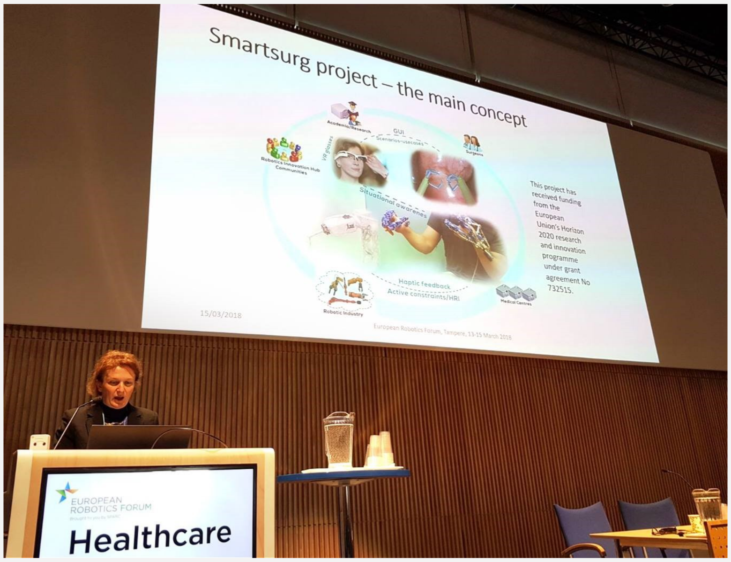
During the first twelve months of the SmartSurg Project, Optinvent defined along with the partners the requirements and specifications of the Head Mounted Display (HMD). The display witch support the surgeon and associate in their work.

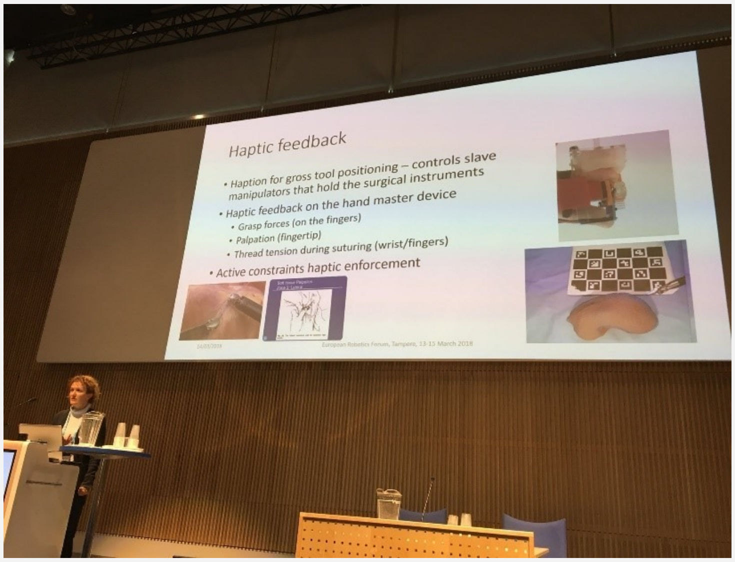
Optinvent has already advanced on the design of the specific "See-through Display" that should be implemented inside the HMD device.

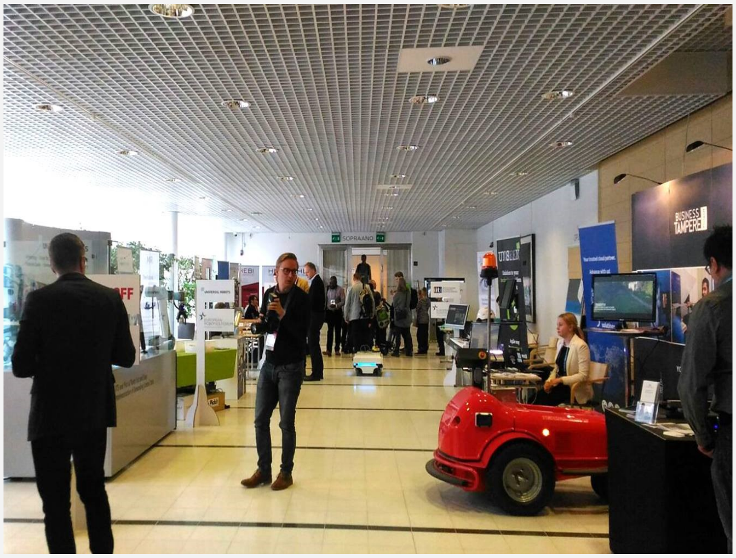
The next step is to finalise the whole HMD design and to launch the production of the HMD prototype. The HMD will be monocular and will be fixed either on the left or right eye. The Display will be transparent (~50% photopic) and could adjusted in front of the user eye, with a full color HD resolution (1280x720 pixels) and 37deg Field of View.

European Robotics Forum 2018

In the frame of European Robotics Forum (ERF) 2018 (13-15 March 2018 Tampere - Finland) SMARTsurg partners (UWE-Bristol Robotic Laboratory and Politecnico di Milano) co-organized and participated to the Workshop on Networking for new trends in surgical robotics. Sanja Dogramadzi, Bristol Robotic Laboratory, UK, presented SMARTsurg.







Dissemination activities

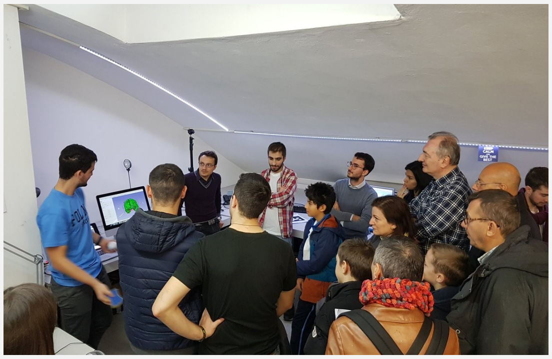
- **SMARTsurg presented from POLIMI at ARS Workshop (30-31 October 2017)**

Politecnico di Milano (POLIMI) during 30-31 October 2017 participated in a workshop to state an: “Roadmap to Autonomous Robotic Surgery” organised by Altair Robotics Lab at the Department of Computer Science of the University of Verona. The workshop introduced the activities under European Research Council (ERC) project ARS (Autonomous Robotic Surgery). Experts in the fields of human and animal cognition, machine learning (ML) and artificial intelligence (AI) and robotics were brought together to debate the challenges of robotic autonomy. The workshop organized in two days, with a careful balance of cognition, ELS, robotic topics and open discussion among lecturers and public. Giancarlo Ferrigno and Elena De Momi from POLIMI participated at the workshop and presented the SMARTsurg project.

- **SMIT 2017 in Torino (9-10 November 2017)**

Elena De Momi participated in the 29th Conference of the international Society for Medical Innovation and Technology (SMIT) as invited speaker. The SMIT 2017 took place at the University of Torino, Italy on Thursday November 9th and Friday November 10th 2017 and it’s theme was ‘Technology and care for patients’. Elena De Momi had a talk about “Computer vision and robotics for augmenting the surgeon’s capabilities during the intervention”. Check Elena’s full talk from the following link.

- **Robotics @ POLIMI - OpenLabs 2017**



In the framework of the European Robotics Week the Politecnico di Milano opened it’s robotics lab to the public: press, researchers, students, industry and families, on November 25, 2017. Every year the European Robotics Week offers every year one week of various robotics related activities across Europe for the general public, which highlights the growing importance of robotics in a wide variety of application areas.

SMARTsurg Publications

- **On the Value of Estimating Human Arm Stiffness during Virtual Teleoperation with Robotic Manipulators**

  Frontiers in Neuroscience, Neural Technology, Special issue: Biomechatronics: Harmonizing Mechatronic Systems with Human Beings.

  Buzzi, Jacopo; Ferrigno, Giancarlo; Jansma, Joost M; De Momi, Elena

- **Skill-based human–robot cooperation in tele-operated path tracking**

  Autonomous robots

  Enayati, Nima; Ferrigno, Giancarlo; De Momi, Elena

- **Development of an intelligent surgical training system for Thoracentesis**

  Artificial Intelligence in Medicine

  Nakawala, Hirenkumar Chandrakant; Ferrigno, Giancarlo; De Momi, Elena

- **Performance metrics for guidance active constraints in surgical robotics**

  The International Journal of Medical Robotics and Computer Assisted Surgery

  Enayati, Nima; Ferrigno, Giancarlo; De Momi, Elena

- **Analysis of Joint and Hand Impedance During Teleoperation and Free-Hand Task Execution**

  IEEE Robotics and Automation Letters

  Jacopo, Buzzi; Cecilia, Gatti; Giancarlo, Ferrigno; De Momi, Elena

- **EnViSoRS: Enhanced Vision System for Robotic Surgery. A User-Defined Safety Volume Tracking to Minimize the Risk of Intraoperative Bleeding**

  Frontiers in Robotics and AI

  Penza, Veronica; De Momi, Elena; Enayati, Nima; Chupin, Thibaud; Ortiz, Jesús; Mattos, Leonardo S.

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