SMart weArable Robotic Teleoperated surgery

Newsletter #3

SMART surg

3D reconstruction methods

Quasi-Dense Stereo recovers sparse features based on image intensity gradients. Those features are used as initial seeds to a propagation method to recover image pixels with enough texture information. A semi-dense 3D point reconstruction is achieved by estimating the disparity of those pixels using zero mean cross correlation (ZNCC).
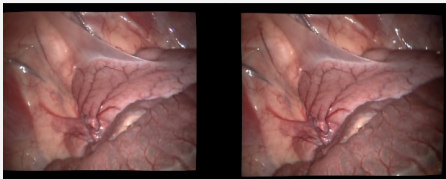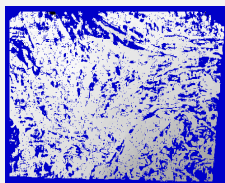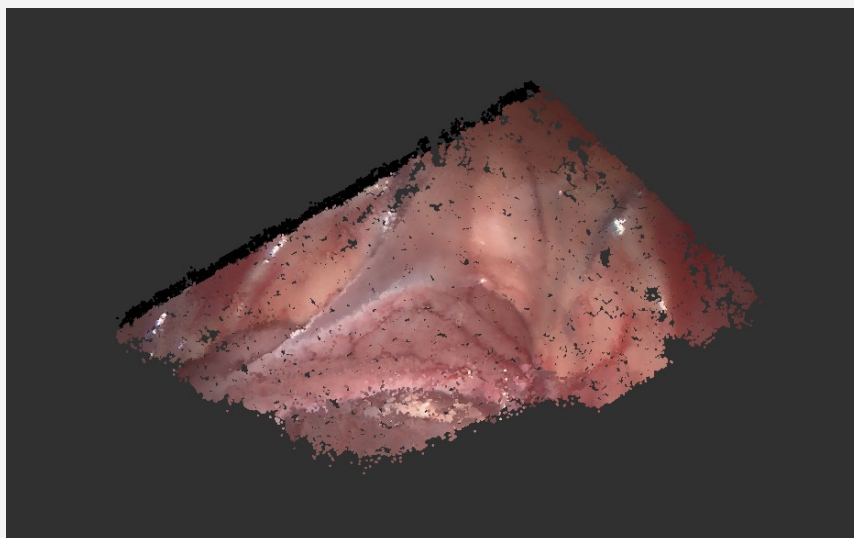

Initial stereoscopic image pair
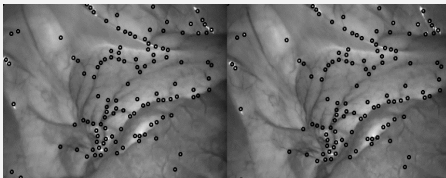
Sparse Features Matching
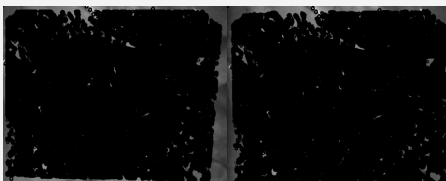

Dense Features Matching

Disparity Image Calculation

3D reconstruction methods

ELAS: Efficient Large Scale Stereo Matching recovers a set of support matches based on Sobel filter responses. Stereo matching is performed using a custom probabilistic generative model. A dense 3D point cloud reconstruction is recovered by estimating the disparity map for every pixel using a maximum a-posteriori estimation.
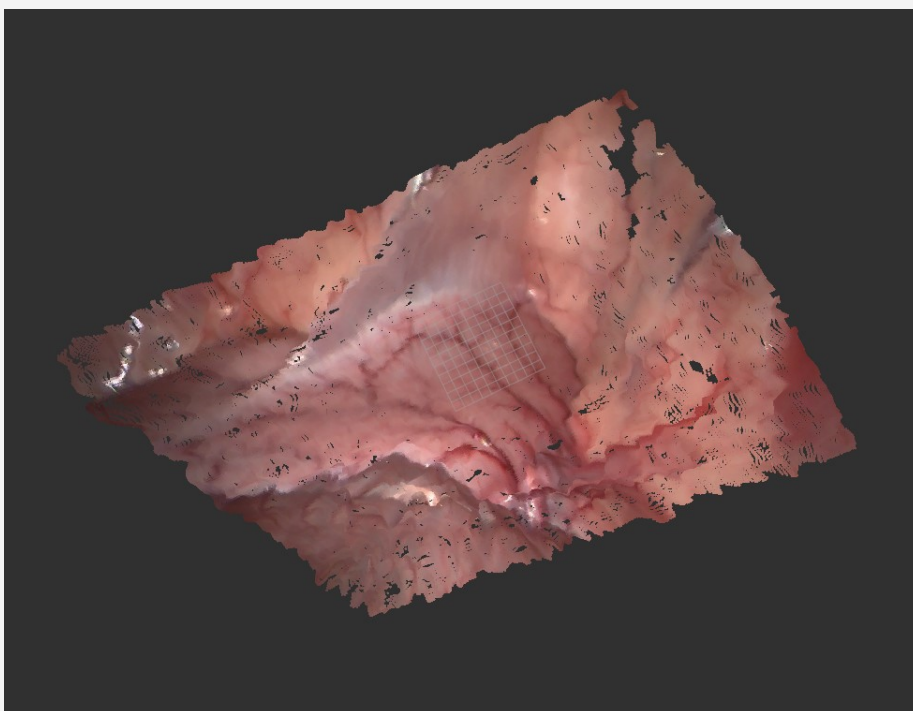
Datasets

The above methods are being integrated in a custom ROS pipeline, in order to be evaluated over various datasets of different surgical areas and conditions. Such datasets include:

In vivo Porcine Procedure, navigating to the Uterine Horn. The laparoscope is rotated around the optical axis causing a change in orientation in the image.

Location	Porcine Uterine Horn
Target	In-vivo exploration
Challenges	Area exploration
Resolution	640x480 pixels
Size	25 seconds at 25 fps
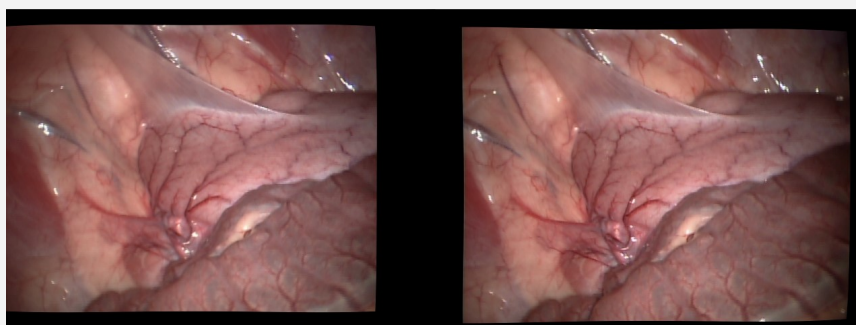
3D reconstruction methods

Datasets

Video sequence of a silicon heart phantom, deforming with cardiac motion and associated CT scans.

Location	Heart
Target	Ex-vivo Phantom
Challenges	Deformation
Resolution	360x288 pixels
Size	90 seconds at 25 fps
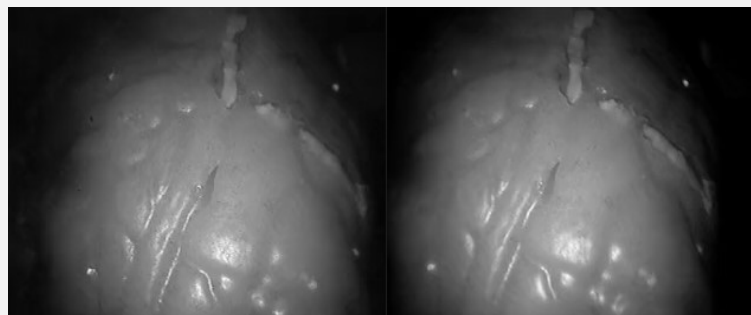
EndoAbs dataset consists of images of kidney, liver and spleen phantoms captured under different illumination conditions.

Location	Kidney, Liver, Spleen
Target	Ex-vivo Phantom
Challenges	Smoke, Reflectances
Resolution	640x480 pixels
Size	~ 250 image pairs

Market analysis and exploitation

The SMARTsurg Team completed in 2017 the Market analysis and Exploitation in a very dynamic market environment.

Early 2018 Intuitive Surgical announced that its installed base of da Vinci systems in clinical use are now exceeding 4, 400 units (yearly double digit growth):

- Over 75+% of the US$ 3.1 Billion business is invoiced in the US with close to US$ 1 Billion revenue in system sales worldwide (2017)

- Intuitive Surgical is increasing its investment to grow in Europe and in Asia. In 2017 Intuitive Surgical and Shanghai Fosun Pharmaceutical formed a J/V

- The growth in da Vinci rental systems is also interesting to note (more than 100 units rented currently)

- Close to 900, 000 surgical procedures were performed with the da Vinci Surgical Systems in 2017 (yearly double digit growth)

In May 2017, Intuitive Surgical launched a new da Vinci model, the da Vinci X, in the U.S. The lower cost da Vinci X uses the same vision cart and surgeon console that are found on the flagship product, the da Vinci Xi system, giving the customers the option of adding advanced capabilities, and providing a pathway for upgrading should they choose to do so as their practices and needs grow.

The SMARTsurg project is making its way in an eco-system where, on top of Intuitive Surgical, the following companies are making explicit efforts to enter the field: Auris Surgical Robotics Inc.; Avatera Medical GmbH; Cambridge Medical Robotics Ltd; Johnson & Johnson and Google Inc. and their joint venture, Verb Surgical Inc.; Medicaroid Inc.; MedRobotics Corp.; meerecompany Inc.; Medtronic PLC; Olympus Corp.; Samsung Corporation; Smart Robot Technology Group Co. Ltd.; TransEnterix Inc.; and Titan Medical Inc.

EL.I.S.A. project

EL.I.S.A. – Electric Impedance Sensing in Surgical Applications – is the result of a collaboration between Altair Robotics Lab (University of Verona), IIT (Italian Institute of Technology, Genova) and NearLab (Politecnico di Milano) and it has been partially funded by the ARS and the SMARTSurg projects.

The main goal of this research activity is to integrate advance sensing capabilities into surgical robotic tools.

The advance sensing is based on a compact embedded bio-electric impedance measurement device that could be integrated with minimum hardware modification in standard surgical tools.

Thanks to impedance measurements, an autonomous robotic system will be able to recognize the contact with different tissue types and in different conditions (e.g. healthy and pathological areas in the same tissue or organ). This information could be of enormous importance in the correct autonomous execution of complex surgical procedures, when visual data are not providing enough information for the robust detection and reconstruction of actual patient conditions.

EL.I.S.A. project was the finalist of the international competition for academia and industry Surgical Robot Challenge 2018 and received Best Paper award at CRAS2018.

Dissemination activities

- **CRAS2018**

  SMARTsurg researchers have attended 8th Joint Workshop on New Technologies for Computer/ Robot Assisted Surgery (10-11 September 2018, London UK).

- **Sanja Dogmadzi @ EuroScience Open Forum (ESOF) 2018**

  The ESOF, held once every two years, is the largest interdisciplinary science event in Europe. It brings together over 4 000 leading thinkers, innovators, policy makers, journalists and educators from all over the world to discuss current and future breakthroughs in science. The 8th edition of ESOF took place in Toulouse, France, from 9 till 14 July 2018.

  Our coordinator Sanja Dogmadzi was invited to speak about "The third millennium surgeon: a robot with artificial intelligence" and present the first results of SMARTsurg.

- **Zoe Doulgeri and Theodora Kastritsi participated @ European Control Conference (June 12-15, 2018, Limassol, Cyprus)**

  Zoe Doulgeri and Theodora Kastritsi presented the following paper "On the Stability of Robot Kinesthetic Guidance in the Presence of Active Constraints" at 2018 European Control Conference (ECC 18).

- **Sixth National Congress of Bioengineering (GNB 2018) @POLIMI**

  The Sixth National Congress of Bioengineering (GNB 2018) was held in Politecnico di Milano, on June 25-27, 2018. The Congress is the melting pot among biomedical research and clinical end users fully inserted in the framework of the most advanced international research in bioengineering, which combines the engineering background with the clinical one.

- **Robotics in Healthcare**

  SMARTsurg's Antonia Tzemanaki discussed surgical robotics in the relaunch event of Bristol's One Health Tech Hub, a network that supports and promotes women and other underrepresented groups in health innovation.

SMARTsurg publications

Journal publications:

- Tzemanaki A., Anil Al G., Melhuish C. and Dogramadzi S, **"Design of a Wearable Fingertip Haptic Device for Remote Palpation: Characterisation and Interface with a Virtual Environment"**, Front. Robot. AI

- J. Buzzi, E. De Momi and I. Nisky, "An uncontrolled manifold analysis of arm joint variability in virtual planar position and orientation tele-manipulation", IEEE Transactions on Biomedical Engineering

Conference publications:

- Tzemanaki, A., Abeywardena S., Psomopoulou E., Melhuish C. and Dogramadzi, S., "Using current measurement to estimate palpation and grasping forces in robot-assisted minimally invasive surgery", In the proceedings of Computer/ Robot Assisted Surgery

- Sayyaddelshad I., Psomopoulou E., Abeywardena S., Tzemanaki A. and Dogramadzi, S., **"Incision Port Displacement Modelling Verification in Minimally Invasive Surgical Robots"**, In the proceedings of Computer/ Robot Assisted Surgery

- Vantadori L., Mariani A., Chupin T., De Momi E., Ferrigno G., "Design and Evaluation of an Intraoperative Safety Constraints Definition and Enforcement System for Robot-Assisted Minimally Invasive Surgery", In the proceedings of Computer/ Robot Assisted Surgery CRAS 2018

- Foti S., Mariani A., Chupin T., Dall'Alba D., Cheng Z., Mattos L., Caldwell D., Fiorini P., De Momi E., Ferrigno G., "Advanced User Interface for Augmented Information Display on Endoscopic Surgical Images", In the proceedings of Computer/ Robot Assisted Surgery CRAS 2018 PDF

- Morelli A., Moccia S., S. Mattos L., Cordima G., De Cobelli G., Ferrigno G, De Momi E., "Towards Deformable Registration for AR in Nephrectomy", VI National Congress of Bioengineering" PDF

- Kastritsi T., Papageorgiou D., Doulgeri Z., "On the Stability of Robot Kinesthetic Guidance in the Presence of Active Constraints", European Control Conference (ECC 18), Limassol, Cyprus

- Nakawala H., De Momi E., Pescatori L.E., Morelli A., Ferrigno G., "Inductive learning of surgical workflow model through video annotations", In the proceedings of 30th IEEE International Symposium on Computer -Based Medical Systems (CBMS), Thessaloniki, Greece PDF

- Penza V, De Momi E., Enayati N., Chupin T., Ortiz J., S. Mattos L., "Safety Enhancement Framework for Robotic Minimally Invasive Surgery", In the proceedings of the 10th Hamlyn Symposium on Medical Robotics, London, UK PDF

Check out SMARTsurg full publications list here.

SMARTsurg meeting

- **SMARTsurg 3rd Plenary Meeting**

The 3rd plenary meeting of the SMARTsurg project was hosted by Optivent in Rennes, France on February 15-16, 2018. During the meeting, the partners had the opportunity to discuss project work progress and next steps. There were also special discussions about and focus to the upcoming deliverables, On-the-fly 3D reconstruction of the surgical field, Design and development of binocular smart glasses for R-A MIS applications, Augmented reality composite view creation and visualisation and Wearable surgical system demonstration.

- **SMARTsurg 4th Plenary Meeting**

The 4th plenary meeting of the SMARTsurg project was hosted by University of the West of England / Bristol Robotics Laboratory in Bristol on September 20-21, 2018. During the meeting, the partners had the opportunity to discuss project status per work package, the upcoming deliverables about the integrated SMARTsurg system prototype with all the software and hardware developed in WP4-WP6 and the deployment and testing of the developed SMARTsurg demonstrators.

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