SMart weArable Robotic Teleoperated surgery

Newsletter #6

Inside this issue:

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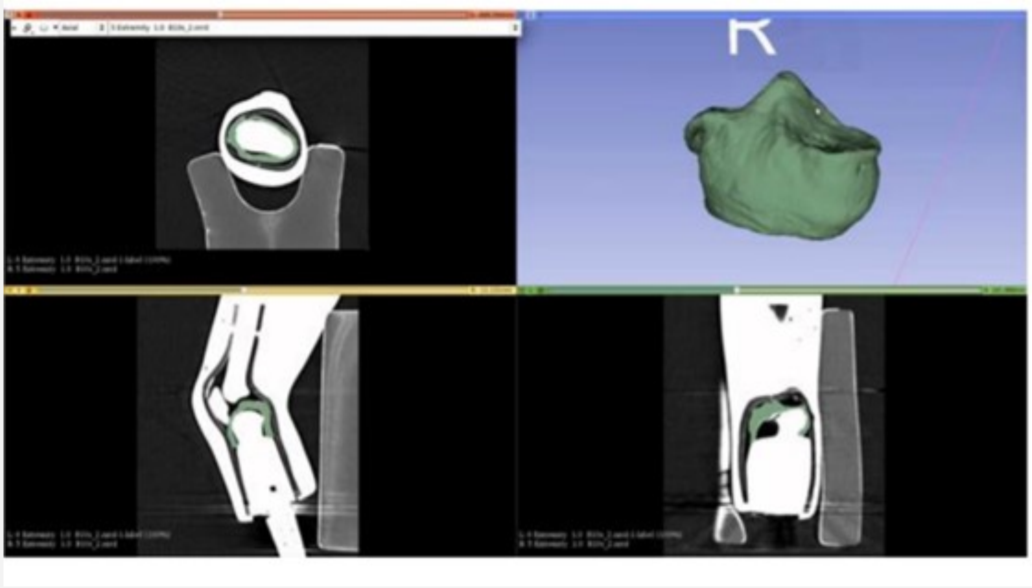
Extraction of 3D models, Pre-operative Data

Taking into account all the information provided by the patients' pre-operative examinations is crucial for a positive outcome of an MIS (Minimally Invasive Surgery) procedure. Medical imaging (CT, MRI) are used to extract information of the surgical field prior to the surgery. In order to make valuable use of this information within an augmented reality module we can extract 3D models of the anatomical areas of interest.

3D model extraction using 3D Slicer

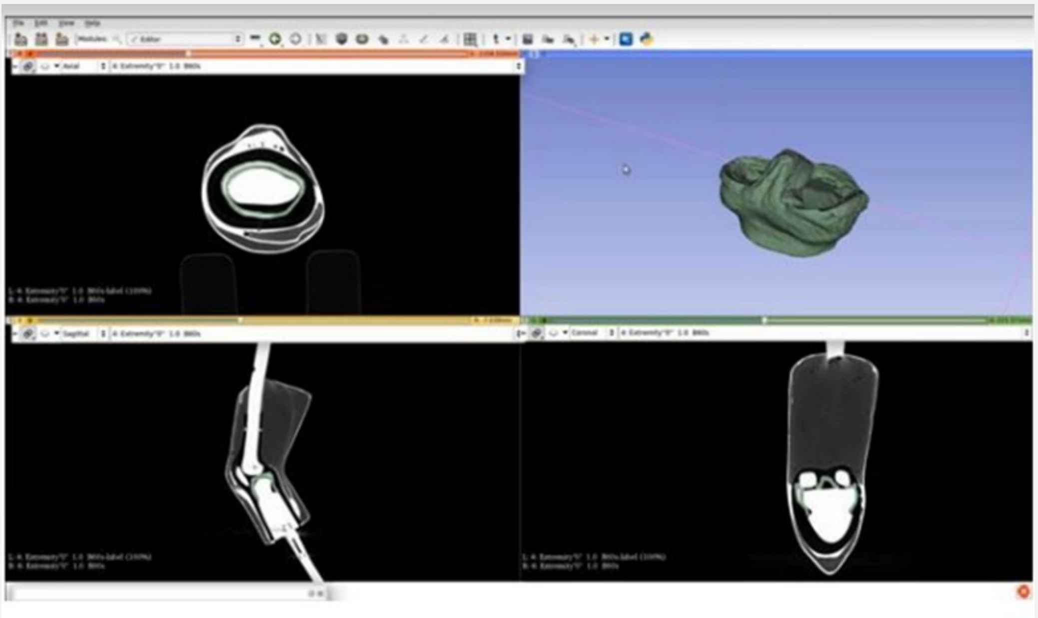
The 3DSlicer software, was used to review pre-operative CT images of a knee phantom in order to extract the 3D model of the anatomical structure of meniscus. We had different meniscus models scanned within the knee phantom corresponding to various meniscus lacerations as also a sample corresponding to a healthy meniscus. All CT images were reviewed and the anatomical structure of interest was manually annotated within the 3D Slicer software for each CT image series. The corresponding annotations were used to create a 3D representation of the marked area as a surface model for every meniscus model. These models are treated as the pre-operative "ground-truth" data, and are used in the Augmented Reality module of SMARTsurg framework. The 3D Slicer environment and the manual annotations, together with the corresponding 3D model for the "healthy" model can be seen in the image below.



3D Slicer software environment showing the annotation of a healthy sample. An expert reviews the CT scans and manually annotates the phantom meniscus model in any of the CT planes (axial, coronal, sagittal). The corresponding area is then automatically annotated in the other two views and also in the 3D model.

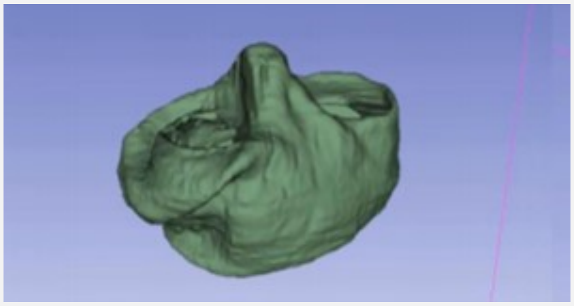
Extraction of 3D models, Pre-operative Data

While the 3D Slicer environment and the manual annotations, together with the corresponding 3D model for the “torn meniscus” model is shown below.

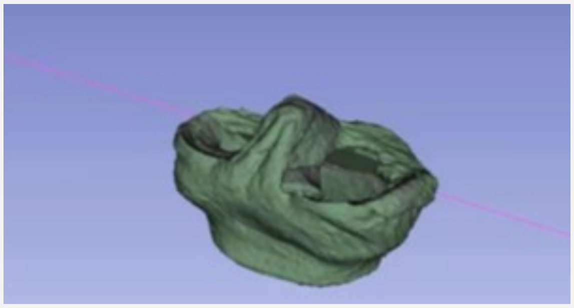


3D Slicer software environment showing the annotation of a torn meniscus sample.

Through the manual annotation, as described previously, a 3D mesh model is extracted that describes in great detail the pre-operative anatomical region of interest and is used by the Augmented Reality module. The 3D models of the aforementioned two examples (healthy, torn) of phantom meniscus can be seen in greater detail in the next images.



Healthy meniscus 3D model, extracted through manual annotation in 3D Slicer software.



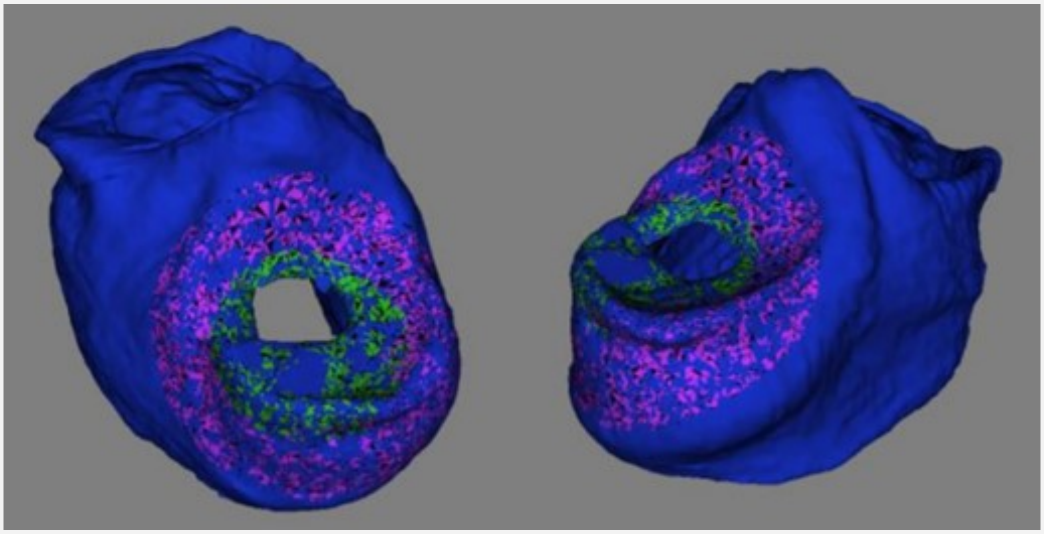
Torn meniscus 3D model, extracted through manual annotation in 3D Slicer software.

Extraction of 3D models, Pre-operative Data

Extraction of ground truth samples from pre-operative 3D models

Using the pre-operative 3D models acquired through the procedure described in the previous section, we developed a framework for segmenting these models to smaller sections for testing the examined surface registration algorithms. Since the anatomical structure of interest during the MIS procedure will most probably be occluded during the registration the need of registering small parts of the pre-operative model to the field of view was created. The framework we created can segment the 3D model in smaller areas, extracting small parts of the surface and keeping information regarding the initial model and the area where the segment was extracted. Using this knowledge, we can extract information regarding the success of the registration by measuring the distance of the initial vertices of the "ground truth" model and the corresponding ones in the surface part that is being registered.

In order to create a preliminary dataset, we used the mesh model of a healthy meniscus, extracted though manual annotation of the meniscus anatomy on every slice inside 3D Slicer software. Using 25 unique random points on the model as seeds for the segmentation, 50 segmented regions were extracted that had from 15% to 50% of overlapping between them. For every seed we used two different values (1.5cm and 2.5cm) as radius, to determine the size of the segmented patch. Every patch was stored both in point-set and surface form. As an extra feature, noise was added to the models in order to simulate noisy input data from the On-the -fly 3D reconstruction of the surgical field. As an initial step for noise simulation we used a trivariate Gaussian distribution ($\mu = 0.0$, $\sigma = 0.06$). Where 1σ distance (0.6mm) in each dimension, corresponds roughly to a total of about 1mm error distance. The average Root Mean Square (RMS) error between the points of the produced noisy models and the points of initial ones is 1.56 mm. The procedure described above has been automated and performed within the ROS framework.

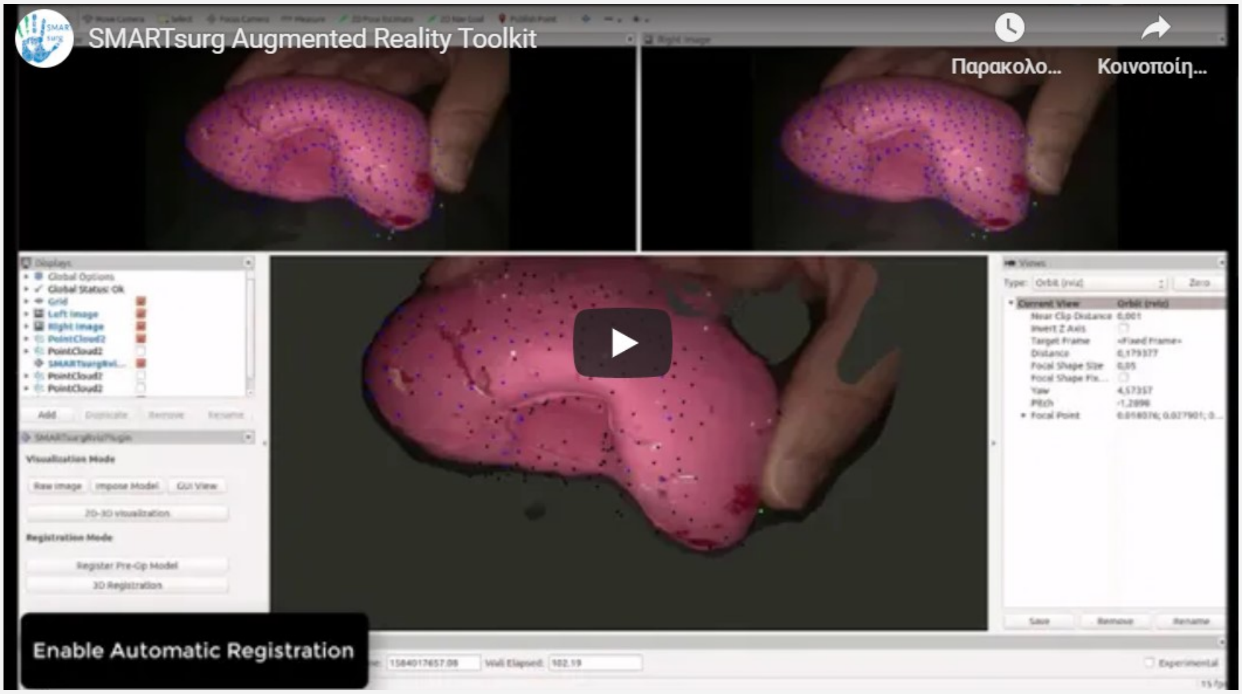


Automatic segmentation of 3D model for ground truth extraction. The 3D pre-operative model (blue) is segmented in smaller regions (magenta, green) to simulate occlusions at the in-operative view.

SMARTsurg Augmented Reality Toolkit

The video shows in more detail the Augmented Reality Toolkit that was developed during the SMARTsurg project.

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



Main Contributors

Researchers/ Technical Team

Prof. Sanja Dogramadzi, UWE Bristol/ BRL *(Project coordinator)*

Dr. Dimitrios Tzovaras, CERTH/ ITI

Dr. Ioannis Mariolis, CERTH/ ITI

Mr. Xristos Papadopoulos, CERTH/ ITI

Mrs. Georgia Peleka, CERTH/ ITI

Mrs. Angeliki Topalidou – Kyniazopoulos, CERTH/ ITI

Mr. Konstantinos Tsiolis, CERTH/ ITI

Mr. Giorgos Zampokos, CERTH/ ITI

Surgeons

Prof. Raimondo Ascione, University of Bristol

Prof. Raj Persad, Bristol Urological Institute

Dr. Michele Catellani, Istituto Europeo di Oncologia - IEO

Dr. Aris Sideridis, TheMIS Orthopaedic Center

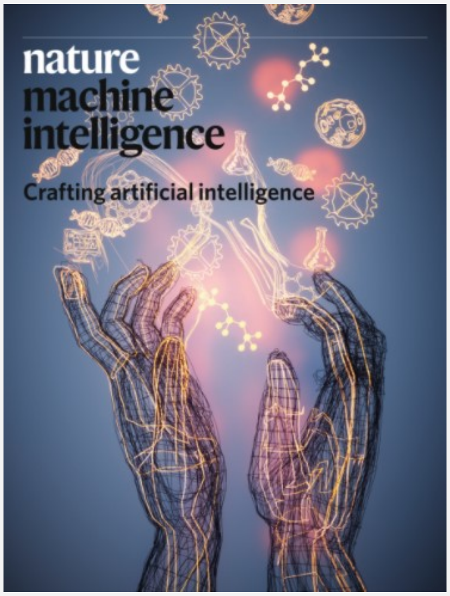
Mr. Anthony Koupparis, Bristol Urological Institute

Into the World of Robotics

The rise of robots in surgical environments during COVID-19

Ajmal Zemmar, Andres M.Lozano, Bradley J.Nelson

Nature Machine Intelligence Journal



The COVID-19 pandemic has changed our world and impacted multiple layers of our society. All frontline workers and in particular those in direct contact with patients have been exposed to major risk. To mitigate pathogen spread and protect healthcare workers and patients, medical services have been largely restricted, including **cancellation of elective surgeries**, which has posed a substantial burden for patients and immense economic loss for various hospitals. **The integration of a robot as a shielding layer, physically separating the healthcare worker and patient, is a powerful tool to combat the omnipresent fear of pathogen contamination and maintain surgical volumes**. In this Perspective, we outline detailed scenarios in the pre-intra- and postoperative care, in which the use of robots and artificial intelligence can mitigate infectious contamination and aid patient management in the surgical environment during times of immense patient influx. We also discuss cost-effectiveness and benefits of surgical robotic systems beyond their use in pandemics.

Robotics investments recap: September 2020

Eugene Demaitre

therobotreport.com

For the first time in months, autonomous vehicles were not the biggest area of investments in robotics and related technologies. Healthcare systems and processors for artificial intelligence pulled ahead in September 2020. However, the total value of robotics transactions dropped from the same period last year.

Surgical robots take the lead in September 2020.

The largest single robotics transaction last month was the Hillhouse Capital-led $512 million investment in MicroPort MedBot Co. The Shanghai, China-based company is developing surgical robotics for orthopedic and cardiovascular procedures.

Into the World of Robotics

Millennials ready for robots to aid family health and wellness, finds IEEE survey

Eugene Demaitre

therobotreport.com

Each generation must learn to adapt to new technologies, but the level of interest and adoption may vary. From artificial intelligence for telehealth to robot-assisted surgery and autonomous vehicles, many millennials with children are ready to accept emerging technologies, found the Institute for Electrical and Electronics Engineers, or IEEE.

In "Generation AI 2020: Health, Wellness and Technology in a Post-COVID World," the IEEE reported the results of surveys conducted in the U.S., the U.K., India, China, and Brazil between Sept. 25 and Oct. 6, 2020. The Piscataway, N.J.-based organization surveyed 400 parents aged 24 to 39 with at least one "Generation Alpha" child under 11 years old in each country, for a total of 2,000 respondents.

Can we stop AI outsmarting humanity?

Mara Hvistendahl

theguardian.com

The spectre of superintelligent machines doing us harm is not just science fiction, technologists say – so how can we ensure AI remains friendly to its makers? Jaan Tallinn, Estonian-born computer programmer, stumbled across these words in 2007, in an online essay called "Staring into the Singularity". The "it" was human civilisation. Humanity would cease to exist, predicted the essay's author, with the emergence of superintelligence, or AI, that surpasses human-level intelligence in a broad array of areas. "Every AI, whether it's a Roomba or one of its potential world-dominating descendants, is driven by outcomes. Programmers assign these goals, along with a series of rules on how to pursue them. Advanced AI wouldn't necessarily need to be given the goal of world domination in order to achieve it – it could just be accidental."

SMARTsurg Journal Publications

Deep Neural Network Approach in HumanLike Redundancy Optimization for Anthropomorphic Manipulators

Su H., Qi W., Yang C., Aliverti A., Ferrigno G., De Momi E.

IEEE Access, vol. 7, pp. 124207-124216, 08/2019

Human-like behavior has emerged in the robotics area for improving the quality of HumanRobot Interaction (HRI). For the human-like behavior imitation, the kinematic mapping between a human arm and robot manipulator is one of the popular solutions. To fulfill this requirement, a reconstruction method called swivel motion was adopted to achieve human-like imitation. This approach aims at modeling the regression relationship between robot pose and swivel motion angle. Then it reaches the human-like swivel motion using its redundant degrees of the manipulator. This characteristic holds for most of the redundant anthropomorphic robots. Although artificial neural network (ANN) based approaches show moderate robustness, the predictive performance is limited. In this paper, we propose a novel deep convolutional neural network (DCNN) structure for reconstruction enhancement and reducing online prediction time. Finally, we utilized the trained DCNN model for managing redundancy control a 7 DoFs anthropomorphic robot arm (LWR4+, KUKA, Germany) for validation.

Towards Model-Free Tool Dynamic Identification and Calibration Using Multi-Layer Neural Network

Su H., Qi W, Hu Y., Sandoval J., Zhang L., Schmirander Y., Chen G., Aliverti A., Knoll A., Ferrigno G., De Momi E.

Sensors 2019, 19(17), 3636, 08/2019

In robot control with physical interaction, like robot-assisted surgery and bilateral teleoperation, the availability of reliable interaction force information has proved to be capable of increasing the control precision and of dealing with the surrounding complex environments. Usually, force sensors are mounted between the end effector of the robot manipulator and the tool for measuring the interaction forces on the tooltip. In this case, the force acquired from the force sensor includes not only the interaction force but also the gravity force of the tool. Hence the tool dynamic identification is required for accurate dynamic simulation and model-based control. Although model-based techniques have already been widely used in traditional robotic arms control, their accuracy is limited due to the lack of specific dynamic models. This work proposes a model-free technique for dynamic identification using multi-layer neural networks (MNN). It utilizes two types of MNN architectures based on both feed-forward networks (FF-MNN) and cascade-forward networks (CF-MNN) to model the tool dynamics

SMARTsurg Journal Publications

Neural Network Enhanced Robot Tool Identification and Calibration for Bilateral Teleoperation

Su H., Yang C., Mdeihly H.,Rizzo A., Ferrigno G., De Momi E.

IEEE Access, vol. 7, pp. 122041-122051, 08/2019

In teleoperated surgery, the transmission of force feedback from the remote environment to the surgeon at the local site requires the availability of reliable force information in the system. In general, a force sensor is mounted between the slave end-effector and the tool for measuring the interaction forces generated at the remote sites. Such as the acquired force value includes not only the interaction force but also the tool gravity. This paper presents a neural network (NN) enhanced robot tool identification and calibration for bilateral teleoperation. The goal of this experimental study is to implement and validate two different techniques for tool gravity identification using Curve Fitting (CF) and Artificial Neural Networks (ANNs), separately. After tool identification, calibration of multi-axis force sensor based on Singular Value Decomposition (SVD) approach is introduced for alignment of the forces acquired from the force sensor and acquired from the robot. Finally, a bilateral teleoperation experiment is demonstrated using a serial robot (LWR4+, KUKA, Germany) and a haptic manipulator (SIGMA 7, Force Dimension, Switzerland).

"Deep-Onto" network for surgical workflow and context recognition

Nakawala H., Bianchi R., Pescatori LE., De Cobelli O., Ferrigno G., De Momi E.

International Journal of Computer Assisted Radiology and Surgery, 11/2018

Surgical workflow recognition and context-aware systems could allow better decision making and surgical planning by providing the focused information, which may eventually enhance surgical outcomes. While current developments in computer-assisted surgical systems are mostly focused on recognizing surgical phases, they lack recognition of surgical workflow sequence and other contextual element, e.g., "Instruments." Our study proposes a hybrid approach, i.e., using deep learning and knowledge representation, to facilitate recognition of the surgical workflow. We implemented "Deep-Onto" network, which is an ensemble of deep learning models and knowledge management tools, ontology and production rules. As a prototypical scenario, we chose robot-assisted partial nephrectomy (RAPN). We annotated RAPN videos with surgical entities, e.g., "Step" and so forth. We performed different experiments, including the inter-subject variability, to recognize surgical steps. The corresponding subsequent steps along with other surgical contexts, i.e., "Actions," "Phase" and "Instruments," were also recognized.

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smartsurg-project.eu

info@smartsurg-project.eu

@SMARTsurg

@SMARTsurg Project

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

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