STIFF-FLOP Newsletter

June 2014 www.stiff-flop.eu

STIFF-FLOP Review Meeting and European Surgical Robotics Demonstration Day, Leuven, Belgium

STIFF-FLOP held their second review meeting at the University of Leuven, Belgium, on 25 and 26 March 2014. After the second year of the project ended in December 2013, the new Project Officer, Dr. Christoph Klein, organised his first review meeting with the STIFF-FLOP consortium. Three reviewers continued to offer their expertise and helped to lead this project to success:

Professor Peter Brett
Brunel University, UK

Dr Ulrich Seibold
German Aerospace Center, GER

Professor Jaydev Desai
University of Maryland, USA

The event was part of a block review meeting with the two other leading EU-funded research projects µRALP and CASCADE.

The First European Surgical Robotics Demonstration Day which was held on 27 March as part of the block review and showed the latest developments of the three projects attracted a lot of interested people for a morning of hands-on demonstrations followed by an afternoon workshop with distinct speakers covering various aspects of surgical robotic technology.

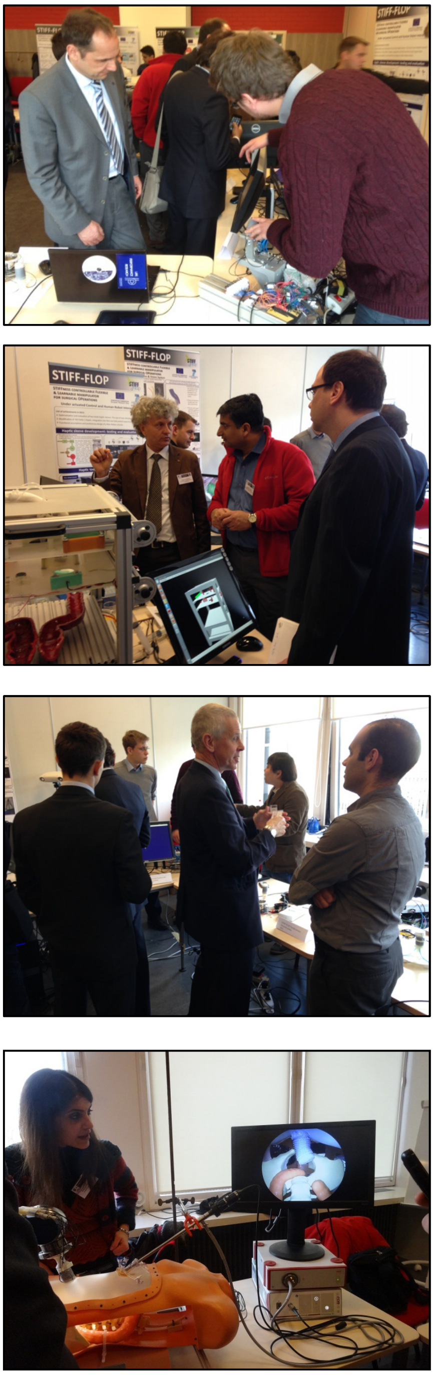

Figure 1: Impressions of the STIFF-FLOP Review Meeting in Leuven, Belgium.

Issues:

For further information about STIFF-FLOP, please contact

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STIFF-FLOP Integration Workshop

After the second review meeting, several workshops have been held at KCL in May and June to integrate hard- and software developed by all STIFF-FLOP partners.

The work focused on the integration of sensors and the fabrication of a STIFF-FLOP manipulator with an integrated stiffening chamber.

A magnetic measurement system has also been integrated in the ROS environment in order to track the pose of each module accurately.

With the support of Shadow, Tecnalia, UoS and IIT integrated their modular control architecture using the new RoNeX interface.

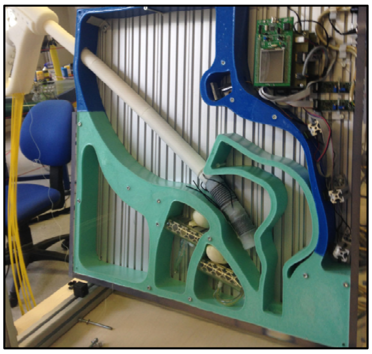

Figure 2: STIFF-FLOP's hand-held device in the 2:1 scale phantom

The 2:1 Scaled Surgery Benchmarking Platforms

Surgical minimally invasive procedures are very complex motion sequences that require a high level of preparation and surgical skill training. New tools developed for the use of new medical procedures also require early tests. Benchmarking is an essential part of the design of prototypes.

The Foundation of Cardiac Surgery Development (FRK) prepared a surgical benchmarking platform for conducting STIFF-FLOP benchmarking experiments.

Benchmarking scenarios have been defined and designed and fabrication of special test rigs and objects (such as phantoms representing organs with variable stiffness) has been carried out.

To model the functions of organic systems such as the cardiovascular or digestive systems, it is necessary to consider anatomical, physical, and physiological properties. There is an additional degree of complexity due to the coupled nature of physiological and physical properties. Two types of test stands have been designed and manufactured:

- Benchmarking platform - reflecting functional characteristics for medical procedures including the obstacle track for training and evaluation of surgical skills.
- Anatomical platform - based on the anatomical model which reflects the real geometry of the human body.

Due to the heterogeneity of the biological material, modelling of mechanical properties of human organs using artificial organ material is very challenging. The selected artificial materials cover the basic range of variability of the mechanical properties of the human body used to simulate the surgical

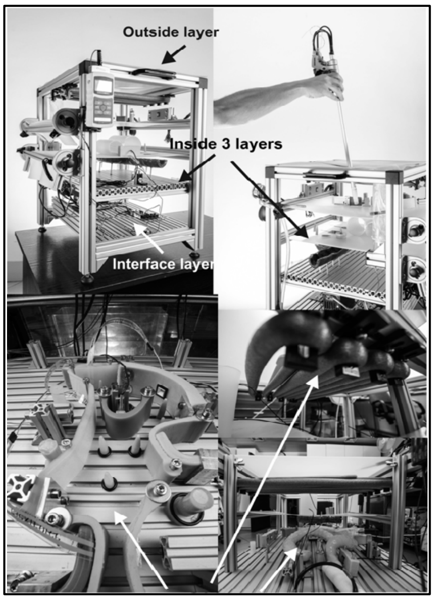

Figure 3: The multi-layer benchmarking platform.

procedures. Our platform fulfils the conditions of second-generation simulators because it describes the anatomy, in particular the geometry of the structures involved in a surgical intervention, and it includes the modelling of the physical properties of living tissues. The introduction of

biomechanical properties to our platforms is essential allowing realistic interactions between surgical instruments and soft tissue, including deformations during basic manual operations like cutting or sewing. Due to large size of the current model of the arm, it was necessary to build platforms in 2:1 scale.
The benchmarking platform (Figure 3) includes - like the anatomical model - a flexible abdominal wall made of silicon. It is fixed by special couplings to the chassis so that it can be freely configured (move, change the number of layers). However, in contrast to the anatomical model, the test platform allows experiments in a freely scalable 3D space (maximum scale of 4:1). The frame of the platform and basis allows the attachment of any organ models and sensors. In addition, we can change the workspace by moving any aluminium profile in x, y and z direction.

The operational area enables us to install some flexible elements to simulate abdominal organs, and contains measuring sensors. Each element can be easily adapted to the need of the benchmarking test. The original solution to our benchmarking platform is the usage of a so-called multi-storey system allowing the free distribution of platform elements in 3D space. This system consists of a number (1 to 3) of additional flexible planes, stretched at different heights and different widths. These planes can play the function of a variety of abdominal organs by attaching the various testing components and also properly formed organs of different shape by cutting (incision). Furthermore, the individual test elements can include sensors. In this way, additional 3D planes (contours, the barrier track, horizontal and vertical curtains) allow modelling a variety of surgical procedures.

To simulate surgical procedures in the lower gastrointestinal tract in these quasi-3D platforms (in 2:1 scale) an additional model was created based on the anatomical shape in sagittal and frontal plane.

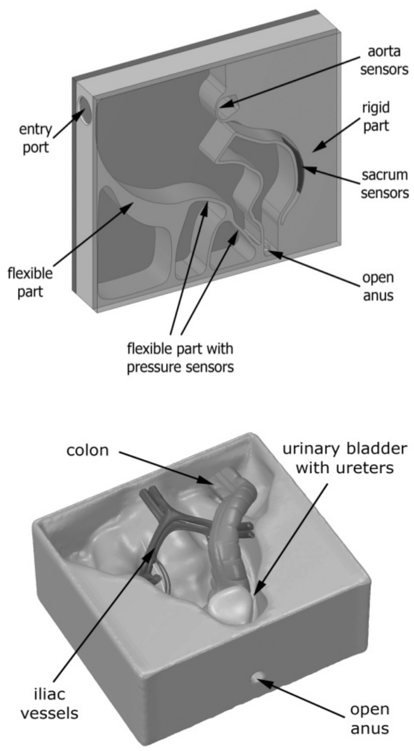

Figure 4: The design of a new anatomical phantom model (scale 2:1) in sagittal and frontal plane.

Figure 5: The final model of a 2:1 scale sagittal plane.

While building our platforms, we paid special attention to the internal geometry of the operating field and functionality of minimally invasive procedures.

That way, we used only generally available materials like silicon and urethane rubber (Contact Smooth-On, Inc.) with different mechanical properties.

(a) Mold Max® 30,
(b) Mold Max® 40,
(c) OOMOO® 30,
(d) Ecoflex® 30 Supersoft Silicone,
(e) VytaFlex® 40, Rebound 25

The main anatomical areas for this model can be applied to:

- Colonoscopy or sigmoidoscopy – for the endoscopic examination of the large bowel and the distal part of the small bowel with optic camera passed through the anus for a visual diagnosis and for biopsy or removal of suspected colorectal cancer lesions.
- Proctocolectomy – for the surgical removal of the rectum and all or parts of the colon.
- Colectomy – for the surgical resection of any extent of the large intestine (Colon resection).

Exciting News from Shadow

Figure 6: Brand new RoNeX modules arrived at the Shadow robot company

Exciting news from Shadow: The first production batch of 200 RoNeX modules have arrived back from our UK based PCB manufacturer, and are now going through production test. So, we have taken to market a spinout product from STIFF-FLOP before the middle of Year 3! For Shadow, this has been a long journey evolving the product with feedback from all the STIFF-FLOP partners, and we are really pleased to be taking this to market!

RoNeX is the product name for integration platform developed in STIFF-FLOP to easily connect all the hardware systems used in the project.

Half of these RoNeX have already been purchased by a Chinese distributor whilst the remainder will be available to purchase directly from Shadow Robot Company.

Shadow has already had pre-orders via its online shop and will start shipping RoNeX to customers in the next couple of weeks.

Find out more at:
www.shadowrobot.com/products/ronex/

Figure 7: The new RoNeX boards stacked together.

Soft Phantom Organs

Soft phantom organs based on CT scans of a human male were fabricated using a combination of gelatine and silicone materials. The 1:1 true to in-vivo anatomy model allows for demonstration of a STIFF-FLOP module reach as well as manipulation of tissue which responds similarly to human tissue at low strain rates. The model flexibility allows for dissection of fatty tissue around the colon (vessel rich mesentery) using a knife or a cautery hook if needed, allowing the demonstration of the colon mobilisation, the critical aspect of rectal resection. This phantom environment can help demonstrate different aspects of the STIFF-FLOP project including motion planning, tip control, and mechanical versatility of the flexible laparoscopic tool.

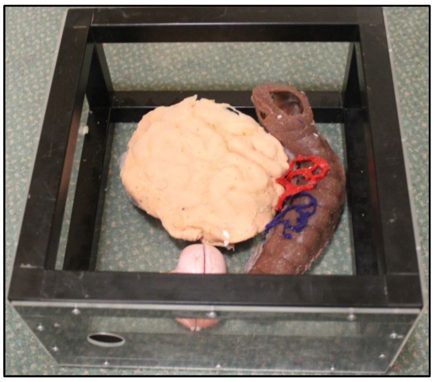

Figure 8: A soft elastic 1:1 phantom environment of the lower abdominal based on CT scans of a male human.

Evaluation of a Magnetic 3D Measurement System for Application in Computer-assisted Surgery

3D measurement systems are essential components for applications in computer-assisted surgery to permanently acquire the spatial position of surgical instruments with regards to the patient's anatomy. The accuracy of these systems is of crucial importance.

Manufacturers only provide guaranteed error limits and only in very few cases error distributions in measurement volumes. This lack of information prevents the use of those systems in several applications. Sahm et al.[1] introduced a tailor made experimental setup to solve this problem for optical 3D measurement systems. It evaluates the accuracy of marker based localisation systems. Their setup aims at providing a low cost and flexible environment to produce sufficiently precise and reproducible data to generate calibration maps for the requested measurement volume. The basis here is a LEGO brick base plate calibrated by a high precision coordinate measuring machine afterwards. This approach seems appropriate because the LEGO system provides well usable equipment with high precision.

The poses of markers at defined positions in workspace have been recorded relative to a fixed marker.

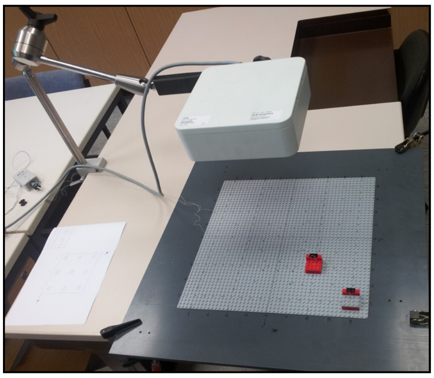

Figure 9: Test setup for accuracy measurements with the magnetic tracking system

Tests have been conducted multiple times for each position in order to eliminate noise. These results were compared to optical tracking systems such as the Axios Cambar B2 and NDI Polaris. We also explored the backlash when introducing objects of different size and material into the measurement volume and investigated a basic calibration based on gathered information.

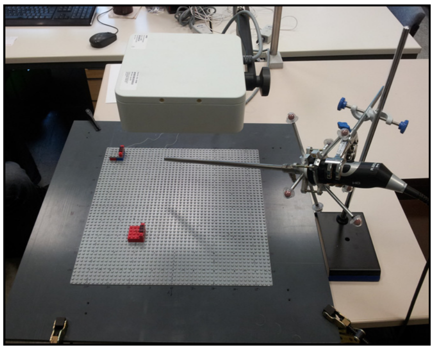

Figure 10: Accuracy measurements with an endoscopic camera in the operation area

The magnetic system has demonstrated stability in the periphery of electromagnetic disturbances like connecting smart phones within the workspace. We were able to identify critical situations when electrically conducting material was placed near the measurement volume. In some cases absolute and relative values showed quite unexpected results that need further investigation.

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[1]Sahm,S.; Kerstein, T.; Scarpin, D.; Roth, H.; Wahrburg, J; "Evaluation of Optical 3D Measurement Systems for Application in Computer Assisted Surgery", tm-Technisches Messen, pp. 379-387, 2013.

Self-Recognition Mechanism between Skin and Suckers Prevents Octopus Arms from Interfering with each other

The Hebrew University (HUJI) research group has recently found and reported (Nesher, Levy et. al., 2014) about yet another unusual motor control mechanism in the octopus. The hundreds of suckers on each octopus arm have a strong tendency to adhere to anything they contact, so after many years of working with the octopus, the team suddenly realized that an important question must be answered: "if octopus arms stick to anything they touch, why don't they stick to each other?" Initially this might seem like a strange question; why would the arms grab each other when the animal does not want them to, and why do these interactions have to be controlled and prevented in the first place? Well, deeper examination of the facts reveals that the octopus brain does not know exactly where its arms are, and what they are doing. This is true because of two reasons: (1) the octopus arm is partially independent, autonomically executing motor programs that are embedded inside its neuromuscular system, and (2) the enormous flexibility of the arms limits the ability of representing their posture inside the nervous system, because there is no finite number of parameters that can accurately represent it. Considering those facts, this question become very reasonable and, in fact, it is unreasonable that no-body thought of asking it until now. To answer the question, researchers began their study with amputated octopus arms that continue to live and behave for more than an hour after amputation. They saw that the arms grabbed anything but other octopus arms, regardless of their origin, the same octopus or another conspecific. At this stage it was clear that there is a built-in mechanism inside the arm that inhibits the attachment reflex of the suckers upon contact with another arm. By peeling the skin off a slice of amputated arm and presenting the skin and the flesh separately to another amputated arm the researchers succeeded in establishing the understanding that the mechanism is triggered by the contact between the skin and the suckers. The amputated arm firmly grabbed the peeled flesh, but avoided grabbing the skin that was stretched over plastic disks. When only part of the plastic disk was cover with octopus skin, the suckers' behaviour was individual, as even neighbouring suckers behaved differently according to the material they contacted, grabbing the plastic and avoiding the skin. At this stage it was yet unclear what the suckers' sense upon contact with the skin; it could have been the texture of the skin for example. The researchers suspected it was something chemical, so they extracted molecules from the octopus skin, using hexane, and embedded them in gel that was used to coat plastic disks. The amputated arm avoided grabbing those disks, confirming the mechanism is based on molecules in the skin. When molecules from fish skin were mixed in the gel instead of molecules from octopus skin, then the amputated arm firmly grabbed the disk with the gel, confirming the inhibition was indeed due to the octopus skin molecules in the gel.

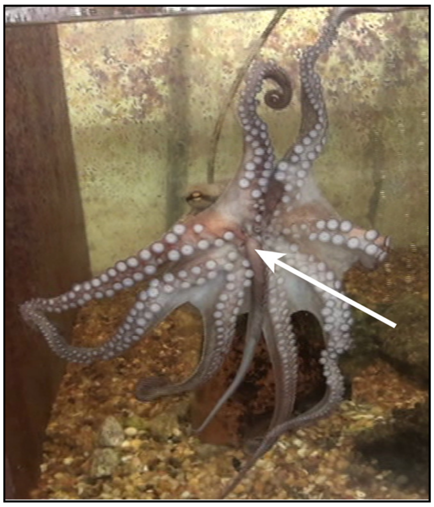

Figure 11: An octopus holding its own amputated arm in the mouth. The amputated arm (pointed by the arrow) was presented to the octopus about 30 minutes after amputation. The octopus avoided grabbing the amputated arm by the skin, and brought it to its mouth by grabbing only the exposed flesh at the amputation site. Now it is holding the amputated arm only at the flesh in the amputation site, and only with its beak, untouched by its arms and web of skin that stretches between them, as it would do with a typical food item.

The HUJI team then wanted to see how this mechanism is integrated in the behaving animal. Since octopuses are cannibalistic, they were offered with freshly amputated octopus arms. Indeed, sometimes the octopuses would snatch the amputated arm and eat it as any other food item. But occasionally, the octopus would display an odd behaviour; it would kind of dance around the amputated arm, pet it, rub it, but avoid grabbing its skin. Then it would sometimes find the exposed flesh at the amputation site and grab the arm only from there and bring it to its mouth, but then hold it only in its mouth, untouched by its arms and web of skin that stretches between its arms. The amputated arm would stay there dangling as spaghetti for a while until dropped. Amazingly, the researchers noticed that octopuses treated their own amputated arms significantly different relative to how they treated amputated arms of other conspecific octopuses. Although it is not entirely conclusive, an octopus would more likely treat an arm of another conspecific octopus as a food item, and more likely treat its own amputated arm not as a food item.

The researchers concluded that a self-recognition mechanism is embedded inside the arm. The basic built-in mechanism in the arm inhibits the attachment reflex of the suckers upon contact between them and the skin. The mechanism is overridden by the brain that can cancel its basic behaviour and force the arm to grab octopus skin after all. One of the brain's considerations is the origin of the skin, self or another conspecific octopus.

The HUJI group suggested that such a mechanism can be embedded in the soft surgical manipulator that is being designed by the STIFF-FLOP consortium. They offered to program the manipulator to recognize and avoid specific materials while the robotic octopus arm is manoeuvring inside a human body, in the same way that the octopus arm is designed to avoid grabbing octopus skin.

Investigation of Different Novel Soft Actuator Designs

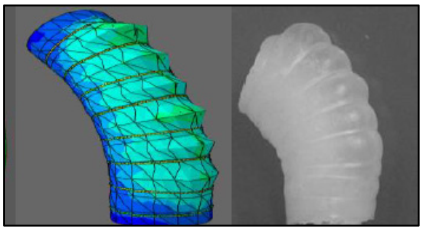

Figure 12: Use of nylon chords embedded in the silicone module to distribute radial expansion in the STIFF-FLOP module.

The University of Surrey (UoS) investigated different novel soft actuator designs that can improve the performance of the robotic actuators including improved integration of sensors that are vital for control as well as the elimination of radial expansion of the hyperelastic rubber material. This was achieved using composite silicone grades and harnesses, allowing for the improvement of functionality while maintaining the flexibility and without hindering the scalability of the stiff-flop module.

FEA was used to investigate the designs before the successful designs were fabricated and tested. The results of some of these investigations will be disseminated at the 2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics.

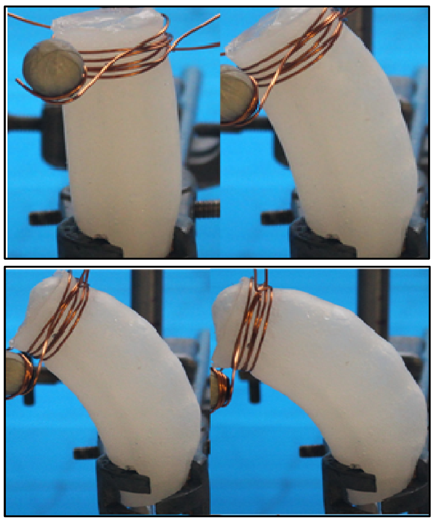

Figure 13: Composite silicone module that allows actuation with greatly reduced radial expansion (only 10-20% increase in diameter for tested combinations compared to 70% for the single material counterpart).

Cognitive Development in Bio-inspired Manipulator

One of the aims of the cognitive modules within the STIFF-FLOP project is to use machine learning tools to control the flexible body of the robot So that the surgeon exclusively concentrates on the tip motion while performing the surgical procedure.

For this purpose, IIT developed the Robot Body Behaviour Control (RBBC) algorithm that is able to learn from demonstrations given by the surgeon what it the appropriate behaviour of the body of the robot. Since this controller is encoded in the null space, it does not interfere with the task space commands and allows the flexible body of the robot to follow a desired path while moving inside a constrained space.

The algorithm exploits the variability of the demonstrations provided by the surgeon to build a statistical model containing both the information about the desired trajectory and the allowed variability, depending on the amount of free space that is present along the desired trajectory.

This statistical model is then used at execution time to extract the desired displacement commands for any point along the kinematic chain that allows the robot body to track the desired trajectory within the demonstrated variability.

This controller is based on a minimal intervention principle, consisting in correcting the behaviour of the robot body only where this is required to fulfil the task.

The algorithm was tested in simulation within a phantom environment on a simple insertion task, consisting in entering inside a cavity with the whole body of the robot. The algorithm was able to exploit the variability to accomplish the task while avoiding hitting the borders.

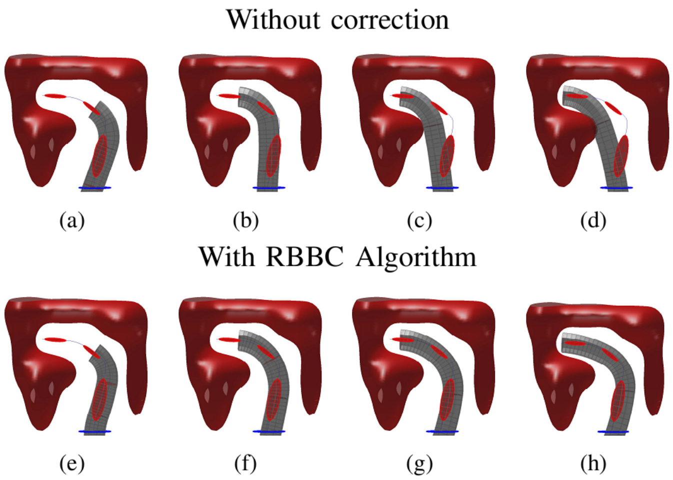

Figure 14: Insertion task: The RBBC algorithm allows the whole robot to enter inside a constrained space, by exploiting the variability where possible and tracking the trajectory precisely where needed.

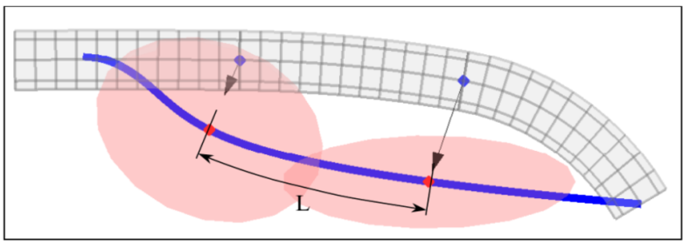

Figure 15: A graphical explanation of the RBBC algorithm. The displacement commands are proportional to the probability of lying outside the demonstrated variability. In this way, the robot is kept near the tracked trajectory only where needed.

14th World Congress on Endoscopic Surgery, Paris, June 25-28, 2014

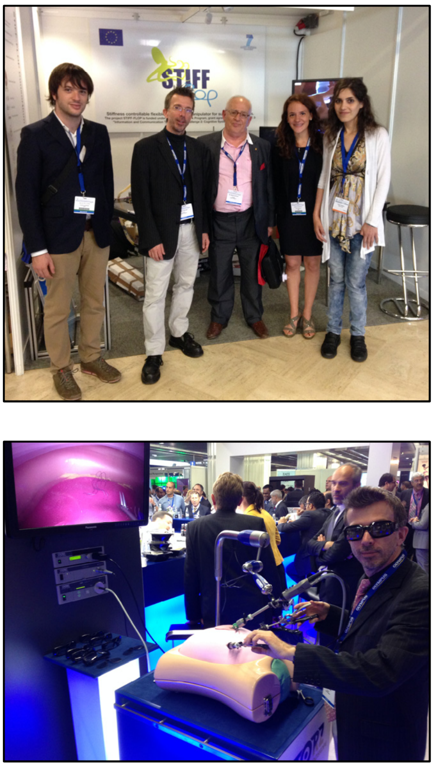

Figure 16: STIFF-FLOP Coordinator Prof. Kaspar Althoefer and Team with Prof. Sir Alfred Cuschieri (top) and Prof. Althoefer testing the 3D laparoscopic surgerical demo of Karl Storz (bottom).

The 14th World Congress of Endoscopic Surgery has been held in Paris from June 25-28, 2014 under the auspices of the European Association for Endoscopic Surgery (EAES), the International Federation of Societies of Endoscopic Surgeons (IFSES) and in conjunction with several other societies, including the SFCE (Société Française de Chirurgie Endoscopique, SAGES (Society of American Gastrointestinal and Endoscopic Surgeons), the Endoscopic and Laparoscopic Surgeons of Asia (ELSA), Asia Pacific hernia society, International Society for Laparoscopic Colorectal Surgery (ISLCRS), Federación Latino Americana de Cirugia (FELAC), and Asociacion Latinoamericano de Cirugia Endoscopica (ALACE).

STIFF-FLOP organised a Technology Symposium which was part of the WCES 2014 and received huge interest from engineering and medical conference participants. STIFF-FLOP will publish presented work of all speakers on **www.STIFF-FLOP.eu**.

Latest STIFF-FLOP results were presented in a provided booth during the exhibition. Medical students from UNITO conducted a survey giving experienced surgeons the opportunity to evaluate the current system.

Professor Sir Alfred Cuschieri (Professor of Surgery at the Scuola Superiore Sant'Anna in Pisa and Chief Scientific Advisor to the Institute of Medical Science and Technology (IMSaT)) visited the STIFF-FLOP stand to meet the STIFF-FLOP team and to experience first-hand the newly developed STIFF-FLOP surgical robot arm.

STIFF-FLOP @ the SCHUNK Expert Days and Robots Live!

KCL has been invited by SCHUNK and the National Museum of Flight, National Museum of Scotland to demonstrate the STIFF-FLOP surgical system. The exhibitions took place on 25-27 February and 15 June respectively.

Media coverage from both events are summarised on

www.Kings-CoRe.com

www.STIFF-FLOP.eu

Figure 17: STIFF-FLOP @ the SCHUNK Expert Days.

ICRA Workshop on Soft and Stiffness-Controllable Robots for MIS

KCL organised a full-day workshop in collaboration with ETH at the 2014 IEEE International Conference on Robotics and Automation (ICRA), Hong Kong on 1 June 2014.

The workshop brought together medical experts active in the field of minimally invasive surgery and roboticists creating and studying soft and stiffness controllable robot devices.

This ICRA 2014 workshop reviewed current technologies used in robot-assisted minimally invasive surgery and explored the current paradigm shift from traditionally rigid surgical tools to robotic systems that are highly redundant, soft and possibly capable of changing their structural stiffness to adapt to surgical needs. The workshop explored the advantages of these new robotic concepts and the challenges that lie ahead to create functional robot systems that can be employed in the operating theatre of the future.

More details on:
icra14-softmedicalrobots-workshop.com

Figure 18: Round table discussion.

8th Excellence in Teaching Conference at King's College London

Figure 19: The HapTEL project team.

Professor Kaspar Althoefer reported on pseudo-haptics developed in the framework of STIFF-FLOP at the Excellence in Teaching Conference at King's College London, 16 June 2014. Pseudo-haptics represent an ideal tool for the training of surgeons, dentists and other clinicians during their studies. Professor Althoefer is currently discussing how haptics and pseudo-haptics can be incorporated into low-cost but effective training tools for medical students. In this context, Professor Althoefer collaborates with Professor Margaret Cox (Professor of Information Technology in Education, King's College London) as part of the HapTEL project to design haptic-based educational tools for dentists and general practitioners.

STIFF-FLOP Presentations at the International Conference on Advanced Robotics and Intelligent Systems (ARIS 2014)

Professor Kaspar Althoefer was invited to attend ARIS 2014 and presented the newest developments of STIFF-FLOP as part of his keynote speech at the conference held at the National Taiwan University of Science and Technology (Taiwan Tech). Professors Chung-Hsien Kuo and Chin-Hsing Kuo (both from Taiwan Tech) expressed great interest to collaborate on innovative medical robotic systems. The paper "A Tactile Palpation Probe using Optical Fibers and Camera System" summarising research on tactile sensors conducted as part of STIFF-FLOP and presented by Professor Althoefer at the conference won the 2nd best paper award.

At ARIS 2014, Professor Althoefer also reported on the granular jamming work being conducted as part of STIFF-FLOP ("The granular jamming integrated actuator" by A. Jiang, S. Adejokun, A. Faragasso, K. Althoefer, P. Dasgupta, T. Nanayakkara).

Figure 20: Distinguished Guests at the International Conference on Advanced Robotics and Intelligent Systems (ARIS 2014).

Tokyo Institute of Technology visiting King's CoRe

Hiroyuki Miyamoto, team member of the Omata and Takayama Lab, gave a seminar presentation on retraction of internal organs which maintains visibility and workspace. Conventional retractors could damage organ tissues due to their limited shape and dexterity. To overcome this problem, an assemblable hydraulic driven hand was presented. Its first prototype is a three-fingered hand of which fingertip joints are water pressure driven. The study experimentally verified the benefits of the hydraulic drive mechanism. That is, it can simplify the structure and can estimate the fingertip load via the measurement of the water pressure. However, sterilization of the piston and the friction caused by the O-rings installed on the pistons remain problems. Therefore, this paper employs silicone rubber bellows for actuation instead of the pistons and develops two types of fingers. One employs a detachable bellows with a case as a replacement of the piston of the first prototype. The other directly drives its fingertip joint with embedded bellows for further simplification of the structure. Experimental results show that both fingers can generate appropriate forces for retraction. For the finger with the embedded bellows, the hysteresis of its fingertip force can be reduced to approximately one tenth compared to the first prototype.

Advances in Real-time FEM for Medical Simulations by Dr. Christian Duriez, INRIA

Dr. Christian Duriez who is working at INRIA on Fast Finite Element Methods, simulation of contact response and other complex mechanical interactions, new algorithms for haptics and soft-robots in SOFA gave a talk at the Centre for Robotics Research, King's College London: In recent years, there is a growing interest for deformable robots, also called soft-robots, which are often inspired by nature. But traditional control methods do not fully apply to such robots, which are composed of an infinite number of degrees of freedom. New control strategies and models need to be found. In another context, in medical simulation, recent research results have demonstrated that we can compute finite element models (FEM) of deformation in real-time, in order to capture the deformations of the soft tissues and the interaction with the surgical instruments.

Conference contributions:

Event:	**Guy Levy (won a travelling award): The 24th Annual Meeting of the Society for the Neural Control of Movement (NCM), Amsterdam, Netherlands**
Title:	Octopuses use unique motor control strategies for arm coordination in crawling
Date:	April 22-26, 2014

Event:	**The Second International Conference on Advanced Robotics and Intelligent Systems, Taipei, Taiwan**
Title:	Variable stiffness robots for minimally invasive surgery: A new paradigm
Date:	June 6-8, 2014

Papers:

J. Konstantinova, M. Li, G. Mehra, P. Dasgupta, K. Althoefer, T. Nanayakkara, "Behavioral Characteristics of Manual Palpation to Localize Hard Nodules in Soft Tissues," Biomedical Engineering, IEEE Transactions on, vol.61, no.6, pp.1651-1659, 2014.

J. Konstantinova, A. Jiang, K. Althoefer, P. Dasgupta, T. Nanayakkara, "Implementation of Tactile Sensing for Palpation in Robot-Assisted Minimally Invasive Surgery," IEEE Sensors, Journal, 2014 – accepted for publication on 10th of May, 2014.

M. Li, H. Liu, A. Jiang, L. D. Seneviratne, P. Dasgupta, K. Althoefer, H. Wurdemann, "Intra-operative tumour localization in robot-assisted minimally invasive surgery: a current review", Proceedings of the Institution of Mechanical Engineers Part H: Journal of Engineering in Medicine, 228(5):509-522, 2014.

H. Xie, A. Jiang, H. Wurdemann, H. Liu, L. Seneviratne, K. Althoefer, "Magnetic Resonance-Compatible Tactile Force Sensor using Fiber Optics and Vision Sensor", IEEE Transaction on Sensors, 14 (3), pp. 829-838, 2014.

M. Cianchetti, T. Ranzani, G. Gerboni, T. Nanayakkara, K. Althoefer, P. Dasgupta, A. Menciassi, "Soft Robotics Technologies to Address Shortcomings in Today's Minimally Invasive Surgery: The STIFF-FLOP Approach", Soft Robotics, 1 (2), pp. 122-131, 2014.

I. Zelman, M. Titon, Y. Yekutieli, S. Hanassy, B. Hochner, T. Flash, "Kinematic decomposition and classification of octopus arm movements", Frontiers in Computational Neuroscience 7, 2013.

B. Hochner, "How Nervous Systems Evolve in Relation to Their Embodiment: What We Can Learn from Octopuses and Other Molluscs", Brain Behavior and Evolution 82:19-30, 2013.

B. Hochner, T. Shomrat, "The neurophysiological basis of learning and memory in an advanced invertebrate – the octopus" in: Cephalopods Cognition edit: A-S. Darmaillacq, L. Dickel, J.A. Mather , Cambridge University Press (in press).

B. Hochner, T. Shomrat, "The Neurophysiological Basis of Learning and Memory in Advanced Invertebrates The Octopus and the Cuttlefish" in: Invertebrate Learning and Memory, in the series, Handbook of Behavioral Neuroscience (Series Editor: Joe Huston, Düsseldorf, Germany), published by Elsevier/Academic Press. Title: Invertebrate Learning and Memory. Editors: Randolf Menzel and Paul R. Benjamin, 2013

S. Calinon, D. Bruno, M.S. Malekzadeh, T. Nanayakkara, D.G. Caldwell, "Human-robot skills transfer interfaces for a flexible surgical robot", Computer Methods and Programs in Biomedicine 116, pp. 81-96, 2014.

N. Nesher, G. Levy, F.W. Grasso, B. Hochner, "Self-Recognition Mechanism between Skin and Suckers Prevents Octopus Arms from Interfering with Each Other", Current Biology 24:1271-1275, 2014.

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H. Xie, H. Liu, K. Althoefer, "A Tactile Palpation Probe using Optical Fibers and Camera System" The Second International Conference on Advanced Robotics and Intelligent Systems (ARIS 2014), Taipei, Taiwan, 2014.

A. Jiang, S. Adejokun, A. Faragasso, K. Althoefer, P. Dasgupta, T. Nanayakkara, "The granular jamming integrated actuator" The Second International Conference on Advanced Robotics and Intelligent Systems (ARIS 2014), Taipei, Taiwan, 2014.

Y. Elsayed, C. Lekakou, C. Saaj, T. Geng, "Design optimisation of soft silicone pneumatic actuators using finite element analysis," 2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, Besançon, France, 2014.

Meetings Abstracts:

A.L. Turchetti-Maia, B. Hochner, T. Shomrat, "NO mediates LTP induction in the learning and memory area in the brains of octopus and cuttlefish", SFN Meeting, San Diego CA, 2013.

G. Levy, B. Hochner, "Coordination of flexible arms in the crawling behavior of the octopus", Society for Neuroscience Meeting, San Diego CA, 2013.

G. Levy, B. Hochner, "Octopus crawling involves a unique strategy for arms coordination", Israel Society for Neuroscience. Dec 14-17, 2013, Eilat Israel, 2013.

G. Levy, T. Flash, B. Hochner, "Octopuses use unique motor control strategies for arm coordination in crawling", Society for the Neural Control of Movement (NCM) Annual Meeting, Amsterdam, Netherlands, 2014.

N. Nesher, G. Levy, F.W. Grasso, B. Hochner, "Self-recognition mechanism between skin and suckers prevents octopus arms from interfering with each other", Society for the Neural Control of Movement (NCM) Annual Meeting, Amsterdam, Netherlands, 2014.

Advisory Groups

A number of advisory groups were set up and colleagues from different scientific backgrounds agreed to be members of these groups and provide advice to the project where required.

Special Interest Group

- Prof. Andreas Melzer, University of Dundee, UK
- Dr. Irion, Dr. Solleder, Dr. Nowatschin, Karl Storz, Germany
- Dr. Shamim Khan, Guy's Hospital London, UK

Peer Review Board

- Prof. Elena De Momi, Politecnico di Milano, Italy and Co-Investigator of EuRoSurge
- Prof K. Schilling, University of Wuerzburg (to be confirmed)

EAES Task Force

- Prof. Alberto Arezzo and Prof. Mario Morino, Digestive, Colorectal, Oncologic and Minimal Invasive Surgery, Department of Surgery, University of Torino, Italy
- Prof. Rajesh Aggarwal, Department of Surgery, Perelman School of Medicine, University of Pennsylvania, USA
- Prof. Yoav Mintz, Director of Center for Innovative Surgery, Hadassah-Hebrew University Medical Center, Jerusalem, Israel
- Prof. Carsten N. Gutt, Department of Surgery, Klinikum Memmingen, Germany
- Prof. Paolo Pietro Bianchi, Unit of Minimally-Invasive Surgery, IEO Istituto Europeo di Oncologia, Milan, Italy

The TASK FORCE for continuous clinical feedback and consultancy was established and the STIFF-FLOP project was presented officially to all members during the 2012 EAES annual meeting (in Brussels, 20-23 June 2012).