Newsletter

June 2013 **www.stiff-flop.eu**

EUROPEAN COMMISSION
European Research Area

SEVENTH FRAMEWORK PROGRAMME

STIFF-FLOP's First Review Meeting Successfully held at IIT, Genoa

Figure 1: The STIFF-FLOP team with the reviewers and project officer at the review meeting in Genoa.

STIFF-FLOP held their first review meeting at IIT in Genoa from April 8th to 10th, 2013 (Figure 1). After the first year of the project ended in December 2012, the Project Officer, Cecile Huet, organised the first review meeting with the STIFF-FLOP consortium. Three reviewers offered their expertise and help to lead this project to success:

- Professor Peter Brett
  Brunel University, UK
- Dr Ulrich Seibold
  German Aerospace Center, GER
- Professor Alon Wolf
  Technion, IL

Figure 2: King's Team demonstrating their research on granular jamming at IIT, Genoa.

During the review meeting, the King's team demonstrated their research on granular jamming in WP1 (Figure 2) and multi-modal sensing research in WP2 (Figure 3).

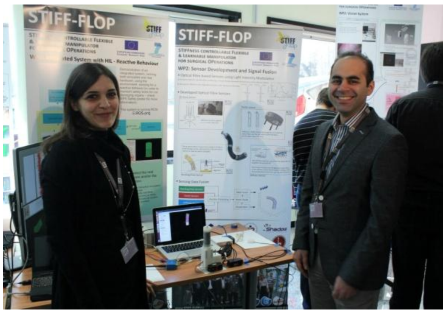

Figure 3: King's Team presenting multi modal sensing at IIT, Genoa.

Issues:

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WP1 - FEA Modelling of the Silicone Module at the University of Surrey

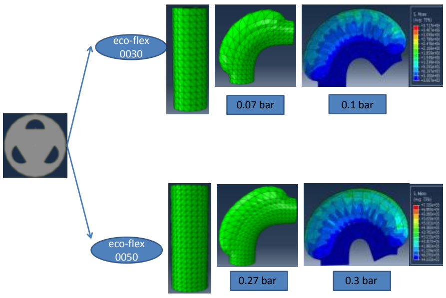

Figure 4: The FEA model simulating the bending angle and the stress analysis of the module fabricated with two different materials

UoS developed the finite element modelling of the silicone chamber under pneumatic pressure actuation using a hyper-elastic material modelling. The FEA model is used to optimise behaviour of the silicone module in terms of bending angle, stress, expansion ratio and amount of free area, in terms of the geometry of the module, materials and channel design. The FEA model is a smart tool for on-going optimisation of the model and acts as a preliminary foundation of future modelling enhancements to include the braided sheath as well as the stiffening mechanism.

WP1 - Research on Different Sheaths at the University of Surrey

Mechanical and physical characterisation of different sheath including PET and Nylon monofilament crimped braided bellow designs. The change of the physical dimensions (maximum width and pitch length) are normalised against initial dimensions while being subject to cyclic mechanical tensile testing at different loading speeds to investigate the hysteresis performance of the different crimped solutions.

Figure 5: Cyclic loading of Nylon monofilament chemically crimped braided sheath.

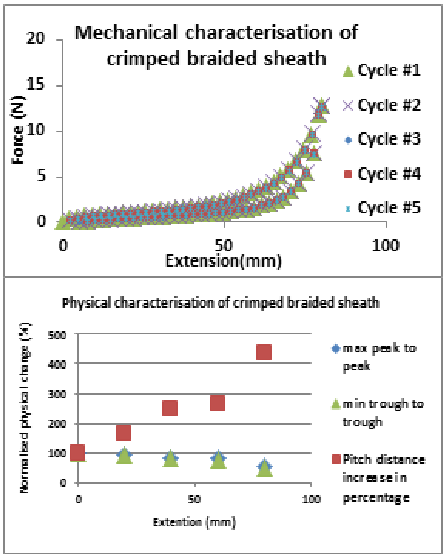

Figure 6: Hysteresis behaviour of the nylon sample and physical behaviour of the sample.

Design of a braiding platform that imitates the May-pole braiding technique, this would allow for the development of braided multi-filament softer sheaths, composite material braiding, as well as the incorporation of other STIFF-FLOP components such as optical fibers within the main sheath to facilitate the integration of components from other partners.

Figure 7: A component of the braiding tool.

WP2: Implemented Bio-Inspired Bending and Stretchable Tactile Sensor for Single Module

Inspired by the nervous system in octopus, which enables bending perception and preferentially located in periphery of the arm, a curvature sensor has been developed at KCL. This new sensor was presented at the 2013 IEEE International Conference on Robotics and Automation (ICRA), and integrated into the STIFF-FLOP arm. This type of sensor exploits light intensity modulation in an arrangement of peripherally-located optical fibres. This allows interpolating the bending radius and the elongation of the manipulator in three-dimension based on the measurements of the arc lengths of the three fibres embedded along the longitudinal axis of the manipulator. Figure 8 shows Hardware-in-the-Loop (HIL) visualization of the STIFF-FLOP arm integrated with the developed curvature sensor.

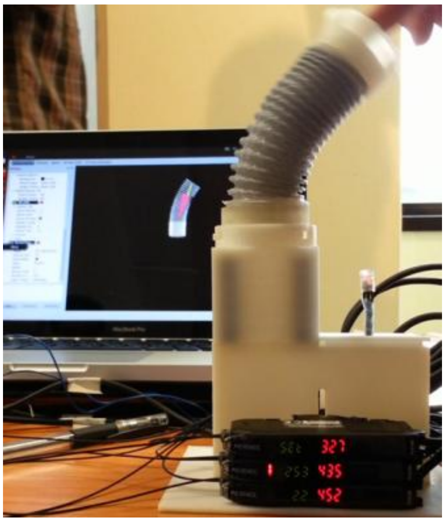

Figure 8: HIL visualization of bending in STIFF-FLOP manipulator, the 3D curvature of the arm.

One of the objectives of the developed STIFF-FLOP soft manipulator is to reconfigure itself and to control its pose to avoid any damage to organs and to provide haptic feedback to the surgeon. The research team from KCL have integrated tactile sensors with the structure of this modern soft flexible tool. This MR-compatible bio-inspired tactile sensor sleeve takes inspiration from the sensing mechanism in cucumber tendrils. In order to acquire tactile signals independent of the soft structure of the actuator during manipulation, retractable hemispherical tactiles were developed based on intensity modulated sensing techniques and distributed along the robot (see Figure 9). Due to the basic structure of a single tactile sensor, it is miniaturiseable and suitable for MIS. Multiple sensors are connected along the arm by a sleeve of a softer silicone material. The main achievement of the developed sensor system is that each tactile sensor independently functions despite of any elongation or bending of the manipulator.

Figure 9: Implemented silicone sensor sleeve with tactile sensors.

WP2 - Implementation of the Position Sensors Data Integration at PIAP

Industrial Research Institute for Automation and Measurements (PIAP) successfully demonstrated the implementation of the position sensors data integration into co-development architecture of the STIFF-FLOP project. The work was done in collaboration with KCL and their development of the sensors itself. The program has been implemented in ROS using the integration board provided by SHADOW.

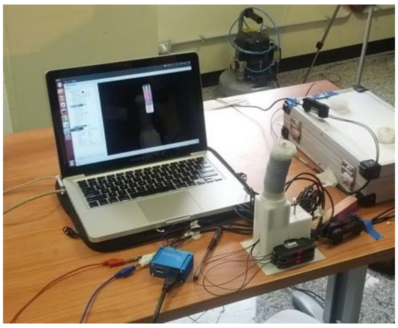

Figure 10: STIFF-FLOP position sensor test-bed, demonstration session at IIT, Genoa.

Current research focuses on implementing the first data fusion approach based on the developed STIFF-FLOP arm models. The algorithm will fuse data obtained from pose sensors with the position determined by measured forces and applied pressure to arm segments.

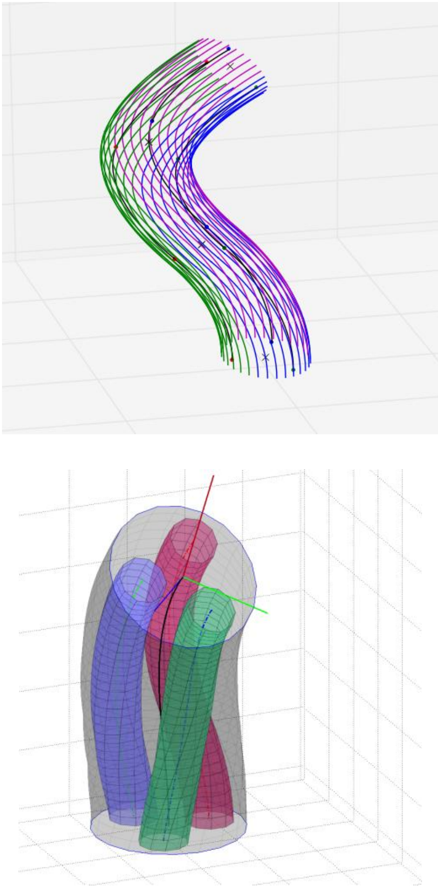

Figure 11: STIFF-FLOP arm position model. First approach (left) was based on three chamber lengths for each module and constant curvature idea. Current position approximation model allows taking into account force applied to segment tip and to determine position and orientation of the structure (right).

The approach chosen by the researchers is to use the model (realised and run in Matlab) as a source of data about simulated module. That data will be streamed to ROS based environment where module position will be calculated following two methods. Firstly, with use of the chamber lengths and, secondly, with use of pressures and forces applied. The idea is to have a real-time testing setup that allows a comparison of positions obtained from different information sources. Further that concept will be developed to perform fusion of two module positions with application of Kalman filters.

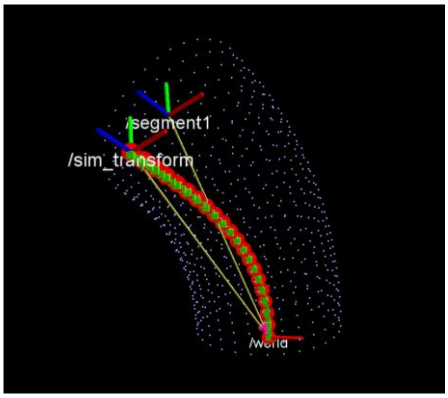

Figure 12: STIFF-FLOP arm position visualized in ROS. The difference between position estimated from chamber lengths ("/segment1") and simulated position of the module deformed by the force applied to the tip ("/sim_transform") is visible.

WP3 – Skill Transfer Across Robots

One of the aims of cognitive development in the STIFF-FLOP project is to transfer skills from doctors to the flexible robot, so that the latter can automously assist the surgeons during operations. A joint work between IIT and KCL resulted in the development of new algorithms to transfer skills across robots of different embodiments, by means of machine learning techniques.

Robot learning covers techniques ranging from imitation to self-refinement strategies. Imitation similarly encapsulates a wide spectrum of techniques from "blindly" copying the actions demonstrated by a human operator to the understanding of the key goals and intents underlying the demonstrations.

Our approach, at the crossroad of inverse optimal control and inverse reinforcement learning, is to extract a context-dependent reward function from demonstrations and search for a controller that would maximize this reward function.

We have developed a learning strategy based on a set of predefined candidate reward functions, used to extract from the user controlling the robot how the different rewards are relevant for different parts of the task.

The experiments were performed by using an Inverse kinematics solver of the STIFF-FLOP robot, developed by IIT. It is based on the hypothesis that the single modules of the manipulator behave as constant curvature sections. The developed Inverse Kinematics technique allows controlling the position and the orientation of the tip of the robot by changing the bending and the elongation of 3 concatenated modules. The redundancy of the robot can be exploited in various learning scenarios, such as obstacle avoidance or performing precise configuration control.

As an example, the task of sequentially passing through a given number of points in the robot workspace was studied, requiring that the robot's body avoids hitting an obstacle. The task was demonstrated using a conventional Barrett WAM 7 DOFs rigid-links manipulator.

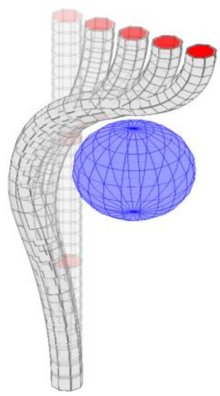

Figure 13: Exploitation of the redundancy to avoid an obstacle using Inverse Kinematics.

The extracted reward function was used to incrementally refine the task using the STIFF-FLOP Inverse Kinematics solver. As a result, the robot was able to refine the task and reproduce it without hitting the obstacle.

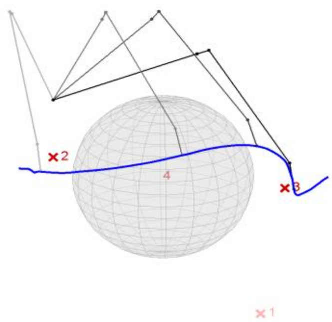

Figure 14: Demonstration of the task using a Barrett WAM arm.

The developed learning algorithm enables the robot to search for its own way of fulfilling the underlying goals of the task. An interesting property is that the model works with suboptimal demonstrations, thus providing a self-refinement mechanism that can go beyond the demonstrated skills.

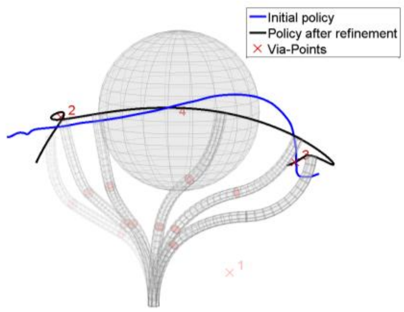

Figure 15: Task learnt by the STIFF-FLOP robot.

WP4 - Advancements in the Development of the Control Algorithm at the University of Surrey

Figure 16: Demonstration session at IIT, Genoa

University of Surrey (UoS) successfully demonstrated the implementation of the low level pressure control and middle level control using the inverse kinematics model using 3D joystick control using a single STIFF-FLOP module. Further we demonstrated the integration of the tactile sensor from partner KCL and how the manipulator responds to reflexes. This was implemented in ROS using the integration board provided by SHADOW.

Current focus is on implementing the low level control using the Vicon tracking system in ROS, refining the kinematics and dynamic models and extending the utility of the control algorithms for two integrated modules of the three chamber pneumatic controlled tubes from partner SSSA.

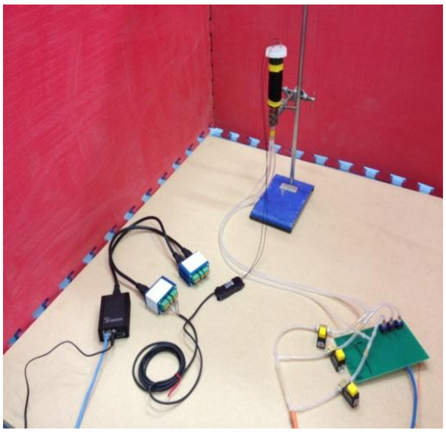

Figure 17: STIFF-FLOP Real-time control test-bed.

We are currently implementing the following tasks:

(1) We are investigating one analytical modeling method, Linear Parameter-Varying (LPV) model, with our single module. It's a systematic method for obtaining the nonlinear controller in a linear-like fashion. Meanwhile, we are also looking at the physical model proposed by PIAP that explicitly involves the internal force and external forces of the single module. We are trying to identify the parameters of this model using our recorded data.

(2) As for the controller, we are designing the high level control algorithm that can deal with the disturbances caused by the environment/movements of the modules.

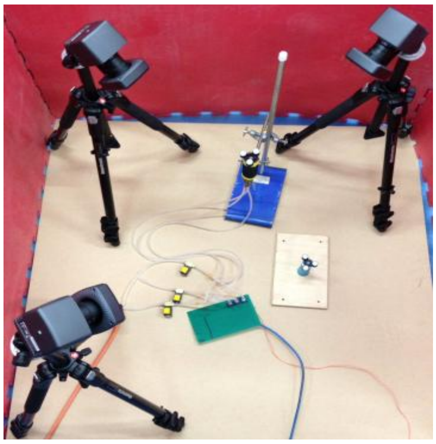

Figure 18: Vicon tracking system integrated test-bed for 3D joystick control.

WP5 - Advancements on the Development of a Benchmarking Platform

We have been advancing on the development of a benchmark platform that will be used to assess the capacities of the robotic arm itself. This evaluation is intended to take place before considering a more complete evaluation of the whole system that will be performed using a more realistic test rig reproducing the human body and the complete surgical operation site, system that is currently developed by FRK.

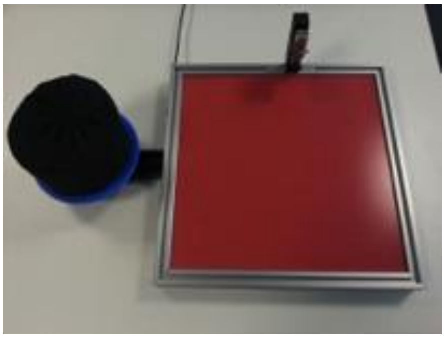

Figure 19: The Robotic arm benchmarking setup: complete system, with the instrumented planar plate (in red), the load cell used to measure the interaction force onto the variable stiffness structure on the left side and the push/pull sensor on the center of the top side of the planar plate.

The system illustrated on Figure 19 is intended to assess the embedded intelligence in the arm: can the robot change its shape to minimize the contact measured with an organ? Can it monitor that interaction with environment while moving on a predefined path? Can it still maintain a sufficient force level at the tip ? All these questions can be assessed with this first benchmarking platform. The latest version of the platform contains 3 different sensing means. The first one corresponds to a sensorized plate that permits to detect and locate a contact point while estimating the interaction force. This can be used to check the capacity of the arm of following a given trajectory while producing a given force with its tip. The second one is a push-pull module that can be used to analyze the contact force the arm can produced at a specific point in both directions. The third one is a variable stiffness structure mounted onto a load cell. The variable stiffness is obtained by the use of Var-Stiff technology that permits to control the rigidity of a sheet-like material which stiffness depends on vacuum pressure of a sealed material pouch. This stiffness of the external perimeter of that simple phantom can thus be changed online by regulating the vacuuming, and the behavior of the robotic arm can be analyzed while interacting with such system. The interaction force in between that element and the arm is estimated by the load cell located bellow. This can be used to assess that the arm, while moving around that structure, is not realizing a contact force to high, according to the specifications defined.

This benchmarking platform is designed to be scalable and adjustable. The placement of the different components onto the planar plate can be adjusted at will, and the plate dimensions could be changed with limited cost. Furthermore, any type of object could be considered as obstacle, replacing easily the variable stiffness element: as the next figure illustrate the interaction forces can be still measured with any structure (up to real organ) that can be rigidly connected to the sensing element.

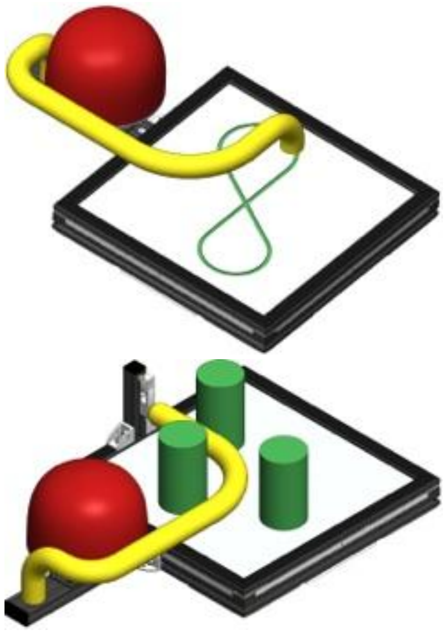

Figure 20: Illustration of the experiments that can be performed with the platform (the yellow tube representing the arm): reproduction of a given contact trajectory onto the plate, while avoiding or limiting the interaction with an obstacle ; reaching a desired pushing or pulling site while avoiding various elements in the environment.

The evaluation of the robotic arm behavior and capacities will be a first assessment that could provide some important insights about the readiness of the arm to be inserted into a complete surgical platform and to be operated by surgeons.

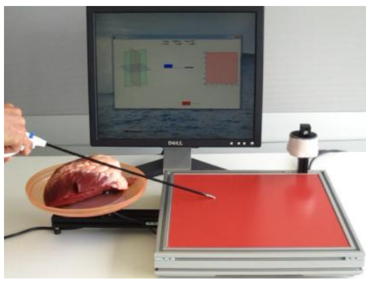

Figure 21: The sensed obstacle site (on the left) can be easily configured to receive any kind of element to consider various type of interaction: here a real calf heart is presented as an illustration.

SSSA: Performance of a STIFF FLOP Module

The Scuola Superiore Sant'Anna (SSSA) worked on the characterization of the STIFF-FLOP module, in particular on the omni-directional bending, the elongation, the stiffening mechanism and its integration in the complete module. Siliconic materials have been mechanically characterized with tensile and compression tests in order to evaluate the stress-strain behavior. This study has allowed to choose the Silicone Ecoflex 0050 for the fabrication of the soft module.

The elastomeric single unit of the STIFF-FLOP manipulator has a cylindrical structure with a diameter of 25 mm and a height of 50 mm. It hosts three equally spaced semi-cylindrical chambers which are embedded in radial arrangement (the fluidic actuators) and a channel centrally placed (for the granular jamming) (Figure 22). When the chambers are inflated they tend to expand in every direction.

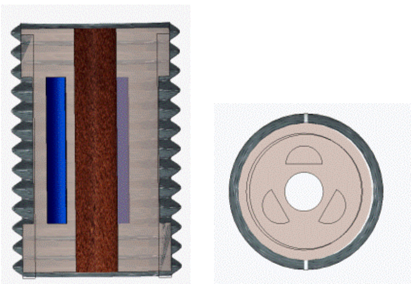

Figure 22: Sketch of the longitudinal and transversal cross section design that includes three pneumatic chambers, one stiffening channel and the external braid.

In order to limit the radial extension, the module is externally provided with a braided bellow-like structure. The pneumatic actuation of a single or a couple of chambers allows the omnidirectional bending, while the activation of all three chambers results in an elongation of the module. The central chamber is dedicated to the granular jamming mechanism which allows a variation of stiffness whenever necessary. The chamber includes a latex membrane within granular materials. When the vacuum is applied the density inside the flexible membrane increases and the stiffness can be tuned thus controlling the vacuum level (Figure 23).

Figure 23: Stiffening membrane in the states of vacuum OFF and vacuum ON.

The STIFF-FLOP module has been characterized in terms of bending and elongation. Fluidic chambers have been actuated singularly, in pairs and all at the same time from 0 to 0.65 bar. Tests on bending performance have demonstrated the possibility to reach a bending angle of 120 deg when a single chamber is inflated and 80 deg in a middle direction when two chambers are simultaneously actuated (Figure 24).

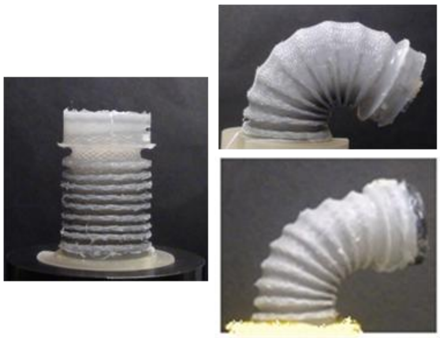

Figure 24: Bending performance from initial configuration pressurizing one and two chambers.includes three pneumatic chambers, one stiffening channel and the external braid.

Elongation tests have demonstrated that a final length of 83.3 mm is achievable, corresponding to an elongation of 86.3 % respect to the initial chambers length (Figure 25).

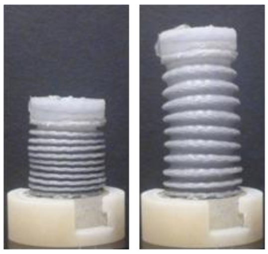

Figure 25: Elongation of the module of 86.3 % respect the initial length.

The force developed has been measured positioning a load cell at the top of the module. Tests demonstrated that one single chamber is able to generate 24.6 N increasing almost linearly respect to the input pressure. In the case of three chambers activated, the force reaches higher values up to 41.4 N which perfectly meets the requirements identified for the specific application (Figure 26).

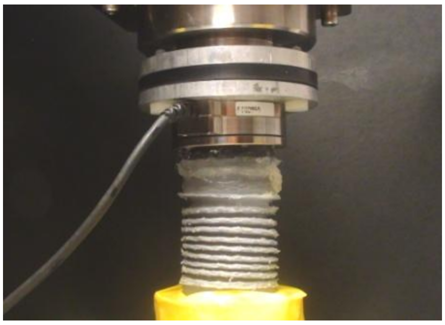

Figure 26: Set up used to measure the force at the top of the module with a load cell.

Stiffening capabilities have been evaluated imposing controlled displacements with a robot and applying 1.5 psi vacuum pressure in the central membrane. The stiffness variation has been recorded in different directions with a load cell by measuring a maximum increase of 36 %.

The squeezing of the module was assessed by manually compressing the module along the radial direction and measuring a decreasing of 40% in the resulting diameter.

The STIFF-FLOP Project at the Cheltenham Science Festival 2013 and the Work Foundation 2013 Annual Debate

Figure 27 : Min Li from King's College London, Centre for Robotics Research demonstrating the Virtual Palpation Environment at the Cheltenham Science Festival 2013.

Members of the Centre for Robotics Research (CoRe) attended the Cheltenham Science Festival 2013 and presented their most recent research results, including advancements achieved as part of STIFF-FLOP (virtual palpation environment and granular jamming). The King's booth was in "The Times Area 42" tent; researchers Liza Kostantinova, Min Li, Allen Jiang and Dr Thrishantha Nanayakkara presented the project to the audience - the Times tent was open to members of the general public aged 14 years old and older. The presentations were a great success: during the 3 days of the festival, the King's team attracted more than 600 festival participants, who were keen to hear about the robotics research at King's. Many more participants took informational pamphlets highlighting the research relating to STIFF-FLOP and other areas of CoRe that were also presented at the Festival, including the DARWIN project, the DARPA robotics Challenge, and Khepera mobile robots as a tool for teaching (Figure 27).

The robotics team from KCL was also invited to show their research on STIFF-FLOP at the Work Foundation 2013 Annual Debate: Will robots and enhanced humans steal our jobs? (Figure 28).

Figure 28: Hongbin Liu, Sina Sareh, Min Li and Ranzani Tommaso (SSSA) at the Work Foundation 2013 Annual Debate: "Will robots and enhanced humans steal our jobs?"

Keynote Speech at the 2013 International Congress of the EAES, Austria

The EAES invited the STIFF-FLOP Project Coordinator Prof. Kaspar Althoefer to give a keynote speech at their 2013 International Congress. Prof. Althoefer was talking about "Flexible Robot Manipulators for MIS: Initial Developments and Considerations" (Figure 29). After being one 18 months into the STIFF-FLOP project, the latest developments were presented to the European endoscopic surgeons. Hence, Prof. Althoefer emphasized on the benefits of the flexible and soft STIFF-FLOP manipulator to the traditional rigid laparoscopic and robotic keyhole surgery. STIFF-FLOP's novelties such as the intelligent control and learning as well as the sensing system were part of his lecture.

Figure 29: Kaspar Althoefer at the 2013 International Congress of the EAES.

STIFF-FLOP/SAFROS Joint Safety Workshop at the 2013 Hamlyn Symposium on Medical Robotic

This workshop aimed at summarizing the results and on-going discussions within some of the EU-funded projects in robotic surgery, such as SAFROS, STIFF-FLOP, Active and µRalp. Although patient safety in all types of surgery seems an obvious concept, the close examination of patient safety in the specific case of robotic surgery raises a number of concerns. The validity of these concerns is demonstrated by the steady growth of lawsuits brought against the manufacturer of surgical robots by patients injured during robot-assisted procedures. Safety in surgical procedures involving high technology devices is a system issue that cannot be solved by optimizing only one, or few, elements involved in the procedure. The optimal balance may be achieved by a combination of factors, including technology management, training, logistics, and concentration of robotic procedures into centers of excellence.

Publications and Press

Conference contributions:

Event: **Intl Conf. on Robotics and Automation (ICRA), Workshop on Semantics, Identification and Control of Robot-Human-Environment Interaction, Karlsruhe (Germany)**
Title: How to improve the generalization capability in imitation learning?, *Sylvain Calinon*
Date: May 10, 2013

Event: **International Conference on Machine Learning (ICML), Workshop on Robot Learning, Atlanta (USA)**
Title Robot learning by imitation with probabilistic dynamical systems, *Sylvain Calinon*
Date: June 20, 2013.

Event: **Distinguished Lecture, King's College London (United Kingdom)**
Title: Robots – Are They Intelligent Yet?, *Kaspar Althoefer*
Date: April 22, 2013

Event: **2013 International Congress of the EAES, Austria**
Title: Flexible robot manipulators for MIS: Initial developments and considerations, *Kaspar Althoefer*
Date: 2013

Event: **The Hamlyn Symposium on Medical Robotics, London (United Kingdom)**
Title: STIFF-FLOP - An inherently safe approach to MIS: Challenges and initial developments, *Kaspar Althoefer*
Date: 2013

Event: **2013 International Workshop on Soft Robotics and Morphological Computation, Switzerland**
Title: MR-compatible Bio-inspired Soft Manipulator with Stretchable Sensing Sleeve for RMIS, *Matteo Cianchetti, Helge Wurdemann, Arianna Menciassi, Kaspar Althoefer, Thrishantha Nanayakkara*
Date: July 14-19, 2013

Event: **Workshop on Technology Transfer and Innovation in Robotic Surgery. European Robotics Forum, Lyon (France)**
Title: What does the digestive surgeon need and expect from a robot?, *Alberto Arezzo*
Date: March 19, 2013

Event: **Annual Meeting of the European Surgical Association (ESA), Beaune (France)**
Title: SYSTEMATIC REVIEW AND META-ANALYSIS OF ENDOSCOPIC SUBMUCOSAL DISSECTION VERSUS TRANSANAL ENDOSCOPIC MICROSURGERY FOR NON-INVASIVE LARGE RECTAL LESIONS, *Alberto Arezzo*
Date: April 12/13 2013

Event: **2nd Joint spring meeting NE Thames ACPGBI Chapter and SICCR, S Vito al Tagliamento (Italy)**
Title: New trends in minimally invasive surgery (VL-NOTES-Robot), *Alberto Arezzo*
Date: April 19, 2013

Event: **IEEE International Conference on Robotics and Automation, Karlsruhe (Germany)**
Title: Surgical robotics practice. Evaluating effectiveness and acceptance of robots in surgery: user centered design and economic factors, *Alberto Arezzo*
Date: March 6, 2013

Event: **Trattamento multidisciplinare del carcinoma colorettale: aspetti innovativi, Torino (Italy)**
Title: Linfonodo sentinella nella chirurgia colorettale, *Alberto Arezzo*
Date: March 28, 2013

Event: **VII International Conference "Russian School of Colorectal Surgery", Moskow (Russia)**
Title: Basic skills in laparoscopic colorectal surgery. Course LAPAROSCOPIC COLORECTAL SURGERY: FROM BASICS TO EXPERTISE, *Alberto Arezzo*
Date: March 28-29, 2013

Event: **VII International Conference "Russian School of Colorectal Surgery". Moskow (Russia)**
Title: Future of miniinvasive colorectal surgery - TEM, single-port, robotics and other. Course LAPAROSCOPIC COLORECTAL SURGERY: FROM BASICS TO EXPERTISE, *Alberto Arezzo*
Date: March 28-29, 2013

Event: **VII International Conference "Russian School of Colorectal Surgery". Moskow (Russia)**
Title: New technologies in Colorectal Cancer surgery, *Alberto Arezzo*
Date: March 30-31, 2013

Event: **Technology Symposium. 21st International Congress of the European Association for Endoscopic Surgery, Vienna (Italy)**
Title: The flexible endoscope as a tool for colorectal surgery, *Alberto Arezzo*
Date: June 19-22, 2013

Event: **21st International Congress of the European Association for Endoscopic Surgery,**
Title: TEM vs ESD: a review. Postgraduate course 2. Colon and rectal surgery, *Alberto Arezzo*
Date: June 19-22, 2013

Event: **21st International Congress of the European Association for Endoscopic Surgery, Vienna (Italy)**
Title: MUSIC Study – an update on EAES granted trial, *Alberto Arezzo*
Date: June 19-22, 2013

Papers:

Rimonda R, Arezzo A, Arolfo S, Salvai A, Morino M. **"TransAnal Minimally Invasive Surgery (TAMIS) with SILS™ Port versus Transanal Endoscopic Microsurgery (TEM): a comparative experimental study".** Surg Endosc. 2013 May 1. [Epub ahead of print]

Arezzo A, Zornig C, Mofid H, Fuchs KH, Breithaupt W, Noguera J, Kaehler G, Magdeburg R, Perretta S, Dallemagne B, Marescaux J, Copaescu C, Graur F, Szasz A, Forgione A, Pugliese R, Buess G, Bhattacharjee HK, Navarra G, Godina M, Shishin K, Morino M. **"The EURO-NOTES clinical registry for natural orifice transluminal endoscopic surgery: a 2-year activity report".** Surg Endosc. 2013 Mar 22. [Epub ahead of print]

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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).