Newsletter

December 2014 **www.stiff-flop.eu**

Block Review Meeting at King's

Following in the footsteps of the successful block review meetings organized by IIT in 2013 and University of Leuven in 2014, King's College London is organising the next block review meeting for the four EU FP7 projects STIFF-FLOP, µRALP, ReMeDi and CASCADE to take place in the w/c 16 March 2015. The 2015 block review meeting will be complemented by the Surgical Robotics Forum organised in collaboration with Innovate UK (RAS SIG). At the Forum, distinguished speakers will talk about requirements in MIS and their experiences with robot-based surgical technology. This event will bring together people from the medical field, robotics engineers and researchers with entrepreneurial expertise.

The 2015 Surgical Robotics Forum British Science Festival will be held in the Cavendish Conference Venue, 22 Duchess Mews, London W1G 9DT, on 18th March 2015. For more information and how to register please go to: http://www.stiff-flop.eu/the-project/block-review-meeting-2015.

Demonstration of the integrated STIFF-FLOP system at King's CoRe

Figure 1: STIFF-FLOP Reviewer Prof. Peter Brett, Brunel University, examines the integrated system.

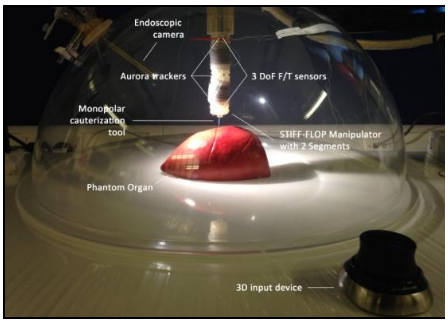

Figure 2: Position and F/T sensors and a cauterization tool at the tip are embedded in a two-segment STIFF-FLOP manipulator.

The STIFF-FLOP consortium successfully demonstrated an integrated STIFF-FLOP system in September 2014. Prof. Peter Brett (Reviewer) visited the CoRe Lab at King's College London to examine the latest progress (see Figure 1).

After the second review meeting in April 2014, consortium members have been working together at the Centre for Robotics Research, King's College London to create a fully integrated STIFF-FLOP manipulator:

Issues:

For further information about STIFF-FLOP, please contact

Kaspar Althoefer
k.althoefer@kcl.ac.uk
+44 (0)20 7848 2431

The structure of the manipulator was changed incorporating an inner channel. Hence, pneumatic pipes, cabling for the tip sensor and the cauterization tool could be fed through this channel.

The STIFF-FLOP consortium was able to show cauterization tasks where soft tissue is separated using heat generated by high-frequency electric currents. Using a 3D mouse, the tip of the manipulator can be controlled in position and orientation. The operator can observe the pose of the STIFF-FLOP robot through the view of an endoscopic camera and in the ROS visualisation based on real pose data.

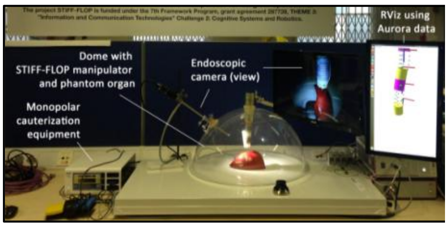

Figure 3: The overall STIFF-FLOP system consists of an endoscopic camera, an RViz visualisation and the integrated STIFF-FLOP manipulator.

Inflatable robot at King's CoRe

King's CoRe has explored a new hybrid actuation principle combining pneumatic and tendon-driven actuators for a soft robotic manipulator. The fusion of these two actuation principles leads to an overall antagonistic actuation mechanism whereby pneumatic actuation opposes tendon actuation – a mechanism commonly found in animals where muscles can oppose each other to vary joint stiffness. Inspiration has been taken from the octopus who belongs to the class of Cephalopoda; the octopus uses its longitudinal and transversal muscles in its arms to achieve varied motion patterns; activating both sets of muscles, the octopus can control the arm stiffness over a wide range.

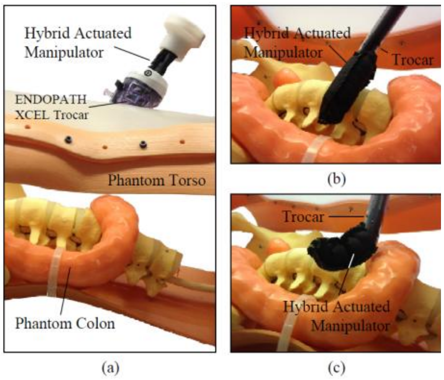

Figure 4: The manipulator is squeezed through an ENDOPATH XCELTrocar of 18mm diameter

The approach mimics this behaviour and achieves comparable motion patterns, including bending, elongation and stiffening. It combines the advantages of tendon-driven and pneumatic actuated systems and goes beyond what current soft, flexible robots can achieve: because the new robot structure is effectively an inflatable, sleeve, it can be pumped up to its fully inflated volume and, also, completely deflated and shrunk. Since, in the deflated state, it comprises just its outer "skin" and tendons, the robot can be compressed to a very small size, many times smaller when compared to its fully-inflated state. This work was presented at IROS 2014.

British Science Festival

In September 2014, the British Science Association held the British Science Festival in Birmingham, in partnership with the University of Birmingham and in association with Birmingham City Council and Birmingham City University and our headline sponsor Siemens. During this year's Festival, STIFF-FLOP was demonstrated as an example for research at the forefront of scientific and technological advancement.

Figure 5: STIFF-FLOP at the british science festival in september 2014

Biologically inspired probabilistic models for transferring skills

Biological inspiration within the STIFF-FLOP robot aims at learning from the octopus strategies to control the highly redundant arm. Motions such as reaching for food can be used to test the representation capability of the developed model, which could then be re-used to encode other types of skills within the surgical environment.

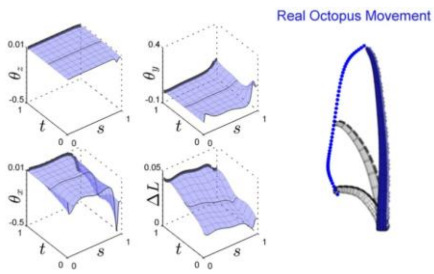

Figure 6: Octopus reaching movement. The black lines on the surfaces show configurations at 3 time steps, with the corresponding pose in Cartesian space.

The first step was to create a procedure that is able to transfer skills between the two different embodiments and is capable of faithfully reproducing observed octopus movement. For this purpose, a set of data from different reaching movements performed by different animals was collected and analyzed by HUJI and exploited by IIT to create a statistical model of the movements.

This motion was then transferred to the STIFF-FLOP robot, by exploiting the modular structure of the arm and a self-refinement procedure that improves the movement, by taking into account some predefined reward functions. This result shows that the statistical model, could be used to reproduce a very similar movement on the STIFF-FLOP robot after a short self-refinement learning process.

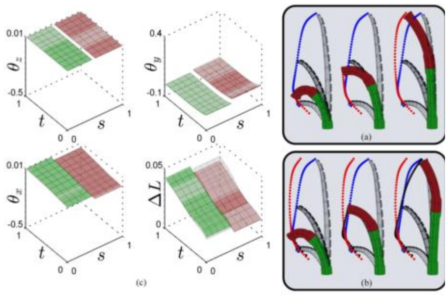

Figure 7: Qualitative comparison of the octopus and STIFF-FLOP robot movements, before (a) and after (b) self-refinement.

The next step will be that of exploiting the developed encoding strategy to perform different motions that are useful for the surgical application. The key aspect of the proposed approach is the possibility of reusing parts of the skill that have been learned for a different category of tasks, by exploiting the correlations and synergies extracted from the movement.

Optimization and evaluation of the multi modular manipulator

Scuola Superiore Sant'Anna (SSSA) worked on the optimization and performance evaluation of the multi-module STIFF-FLOP manipulator. The final aim was to develop a modular manipulator, which exploits its entire length to actively interact with the biological structures in the MIS (Minimally Invasive Surgery) theatre.

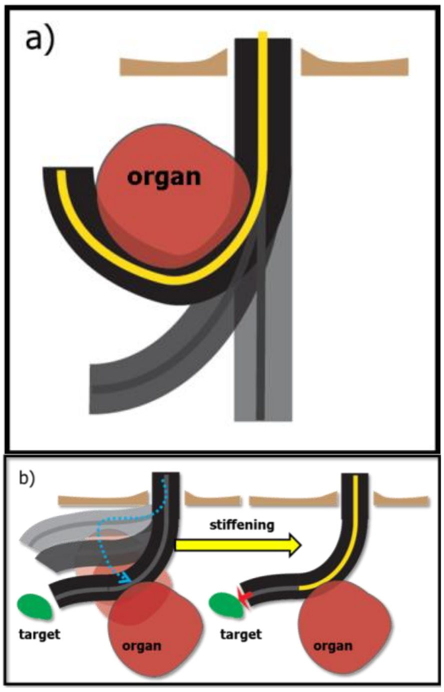

Figure 8: Surgical tasks performed by a tentacle-like stiffness controllable structure. a) Organ retraction, showing the manipulator grabbing and lifting up of the organ. b) Fitting in tiny spaces, shifting down of an organ with the base portion and reaching the surgical target with the distal module. The yellow line indicates the stiffening of the manipulator portion.

Fig.8 proposes a schematic example of that objective: a generic multi-steerable manipulator (in black) can navigate between organs, orientate its tip to properly approach the target, and also modulate the stiffness along its body to withstand the weight of another organ and keep it aside. Such capability would be particularly helpful surgery since it offers the possibility of accomplishing two tasks in one go (for example the retraction of one soft-tissue organ and the manipulation of another organ) by using the same instrument.

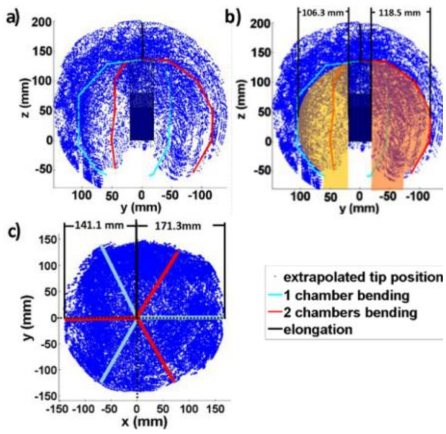

Figure 9: Workspace of the two module manipulator. a) Section of the workspace along the x plane, lateral view. b) Section of the workspace with highlighted the unreachable areas. c) Top view of the work-

The main focus of the research was firstly the assessment of the dexterity of a 2-module manipulator embedding the actuation and a separate stiffening mechanism in each module. The workspace of the 2-module manipulator was experimentally evaluated by tracking different points along the STIFF-FLOP manipulator using the AURORA magnetic tracking system. Fig. 9 shows the extrapolated workspace of the manipulator.

Two different types of tests were carried out to evaluate the forces exerted by the manipulator exploiting the selective stiffening of its body. One test measured the force exerted by the STIFF-FLOP manipulator's tip on a F/T sensor in two different situations: firstly the stiffening was applied to the proximal module while the distal module was actuated against the F/T sensor (Fig.10a), secondly the proximal module was actuated to push the stiffened distal module against the F/T sensor (Fig.10b). For this test the vacuum level for inducing the stiffness of the related module was set to three different values (no stiffening: 0 MPa; partial stiffened: -0.052 MPa, fully stiffened: -0.098 MPa).

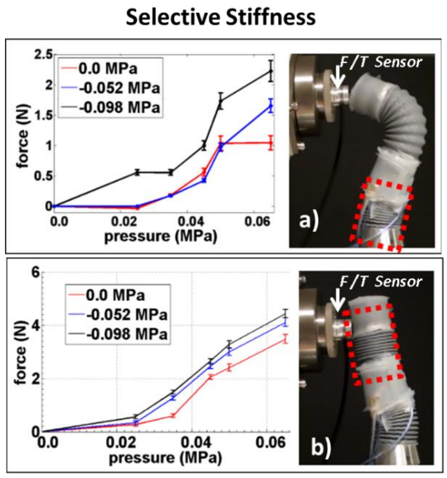

Figure 10: Results from the testing on the combination of actuation and stiffening (highlighted with the dashed square). a) Stiffening of the base module and actuation of the distal one. b) Stiffening of the distal module and actuation of the base one.

The second types of tests aimed at exploiting the stiffening capabilities together with the possibility to generate forces in a more surgery-like scenario. Although the previous described test provided a good overview of the two modules manipulator, it lacks thoroughly demonstrating the real capabilities of such a structure, in comparison with traditional rigid link surgical manipulators. For that reason, scenarios as proposed in the schematic view of Fig. 8 have been taken as guidelines to build a more reliable, credible test set-up for the 2-module manipulator. To reproduce the compliance, in terms of weight and shape of organs or anatomical parts, which the manipulator may encounter during a surgical laparoscopic procedure, water filled balloons have been employed and they have been placed around the manipulator to test its interaction with them. Among the variety of possible tasks, a few key movements were chosen to demonstrate the manipulation and stiffening capabilities. These are the wrapping and retraction of a water filled balloon (800 g, Fig. 11), hung up to a load cell which revealed when the whole weight of the balloon was supported by the manipulator.

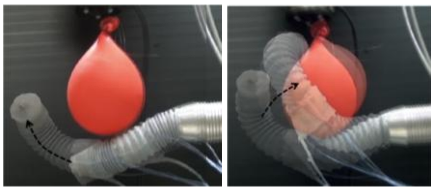

Figure 11: Examples of the 2-module manipulator interacting with water filled balloons and exploiting combined stiffening, dexterity, and force capabilities to perform surgical-like tasks.

Another task is shown in Fig. 12 where the manipulator navigates among compliant objects (water filled balloons), embraces one of them (270 g) and moves it aside.

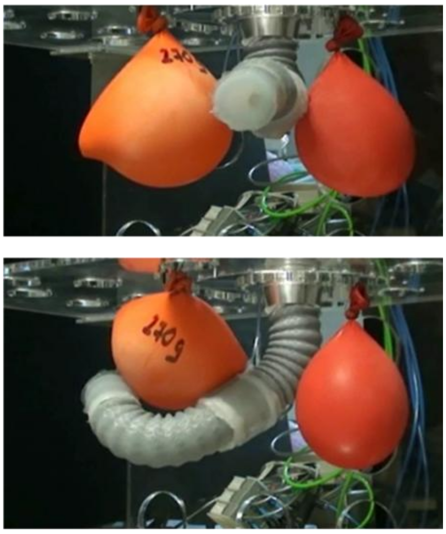

Figure 12: Examples of the 2-module manipulator interacting with water filled balloons and exploiting combined stiffening, dexterity, and force capabilities to perform surgical-like tasks.

The last task, presented in Fig. 13, demonstrates the manipulator supporting a weight of 500 g with the first module and applying a force on an F/T sensor.

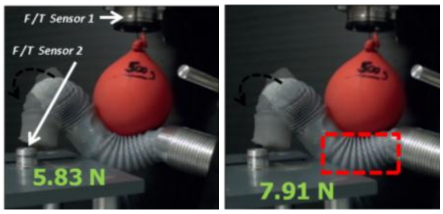

Figure 13: Examples of the 2-module manipulator interacting with water filled balloons and exploiting combined stiffening, dexterity, and force capabilities to perform surgical-like tasks.

The same test was performed without stiffening activation and when the first module was fully stiffened. In this last experiment two F/T sensors were used. One F/T sensor was connected to the water filled balloon (5 N), while the other one was positioned in the proximity of the distal end of the manipulator. In this test, two pieces of information have been extracted: the first F/T sensor allowed verifying that the water filled balloon is completely supported and lifted, while the second F/T sensor measured the amount of force generated on the target (Fig. 13).

STIFF-FLOP - console – the design concept and first tele-test

FRK is leading the developments of console design and tele-control. FRK's concept of a control console is based on a user-interface to control the position of the end effector of the STIFF-FLOP robot arm and a system of feedback information regarding the position and forces created during robot tool-environment interaction; preparing new ground in haptics, operator worn sleeves are integrated with pneumatic or vibrating actuators to relay collisions between the robot arm and the environment to the surgeon. The main idea and technical structure of the operator/surgeon control unit is the ergonomic position that can be achieved during operation, see Figure 14.

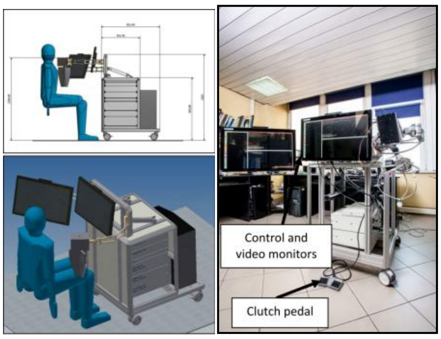

Figure 14: STIFF-FLOP - console - sketches of design concept and prototype

Additionally, the operator can use a touchpad to set certain control parameters such as scaling the motion or force and the number of active sensors. Using our experience from the previous Robin Heart projects, the user interface RiH Delta has been designed and developed especially to suit the needs of the STIFF-FLOP manipulator – the interface allows the free movement of the surgeon's hands using digitally mapping and allows the surgeon to feel the force impact from the working tip (tool) of the robot in the environment of the patient transferred to their palm.

The console includes:

- The computer unit- with Linux and ROS software,
- Mechanical construction of the console body made from ITEM profiles,
- The supply and control rack system,
- Two monitors,
- The Delta human-machine interface with haptic feedback,
- The haptic sleeve integrated with pneumatic or vibrating actuators.

The first test of the new control console was carried out during remote connections between FRK and PIAP (Zabrze –Warsaw). The pictures on this page show the construction of the Delta Master manipulator, with 3 degrees of freedom, prepared for the project STIFF-FLOP, with a force feedback.

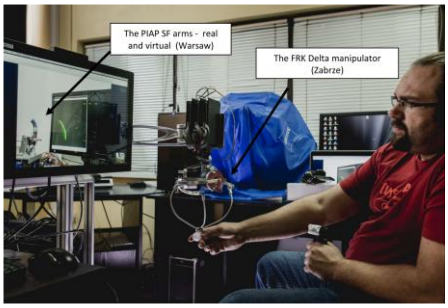

Figure 15: The remote tele-control of the SF arm during the FRK-PIAP connection via the internet (VPN).

The Delta parallel manipulator has large force reflection and high stiffness due to its parallelogram-style structure. The Delta haptic system is equipped with an electronic interface and software libraries prepared to work in the ROS environment. The communication protocol between the Delta haptic system and the ROS System is coded in decimal format.

After the recent tests conducted together with PIAP we could show that the connectivity between the console and Stiff-Flop arm prototype via the internet works well. The test was conducted successfully and represents an important step in the development of STIFF-FLOP control.

Stiff-Flop data fusion system

PIAP advanced methods for sensor fusion over the last year. Since soft manipulators have no rigid links, the modelling of their shape is not trivial. Soft manipulators can bend at any point, twist and elongate as well. External forces can act at any point of the arm and its deformation is distributed not only at discrete points. The above causes the previously used shape calculating algorithms to be insufficient and, because of that, new methods had to be developed. For the purpose of shape estimation, a new data fusion algorithm has been developed by PIAP.

The structure of the data fusion

system is presented in Figure 16. The system takes as input the data from various sensors such as length sensors, force sensors, pressure sensors and vision. The sensor data is then analyzed along a set of steps. The first step involves the chamber length values to be used for a rough approximation of the manipulator configuration. Since the direct force measurement is not available, module shape approximation is required to convert the experienced moments into forces. Knowing the estimated force values, more complex shape calculation method can be employed. The deformation of the manipulator consists of variable bending, torsion and elongation. Because these methods of shape approximation use the estimated force value, the result can be still not very precise. To correct this, we use vision. Replacing the whole shape reconstruction system by a vision system is not possible since there is a high probability that some parts of the manipulator will be occluded. Nevertheless, the position of the visible parts is well-defined. The improvement is performed by adjusting the force approximation using an inverse kinematics algorithm until the simulated shape matches the visible manipulators parts.

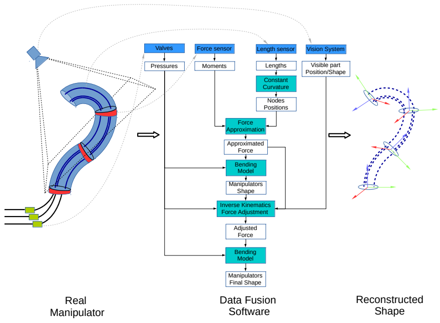

Figure 16: Data Fusion system structure

Control model for the STIFF-FLOP arm

The motions capacities and reachable positions of the STIFF-FLOP arm are clearly depending on the bending capacities of the flexible modules and on the number of flexible and controllable modules embedded within the STIFF-FLOP arm. Adding more flexible modules can be considered as a mean of increasing the reachable space by the arm. Nevertheless the addition of modules is not the only solution for doing so. Indeed, we can consider that the flexible stiff-flop arm is mounted at the end effector of a regular robotic arm. This way, the overall system can not only bend any flexible module, but can also move the base of the flexible STIFF-FLOP arm, increasing thus significantly the reachable space. With such setup, we can furthermore imagine a nice collaboration in between the rigid robot (the regular arm) and the flexible one (based on the STIFF-FLOP modules), in which the bending capacities of the STIFF-FLOP components are mainly activated and used when the surgeon requests a motion that is not feasible by a standard and rigid robotic arm. The bending capabilities can thus be used to complement the motion capabilities of a more conventional surgical robot.

We have been working in that direction, by taking into consideration the STIFF-FLOP base motion in the Inverse Kinematics model (responsible of computing the appropriate system configuration to reach a specified pose in the working frame). In addition to the bending of each STIFF-FLOP module, the location of the STIFF-FLOP base becomes a set of parameters to control as well (as if it was mounted onto a robotic arm and thus able to move through the control of such an robotic arm).

We have been considering two types of control mode of the STIFF-FLOP base, the “free-flying” mode, and the constraint one. In the “free-flying” mode, we suppose the base can move and rotate in any direction. Such mode is useful to benchmark the behavior of the Inverse Kinematics when adding the base parameters (three for the position and three for the orientation) in the control system. Nevertheless in a realistic setup the base motions are likely to be constraint. Indeed the STIFF-FLOP flexible arm is to be inserted into the human body through a trocar, and thus the motion of the standard robotic arm, providing the base motion capabilities, should respect the trocar constraint, maintaining the fulcrum point at the insertion location.

The second control mode is maintaining such constraint using a spherical description of the STIFF-FLOP base location, which enforces directly within the model of this trocar constraint, since all positions and motions defined are expressed with respect to this fulcrum point.

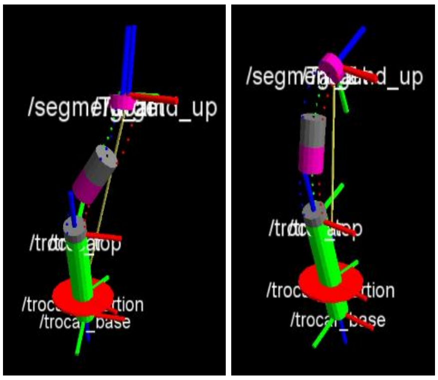

Figure 17: The addition of the STIFF-FLOP base motion (lower gray disc) permits to significantly improves the reachable space. The STIF-FLOP base is mounted onto a rigid support which motions have to respect the fulcrum point (at the centre of the red disc).

The Figure 17 illustrates the combined use of the flexible modules bending and the STIFF-FLOP arm base motions to reach a target tip location provided by the surgeons. On that simulation image, the motion of the STIFF-FLOP base are constrained so that the rigid support of the arm (in green) respect the fulcrum point or single point insertion represented in red.

The extension of the control model to permit the control of the system base (and the underlying standard surgical robotic arm) significantly extends the STIFF-FLOP concept capabilities and potential uses.

News from the University of Surrey

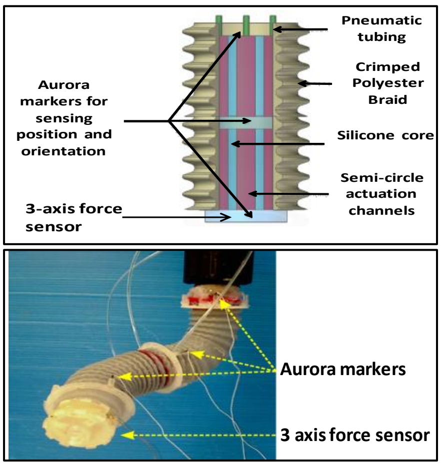

Figure 18: (a) Force sensor from KCL (b) The two-segment STIFF-FLOP manipulator with the integrated Aurora markers and force sensor

The STIFF-FLOP consortium successfully demonstrated the integration of the large-scale system using two flexible modules and validated its performance in real-time for an ex-vivo tissue ablation case study. The two optimised STIFF-FLOP modules (Figure 18) are integrated with position and force sensors. The Aurora magnetic position sensor is used to calculate the bending angle of the modules which in turn are used for the closed loop control of the robot system, as well as for the 3D visualization of the flexible manipulator.

The functionality of the integrated system shown in Figure 19 was demonstrated to one of the reviewers at Kings College London, in September 2014 and described in reports to the Project Officer.

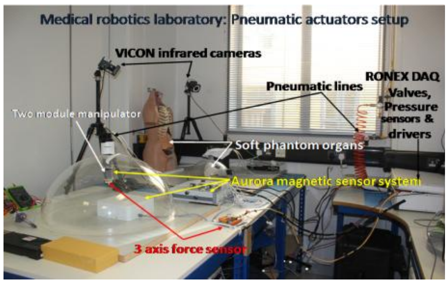

Figure 19: The integrated Stiff-Flop system at UoS

UoS led the work on developing the controller for the 2-segment STIFF-FLOP arm, and contributed strongly to the creation of segments and the phantom organ shown in Fig. 19. The integrated platform was shown to be capable of navigating around a phantom organ of the colon as well as performing ablation of tissue.

Stiffness control in soft robots is challenging because the kinematics and force mapping cannot be decoupled at the tip. In order to sense the stiffness of soft robots, such as the STIFF-FLOP manipulator, an accurate force sensor mounted at the tip is utilized. Moreover, the pressures of the chambers of each segment can be controlled accurately, and they can have direct effects on the stiffness and the tip force of the manipulator. Preliminary investigations were conducted by the team at the University of Surrey to exploit these features to control the stiffness/force at the tip of the STIFF-FLOP manipulator, in order to resist external disturbances. An adaptable stiffness matrix concept, similar to what is used in the control of rigid robots, is utilized here to get a stiffness matrix that relates the force at the tip to the pressures of the chambers.

Stiff-Flop physical-based Model Inverse Kinematics

An inverse kinematics function of a manipulator is normally required for the control if its tip. It provides manipulator configurations that allow the manipulator tip to reach desired positions. The configuration, depending on the manipulator structure can be, for example, its joint angles, segment lengths or input pressures. Since forward kinematics analysis for a continuous, soft robot is quite complicated, the task of determining the inverse kinematics function is also complex. One of the possible ways of resolving this issue is an analytical approach using the constant curvature manipulator model, which provides a simple solution to the forward kinematics problem.

We would like to introduce another approach, which is based on a physical model of the manipulator, called the Bending Model. This model is based on Euler-Bernoulli beam bending theory and does not assume the module curvature to be constant along its length.

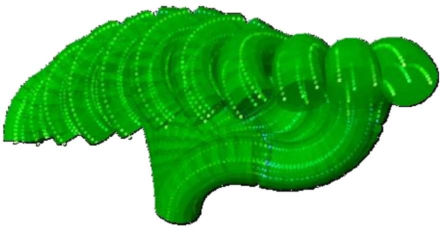

Figure 20: Inverse Kinematics visualization

The algorithm takes position and disturbing forces as input, and calculates pressures which guarantees reaching a goal position under these conditions. It can be launched for any number of modules. Since there are a lot of solutions for such issue, the algorithm finds the nearest one in the solution space. There is a possibility, that the algorithm will not find the solution even if one exists. That is because, local minimum can occur. The inverse kinematics algorithm is able to keep the tip at the desired position under changing environmental conditions. Figure 21 shows its behavior when an increasing force is applied between second and third segment.

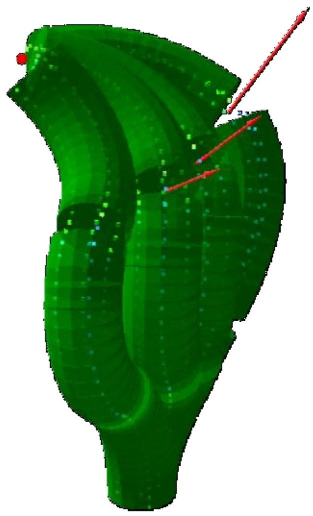

Figure 21: Inverse Kinematics behaviour in respect of changing force value

The 2:1 scaled phantom models in frontal plane

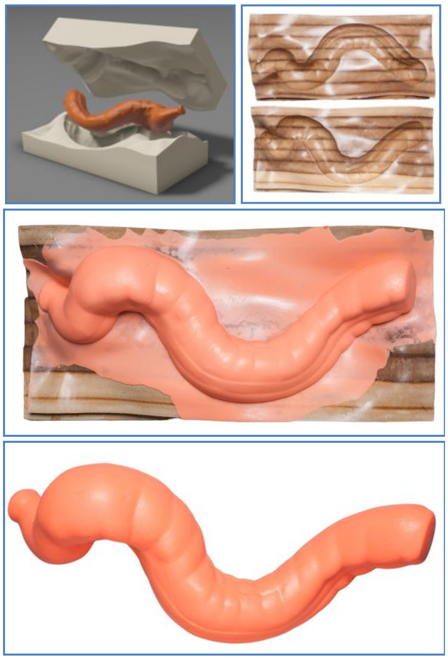

Figure 22: The steps of the production process of flexible organs elements from silicone and Urethane rubber (Contact Smooth-On, Inc.) by moulding: (a) project forms of organs - Autodesc Inventor, (b) the form building, (c) molding process, (d) model of colon

FRK created a novel phantom model based on the anatomical shape of the human abdomen – a new feature is that the abdominal surface is made from PET (Politereftalan etylenu) with different thickness and different numbers of layers adapted to optimally emulate the mechanical properties of the abdominal area of a patient. Depending on the particular tests to be conducted the surface can be opaque or transparent, the latter allowing the researchers to observe the motion of the STIFF-FLOP arm and associated instruments inside the model body.

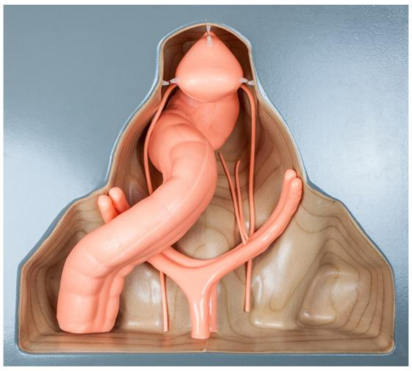

Figure 23: The new 2:1 scaled phantom models in frontal plane

Another novelty is that this new phantom model can be adapted to explore different surgical scenarios: (a) the first version is equipped with a dome containing one trocar port to study single instrument procedures; (b) in the second version the dome is removed and special lateral clamping mechanisms are affixed allowing the mounting of universal arms with ports, tools and a camera.

Aiming for a realistic representation of the abdomen and its content, flexible organ phantoms like the colon, the urinary bladder with urethras, iliac vessels and an anus were created from silicone and Urethane rubber (Contact Smooth-On, Inc.) by means of moulding. The phantom model will be equipped with pressure/force sensors from HoneyWell, TSCDLNN001PGUCV 1PSI AXIAL sensors. The sensors will be placed at various locations within the abdominal region – locations include: below the bladder, on the sacrum, the iliac vessels, the aorta and the colon near the anus. All sensors will be calibrated to give force measurement results in Newton.

Figure 24: The new 2:1 scaled phantom model with the STIFF-FLOP arm entering through a trocar port

New design approach

PIAP has designed, developed and tested a novel actuation solution for the Stiff-Flop project. The previous design relying on external braiding to limit the chamber expansion caused a lot of issues with regards to position sensing as well as actuation. Although this approach was very effective in precventing the external expansion of the module, there were a number of disadvantages. The module cross-section geometry changed under internal pressure, which influenced the behaviour of internal sensors and introduced non-linearities to the actuation system.

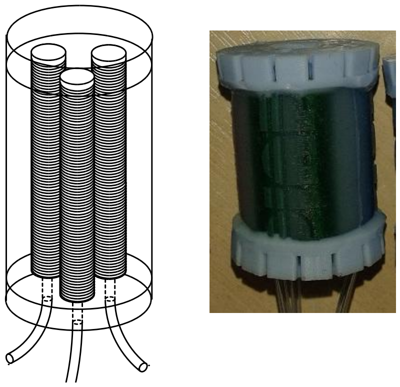

Figure 25: Novel module with reinforced chambers

The solution developed by PIAP is based on a reinforcement of each chamber instead of braiding the module externally. This solution directly eliminates the expansion effect, not only the external symptoms of it. The reinforcement is based on single polyester threaded spirally around each individual chamber (Fig. 25).

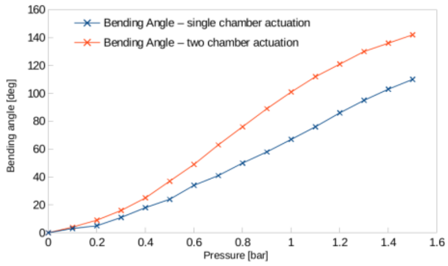

Figure 26: Bending angle achieved for certain values of pressure applied for the new design

This new approach creates chambers that elongate, but are prevented from expansion in radial direction. The cross-section geometry is much more constant during operation and the behaviour of the manipulator is almost linear (Fig. 26).

Using the new approach, the Stiff-Flop module can achieve far greater bending angles and elongate about three times.

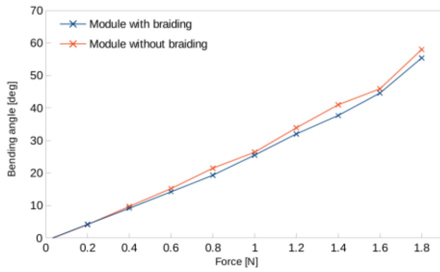

Figure 27: Bending angle achieved by the modules with and without individual chamber braiding when applying external force

The passive properties of the chamber reinforcement have also been tested. The results show that it has almost no influence on the module shape under external disturbance. Therefore, the structure employed in the proposed solution can be easily incorporated in the new modeling algorithm.

Exciting News from the Shadow robot company

Figure 28:.RoNeX Starter Kit, including one Bridge Module, one GIO Module and one Power Injector

Having taken the STIFF-FLOP integration platform and turned it into a CE/EMC certified product, Shadow has now got the RoNeX hardware in production. There has been significant interest from educators wanting to use it as a platform to teach robotics with ROS, as well as uptake from robot designers looking to use RoNeX to speed up their own hardware and systems development.

Shadow's R&D team is very excited by the potential, and is using RoNeX actively in new development projects, and exploring new module types.

The virtual model of the STIFF-FLOP arm in the EON environment

FRK has been active in creating virtual models representing the human abdomen as well as the STIFF-FLOP arm. Virtual Reality Technology is an interdisciplinary technology, integrating CAD/CAM technology, artificial intelligence, computer networking and sensor technology. It is widely used in the design and testing of mechanical models. EON Studio is a software tool using graphical interfaces and is used for research and development on real-time 3D modeling applications. The method is used by FRK for the interactive virtual modeling of the flexible STIFF-FLOP robot arm and motion simulation with interaction between the model of the STIFF-FLOP arm and the surgical environment. The virtual scene reflects the real phantom model of the abdomen in frontal plane with elements of flexible organs like the colon, urinary bladder with urethra and iliac vessels. Using a virtual reality technology to plan surgery procedures increases efficacy of methods and helps to verify the design and concept of the STIFF-FLOP arm.

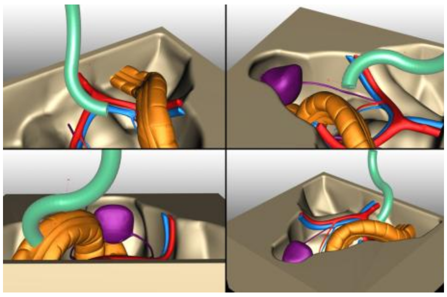

Figure 29: The virtual simulation of medical procedures.

Press:

Invited talks:

Helge Wurdemann, **“Soft Robots for Minimal Access Surgery: An Update on Progress in EU Project STIFF-FLOP”**, presented at the Hamlyn Symposium Workshop on Flexible Access Surgery, Imperial College London, July 2014.

Sylvain Calinon, Danilo Bruno, Milad S. Malekzadeh, Darwin G. Caldwell, Thrishantha Nanayakkara, Benny Hochner, Kaspar Althoefer, **"Development of cognition in stiffness-controllable robot manipulators to aid surgeons during complex minimally invasive procedures"**, presented at the Hamlyn Symposium Workshop on Cognitive Surgical Robotics, Imperial College London, July 2014.

B Hochner. **“The embodied organization of octopus behaviour”**. Invited Speaker to workshop entitled: Small brains, bright minds: Learning and memory in invertebrates. Hokkaido Neuroethology Workshops, July 26-27th 2014, Sapporo Japan

Publications:

A. Faragasso, A. Stilli, J. Bimbo, Y. Noh, H. Liu, T. Nanayakkara, P. Dasgupta, H.A. Wurdemann, K. Althoefer **“Add-On Stiffness Probe for Real-Time Soft Surface Characterisation in MIS”** IEEE Engineering in Medicine and Biology Society, 2014.

Y. Noh, E.L. Secco, S. Sareh, H.A. Wurdemann, H. Liu, K. **Althoefer "A Continuum Body Force Sensor Designed for Flexible Surgical Robotic Devices"** IEEE Engineering in Medicine and Biology Society, 2014.

A. Stilli, F. Maghooa, H.A. Wurdemann, K. *Althoefer* **"A new bio-inspired, antagonistically actuated and stiffness controllable manipulator"** Workshop on New Technologies for Computer/Robot Assisted Surgery, 2014.

E.L. Secco, Y. Noh, S. Sareh, H.A. Wurdemann, H. Liu, K. Althoefer**,"Modular integration of a 3 DoF F/T sensor for robotic manipulators"**, Workshop on New Technologies for Computer/Robot Assisted Surgery, Italy.

Malekzadeh, M.S., Calinon, S., Bruno, D. and Caldwell, D.G. (2014). **"Learning by Imitation with the STIFF-FLOP Surgical Robot: A Biomimetic Approach Inspired by Octopus Movements"**. Robotics and Biomimetics 1:13, 1-15, Special Issue on Medical Robotics (Springer).

Calinon, S., Bruno, D., Malekzadeh, M.S., Nanayakkara, T. and Caldwell, D.G. (2014). **"Human-robot skills transfer interfaces for a flexible surgical robot"**. Computer Methods and Programs in Biomedicine 116:2, 81-96, Special issue on new methods of human-robot interaction in medical practice (Elsevier).

Elsayed Y, Vincensi A, Lekakou C, Geng T, Saaj C, Ranzani T, Cianchetti M, Menciassi A. **"Finite element analysis (FEA) and design optimisation of a pneumatically actuating silicone module for robotic surgery applications"** Soft Robotics, 2014

Wang X, Geng T**,** Elsayed Y**, Saaj** C, Lekakou C**, "A unified system identification approach for a class of pneumatically-driven soft actuators"**. Robotics and Autonomous Systems. 2014, Available online 16 September 2014, ISSN 0921-8890, http://dx.doi.org/10.1016/j.robot.2014.08.017

Hochner B. and Shomrat T., **"The neurophysiological basis of learning and memory in an advanced invertebrate – the octopus"** (2014) in: Cephalopods Cognition edit: A-S. Darmaillacq, L. Dickel, J.A. Mather , Cambridge University Press

M. Cianchetti and 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. June 2014, 1(2): 122-131.

T. Ranzani, M. Cianchetti, G. Gerboni, I. De Falco, G. Petroni, A. Menciassi **"A modular soft manipulator with variable stiffness"** the 3rd Joint Workshop on New Technologies for Computer/Robot Assisted Surgery Verona, Italy 11-13 September 2013.

I. De Falco, M. Cianchetti, A. Menciassi **"STIFF-FLOP surgical manipulator: design and preliminary motion evaluation"** 4th Joint WorkShop on Computer/Robot Assisted Surgery (CRAS), October 14-16, 2014. Genoa, Italy.

T. Ranzani, G. Gerboni, M. Cianchetti, A. Menciassi. **"A bioinspired soft manipulator for minimally invasive surgery"** to be published on Bioinspiration&Biomimetics special issue on "Octopus inspired robots 2014".

Elsayed Y, Vincensi A, Lekakou C, Geng T, Saaj CM, Ranzani T, Cianchetti M, Menciassi A (2014) **"Finite Element Analysis and Design Optimization of a Pneumatically Actuating Silicone Module for Robotic Surgery Applications"** Soft Robotics, ahead of print. doi:10.1089/soro.2014.0016

Cianchetti M, Ranzani T, Gerboni G, Nanayakkara T, Althoefer K, Dasgupta P, Menciassi A (2014) **"Soft robotics technologies to address shortcomings in today's minimally invasive surgery: the STIFF-FLOP approach"** Soft Robotics, 1(2) 122-131

M. Mende, E. Gerz, H. Roth, **"Evaluation of a magnetic 3D measurement system for application in computer assisted surgery compared to established optical tracking systems"**, 9th INTERNATIONAL CONFERENCE on Communications, Electromagnetics and Medical Applications (CEMA'14),Ocotober 16-18, Sofia, Bulgaria.

Workshops:

Cianchetti M, Laschi C (2014) **"The OCTOPUS project as an incubator of soft robotics technologies"** International workshop on Soft Robot @ ICRA 2014, Hong Kong, China.

Jan Czarnowski, Jan Fraś, Jakub Główka, Mateusz Maciaś, Adam Wołoszczuk, Paweł Sałek, "**An intelligent data fusion system concept for the STIFF-FLOP project"**, ICRA 2014 Soft Medical Robots Full Day Workshop

Conference contributions:

Cianchetti M, **"Soft mechatronics for bioengineering and bioinspired robotics"** National Congress on Biomedical Engineering – GNB, Pavia, Italy, June 25-27, 2014.

I. De Falco, M. Cianchetti, A. Menciassi **"A Soft and Controllable Stiffnss Manipulator for Minimally Invasive Surgery: Preliminary Characterization of the Modular Design"** 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), August 26-30, 2014. Chicago, USA

I. De Falco, M. Cianchetti, A. Menciassi **"STIFF-FLOP surgical manipulator: design and preliminary motion evaluation"** 4th Joint WorkShop on Computer/Robot Assisted Surgery (CRAS), October 14-16, 2014. Genoa, Italy.

G. Gerboni, T. Ranzani, G. Ciuti, M. Cianchetti, A. Menciassi **"A new strategy to build a fully modular soft manipulator for MIS"** 4th Joint WorkShop on Computer/Robot Assisted Surgery (CRAS), October 14-16, 2014. Genoa, Italy.

L. Ricotti, T. Ranzani, V. Calarota and A. Menciassi **"Thin and flexible pressure/deformation sensors based on piezoelectric nanocomposites"**. IEEE SENSORS, November 2-5, 2014. Valencia, Spain.

Bruno, D., Calinon, S. and Caldwell, D.G. (2014). "**Learning Adaptive Movements from Demonstration and Self-Guided Exploration"**. In Proc. IEEE Intl Conf. on Development and Learning and on Epigenetic Robotics (ICDL-EpiRob), pp.160-165, Genova, Italy.

Rozo, L., Calinon, S. and Caldwell, D.G. (2014). "**Learning Force and Position Constraints in Human-robot Cooperative Transportation"** In Proc. IEEE Intl Symposium on Robot and Human Interactive Communication (Ro-Man), pp. 619-624, Edinburgh, Scotland, UK.

Calinon, S., Bruno, D. and Caldwell, D.G. (2014).**" A task-parameterized probabilistic model with minimal intervention control"**. In Proc. of the IEEE Intl Conf. on Robotics and Automation (ICRA), pp. 3339-3344, Hong Kong, China.

Bruno, D., Calinon, S. and Caldwell, D.G. (2014**). "Null space redundancy learning for a flexible surgical robot"**. In Proceedings of the IEEE Intl Conf. on Robotics and Automation (ICRA), pp. 2443-2448, Hong Kong, China.

Calinon, S. (2014). "**Skills Learning in Robots by Interaction with Users and Environment"**. In Proceedings of the Intl Conf. on Ubiquitous Robots and Ambient Intelligence (URAI), Kuala Lumpur, Malaysia.

Malekzadeh, M. S. and Calinon, S. and Bruno, D. and Caldwell, D. G. "**A Skill Transfer Approach for Continuum Robots - Imitation of Octopus Reaching Motion with the STIFF-FLOP Robot"**, AAAI Symposium on Knowledge, Skill, and Behavior Transfer in Autonomous Robots (2014) Arlington, VA, USA.

Wang X, Geng T, **Elsayed Y,** Ranzani T, Saaj C, Lekakou, C. "**A New Coefficient-Adaptive "Orthonormal Basis Function Model Structure for Identifying a Class of Pneumatic Soft Actuators"**, IEEE/RSJ International Conference on Intelligent Robots and Systems, 2014

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

Jan Fraś, Jan Czarnowski, Mateusz Maciaś, and Jakub Główka. *Static Modeling of Multisection Soft Continuum Manipulator for Stiff-Flop Project*. Springer, 2014.

Meeting Abstracts

1. Tal Shomrat Ana Turchetti-Maia, Binyamin Hochner (2014). Conservation and convergence in the evolution of the cephalopod neural systems mediating learning and memory. International Congress of Neuroethology, Sapporo Japan.
2. Ana Turchetti-Maia Binyamin Hochner Tal Shomrat (2014). Nitric oxide synthase (NOS) mediates activity-dependent plasticity in an area of the octopus brain involved in learning and memory. International Congress of Neuroethology, Sapporo Japan.
3. Tamar Gutnick Binyamin Hochner Michael J Kuba (2014), Tactile discrimination learning in intact Octopus vulgaris using a two choice maze International Congress of Neuroethology, Sapporo Japan.
4. A. TURCHETTI-MAIA[1,2], T. SHOMRAT[1,3], B. HOCHNER[1,4]; (2014), Nitric oxide synthase is involved in maintenance but not in induction of activity-dependent LTP in the vertical lobe of the octopus. Society for Neuroscience (SfN) Meeting, Nov 14-19, Washington DC, USA
5. L. ZULLO[1], N. NESHER[2,3], F. BENFENATI[1,4], B. HOCHNER (2014), Characterization of the static and dynamic forces involved in the Octopus vulgaris arm muscle performance. Society for Neuroscience (SfN) Meeting, Nov 14-19, Washington DC, USA

Patents in progress:

- Patent about manipulator with reinforced chambers by single thread.
- Patent about manipulator with reinforced chambers manufacturing technology.

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
- Dr. David Noonan, New York, USA

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. The STIFF-FLOP project was presented officially to all members during the 2012 EAES annual meeting (in Brussels, 20-23 June 2012).