# Modern Safe and Economic RMIS through Bio-inspiration using Haptic Feedback and Visual Servoing*

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In Robot-assisted Minimally Invasive Surgery (RMIS), robotic tools enter the body through narrow openings and manipulate soft organs that can move, deform, or change in stiffness. The traditional robotic manipulation concepts that rely on fixed stiffness distributions, such as with the da Vinci Robotic System, have limitations on these laparoscopic and robot-assisted surgical procedures due to restricted access through Trocar ports, lack of haptic feedback, and difficulties with rigid robot tools operating inside a confined space filled with organs. In particular, the da Vinci Robotic System costs more than $1.5m for each robot (service contract: ca. $112,000/year) and $2,200 per instrument every 10 surgeries. The solid structure of the laparoscopic instrument attached to the robotic arms and their external articulation make it problematic to change surgical targets inside the abdomen, and it might be necessary to move the entire robotic trolley. This limits the range of surgical procedures suitable for robotic surgery. As the surgeon does not have haptic feedback from the strong mechanical power of the rigid robotic arms, this can lead to tissue tears. It is of importance to provide help via an additional laparoscopic assistance at the patient's side.

King's College London leads the EU FP7 project called STIFF-FLOP which addresses the challenges of current RMIS systems. The aim is to develop a low-cost manipulator and also a new concept for modern robot-assisted surgery that is inherently safe for the patient. The safety of the STIFF-FLOP robot is continuously assessed by the medical partners of the project from the University of Torino and King's College London.

The manipulator's structure is bio-inspired by the octopus which can manipulate objects while controlling the stiffness of selected body parts and being inherently compliant when interacting with objects. The STIFF-FLOP robotic arm imitates these features of the octopus of being soft, able to elongate and to control the arm's stiffness. Hence, the arm will reconfigure itself and stiffen by pneumatic actuation to perform compliant force control tasks while facing unexpected situations or bending around organs to reach the surgeon's area of intervention and operate on parts of the body that could not be reached previously. As the clinician concentrates on the surgery, innovating novel bio-inspired algorithms make the soft robot learn these skilful manoeuvres and simulate operations beforehand to free him from any additional control tasks. The autonomous skills of the robot will descrease time to finish a surgery while reducing the fatigue of the surgeon. A haptic sleeve will feed back information from force and tactile sensors distributed on the STIFF-FLOP manipulator to the surgeon so that tissue damage will be avoided. Another constraint of current robotics surgery system is the re-positioning of the endoscopic camera so that the surgeon has the optimal field of view. Visual servoing and tracking of the flexible and soft manipulator will support the operating clinician and possibly make a laparoscopic assistant redundant. So, by introducing this modern way of robotic surgery, the STIFF-FLOP development also addresses the reduction of enormous cost factors of today's robots. The robotic arm will be able to adapt and replace laparoscopic tools on current systems. The various sensors can be chosen and easily integrated as desired; the modular robotic arm can be extended by adding additional segments.

The STIFF-FLOP project will allow pushing the boundaries of current medical robotics technology and will develop an ergonomic RMIS system with real cost and safety benefits for patients.

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