BIOENGINEERING AND MEDICAL-SURGICAL SCIENCES

UNITO - Artificial Intelligence for applications in robotic microsurgery and endoscopy

Funded By	UNIVERSITA' DEGLI STUDI DI TORINO [P.iva/CF:02099550010]
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Context of the research activity	The project will pursue an integrated multimodal approach to detect and treat polyps and cancer lesions in the colon. The ambition of the team is to bring the project to clinical applications. From a clinical requirement starting point, progress will involve the integration of newly created methods and techniques, culminating in intensive prototype testing in M20 and benchmarking and evaluation in the human cadaver lab in M24. We will work on new techniques and materials for 3D printing of realistic anatomical models, such as soft and inflatable multi-layered organs like the bowel, based on DICOM databases of patients with confirmed disease. This will exclude the use of wet and in vivo animal labs, not only for ethical reasons but also because, in anatomical terms, no animal colons are genuinely comparable to human colons. In the project follow-up, we will focus on acquiring funds for clinical validation, to establish ENDOTHERANOSTICS technology as a benchmark on a global scale. This will be a joined activity of mixed research groups made up of clinicians and engineers. WP1 — Inflatable Operating chamber (in collaboration with QMUL) We will create a stable operating chamber that can be deployed within the colon positioned at the identified target polyp site, carry out precise surgical intervention. This will be achieved by a transferable, inflatable operating chamber, made of a pre-shaped double-layered, fenestrated balloon which will be inflated at the site of the lesion to lodge itself stably within the colon and its structural elements will be stiffened using an approach based on granular jamming. T1.1 Operating chamber design (M1–M12), reconfigurable inflatable granular- jammable structure, integrating microsurgical arms. T1.2 Operating chamber fabrication (M5–12), identifying suitable materials/particles biocompatible with endoluminal environment. T1.3 Chamber deployment and microsurgical manipulator reconfiguration tests (M12–M20), experimental assessment and evaluation WP2 — Sensing for tissue characterisation: intelligent & multimodal (in collaboration with KCL) We will design probes for wide-field multispectral imaging, photoacoustic and ultrasound microscopy. Multispectral imaging will identify tumour boundaries

	for resection guidance. Photoacoustic microscopy will provide label-free tumour staging, while all-optical ultrasound will provide deep-structure information to facilitate robot control. Machine learning will address long-standing challenges in sensor analytics to generate detection tools that leverage multimodal information to screen large areas effectively. T2.1 Photoacoustic endomicroscopy and all-optical ultrasound (M1–M12), to develop a real-time system. T2.2 Sensorised robotic probe design (M13–M20), articulated concentric robotic probes integrated with highly sensitive contact sensing. T2.3 Multimodal imaging and sensing (M13–M20), wide-field multispectral imaging to ensure improved tissue characterisation. WP3 — Precision surgery: flexible & dexterous For challenging high-precision tissue manipulation, our system will incorporate a miniaturised super-flex design capable of reconfiguration and bimanual operation. At the same time, visual servoing combined with intelligent control will permit high-precision sub-mm accuracy. A chip-on-tip-based stereo vision system will incorporate white light and multispectral imaging to visualise submucosal structures and microvasculature clearly. The miniaturisation of foldable tools will allow sufficient dexterity for oncologically safe polyps and cancer lesions excision. T3.1 Microsurgical robot hardware architecture design (M1–M12), architecture robot design T3.2 Evaluation of structural functionality (M13–M16), to ensure interoperability of its subcomponents. WP4 — Intervention shared control: intuitive & autonomous (In collaboration with UNINA-CREATE) Active control of soft growing robots and supervised auton

Objectives	The project aims to create instruments for digestive tract endoluminal surgery, using robotic technologies that will allow previously impossible interventions. The main goal is to create miniaturised devices that advance inside the patient to operate in a synergistic and collaborative way. Such instruments are capable of performing surgical procedures that go beyond contemporary minimally invasive surgery. Depending on the anatomical district and clinical scenario, an intuitive interface will consist of advanced input devices equipped with tactile feedback and imaging screens (MRI, CT scan, fluoroscopy, US). Before the ENDOTHERANOSTICS robot (Multi-sensor Eversion Robot Towards Intelligent Endoscopic Diagnosis and Therapy, A miniature robotic device applicable to a flexible endoscope for the surgical dissection of gastro-intestinal tract surface neoplasms) begins its action, the environment is screened with all-optical probes, consisting of white light, multispectral and US sensors. Then a miniaturised inflatable operating chamber is set-up in place to keep the environment stable. Ultimately, dissection begins through surgical manipulation. ENDOTHERANOSTICS technology will push the boundaries of minimally invasive robotic surgery beyond the current state-of-the-art, developing solutions to perceiving and interacting with the environment for soft robots, while operating within otherwise inaccessible spaces. Our scientific objectives are: 1- Sensing for tissue characterisation: intelligent & multimodal. Incorporate novel sensing capabilities inspired by machine learning to maximise sensor information content, including wide-field multispectral imaging, photoacoustic endomicroscopy and all-optical ultrasound imaging for in-situ detection and assessment of polyps/cancer. 2- Precision microsurgery: flexible & dexterous. Introduce novel micro-

	surgical robot design with bimanual manipulation, ultrasound and imaging tools for precision surgery. 3- Intervention shared control: intuitive & autonomous. Embed the surgeon in the navigation of the micro-surgical robot, creating AI-based control strategies.

Skills and competencies for the development of the activity	The candidate is expected to be graduated in Medicine & Surgery and to have specific experience in Minimally Invasive Surgery. LS7_02 Medical technologies and tools (including genetic tools and biomarkers) for prevention, diag Free keywords Soft robotics, Inflatable robots, Medical imaging and perception, Autonomous control and manipulation, Intervention shared control