NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Robotic systems for minimally invasive and interventional surgery

Ph.D. candidate

Dr. Pietro Maria MARVULLI

Cycle

XXXIX

Tutor

Prof. Engr. Vitoantonio Bevilacqua, PhD

1. Description of the research program

Minimally invasive and interventional surgery has revolutionized medical practices by reducing patient trauma, shortening recovery times, and improving outcomes. However, these techniques often demand precision and dexterity that surpass the capabilities of human surgeons. Since the first years of the twenty-first century, various robotic systems, such as the Da Vinci Surgical System and the Senhance Surgical System, have emerged as promising tools to address these challenges. These systems offer the potential to enhance the capabilities of human surgeons, allowing for much more precise movements and less energy expenditure during procedures. They have demonstrated their utility across a range of surgical interventions, from urological and gynecological procedures to general and colorectal surgery. One of the key components in these robotic systems' success is the integration of intelligent systems, which harness advanced technologies like medical image analysis and machine/deep learning techniques. These technologies enable the robotic systems to interpret and analyze intraoperative images (endoscopic or ultrasound images), even in real-time, providing surgeons with a detailed view of the surgical field and enhancing their decision-making capabilities. For example, image processing algorithms can assist in identifying anatomical structures, tumors, or abnormalities within both pre-operative (CT and MRI scans) and intraoperative images, aiding in more precise and informed surgical maneuvers. The use of haptic feedback in these systems further allows surgeons to sense and interact

with the tissues they are operating on, enhancing their tactile perception and fine motor control. In the context of robotic surgical systems, the analysis of patient data, which includes information obtained from both pre-operative and intra-operative images, plays a pivotal role in ensuring the success of the surgical procedure. Artificial intelligence, particularly in the form of machine learning and deep learning, can help in the interpretation of patient data, allowing for more personalized and optimized surgical approaches. This personalized approach can lead to improved patient outcomes and quicker recovery times. Furthermore, the collaborative integration of virtual and augmented reality techniques into the robotic system's interface can offer surgeons an enhanced and immersive view of the surgical field. Augmented reality overlays can provide vital information directly onto the intraoperative video feed, guiding surgeons during the procedure. The primary objective of this research project is to investigate, create, build, and validate advanced robotic systems that leverage the technologies that have been presented above to enhance the pre-operational and operational service quality in minimally invasive and interventional surgery. By focusing on the analysis of intraoperative images and leveraging the capabilities of these intelligent systems, the project aims to push the boundaries of what is possible in the realm of robotic-assisted minimally invasive surgery, ultimately benefiting both patients and medical staff.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Study of state of the art and Analysis of open challenges in the field of robotic systems for surgery	Review of the current state of robotic systems in minimally invasive surgery and analysis of the primary challenges in this field, with a particular focus on image-guided procedures. This can provide insights into the direction of current research and the types of data that are essential.		NO

Second academic year (planned)

	Description	Period	Activity abroad
Design and implementation of a Deep Learning based framework for medical imaging-guided robotic system in surgery	Design and implementation of a computational framework based on deep learning techniques capable of processing endoscopic images to support image-guided robot-assisted surgical procedures.		NO

Third academic year (planned)

	Description	Period	Activity abroad
Abroad project	Time spent abroad to develop an innovative robotic system using the hardware available at specialized facilities in the medical robotics field.	1 semester	YES
Validation of presented framework and testing in a simulated scenario	Validation of the proposed framework and testing in a simulated scenario that involves both surgeons and dummies for assessment.		NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Control for Optimization	November-December 2023	Yes	1
	Data-driven fault diagnostic and fault prognosis	June-July 2024	Yes	1
	Intelligent Control Systems	January-February 2024	Yes	2
	Game Theory for controlling Autonomous System (ScuDo Course)		Yes	2
B. Master's degree courses	Big Data Analytics (PoliBa)	First Semester	Yes	6
C. Soft skill courses				
D. Participation to seminars	Introduction to fault diagnosis and fault prognosis			1.5
	Introduction to dynamic control allocation			3
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TBD			4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			**20.5**
G. Individual research activity	Research activities on intelligent systems that assist surgeons in minimally invasive interventions. The study will focus on both the hardware part (surgical robots) and the software part (frameworks based on deep learning).			35
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4.5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			**39.5**
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	TBD		Yes	2
	TBD		Yes	2
B. Master's degree courses	Data Model Identification and Intelligent Control (PoliBa)	First Semester	Yes	6
C. Soft skill courses	TBD			3
D. Participation to seminars	TBD			3

E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			16
G. Individual research activity	Study, design, and implementation of image-based intelligent system for help surgeon in minimally invasive surgical activity. Coding in Python and MATLAB			40
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			44
	TOTAL OF ECTS			**60**

Third academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	TBD			2
F. Presentation of research products at international congresses or workshops	TBD			2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			4
G. Individual research activity	TBD			50
H. Supervision of students				2
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			56
	TOTAL OF ECTS			**60**

4. List of the publications written by the candidate in the triennium

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