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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Cristina Iacono**

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**Student ID: DR993899**

**PhD Cycle: XXXV**

PhD Cycle Chairman: Prof. Stefano Russo

**PhD program student's start date: 01.07.2021**

**PhD program student's end date: 31.01.2024**

**Supervisor: Fanny Ficuciello**

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**Co-supervisor:**

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**PhD scholarship funding entity: Università degli Studi di Napoli Federico II**

## General information

Cristina Iacono received in year 2019 the Master Science degree in Automation Engineering from the University of Napoli Federico II. She attended a curriculum in Automation of Robot-Assisted Surgical Procedures within the PhD program in Information Technology and Electrical Engineering. She received a grant from Università Federico II.

## Study activities

### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1	Matlab Fundamentals	Course	2	DIETI	ITEE
1	Innovation management, entrepreneurship and intellectual property	Course	5	Prof. Pierluigi Rippa	DII
1	Machine Learning	Course	3.2	Prof. Carlo Sansone	ITEE
1	Robot Interaction Control	MSc course	6	Prof. Bruno Siciliano	Polytechnic School
1	Visione per Sistemi Robotici	MSc course	6	Prof. Luisa Verdoliva	Polytechnic School
1	Robotics Lab	MSc Course	6	Prof. Vincenzo Lippiello	Polytechnic School
2	Statistical data analysis for science and engineering research	Course	4	Prof. Roberto Pietrantuono	ITEE
2	Mathematics and Statistics for Life Sciences	Course	4	Prof. Claudia Angelini	CBQ
2	Strategic Orientation for STEM Research and Writing	Course	4	Prof. Chie Shin Fraser	ITEE

### Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
2 <sup>nd</sup>	SIDRA 2021	Bertinoro, (FC)	6	12-17/07/21	University of ....., State

### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	Fundamentals of Deep Learning for Computer Vision	0.4	Luigi Troiano	NVIDIA	ITEE
1 <sup>st</sup>	Numerical Methods for modeling,	0.2	Christian Duriez	Nord-Europe Lille1 University	ITEE

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Cristina Iacono

	simulation and control for soft robots or robots in interaction with deformable environment				
1 <sup>st</sup>	Large Scale Training of Deep Neural Networks	0.4	Prof. Giuseppe Fiameni	NVIDIA	ITEE
1 <sup>st</sup>	Exoskeletons and wearable robotics	0.8	Prof. Nicola Vitiello		ITEE
1 <sup>st</sup>	Robotics in Surgery	0.4	Prof. Alberto Arezzo	University of Turin	ITEE
1 <sup>st</sup>	Design e Nuove tecnologie. Possibili scenari per fronteggiare l' emergenza	0.2		Innovation Village 2020	Innovation Village 2020
1 <sup>st</sup>	La programmazione europea e la ricerca	0.4		Innovation Village 2020	Innovation Village 2020
1 <sup>st</sup>	Health 4.0 La rapidità della medicina e la velocità del cambiamento del nostro mondo	0.4		Innovation Village 2020	Innovation Village 2020
1 <sup>st</sup>	Realtà Virtuale e salute reale. Health 4.0 - Dal bit alla mente: spazi virtuali per la salute	0.2		Innovation Village 2020	Innovation Village 2020
1 <sup>st</sup>	Virtual Seminars on Sensing	0.8	Prof. Carlo Forestiere	DIETI	ITEE
1 <sup>st</sup>	Bias from the wild	0.4	Prof. Nello Cristianini	CVPL - Associazione Italiana per la ricerca in Computer Vision, Pattern Recognition e machine Learning	ITEE
1 <sup>st</sup>	Adversarial Attacks on Image Classifiers	0.4	Prof. Andrea Cavallaro	CVPL - Associazione Italiana per la ricerca in Computer Vision, Pattern Recognition e machine Learning	ITEE
1 <sup>st</sup>	Exploring autonomy in Robotic Flexible	0.4	Prof. Pietro	University of Leeds	ITEE

	Endoscopy		Valdastri		
2 <sup>nd</sup>	Designing a Socially Assistive Robot for adaptive and personalized assistance to patients with dementia.	0.2	Dr. Antonio Andrella	IRI, Spain	ITEE
2 <sup>nd</sup>	Robo Ludens: A game design taxonomy for human-robot interaction	0.2	Dr. John Edison Muñoz Cardona	University of Waterloo, Canada.	ITEE
2 <sup>nd</sup>	Emotions in Reinforcement Learning Agents	0.2	Prof. Joost Broekens	University of Leiden	ITEE
2 <sup>nd</sup>	Upper Limb Prosthetic	0.2	Fanny Ficuciello	DIETI	University of Naples Federico II
2 <sup>nd</sup>	Workshop on Exoskeleton	0.4	Fanny Ficuciello	DIETI	University of Naples Federico II
	Introduction to legged robots and examples of IIT's dynamic legged systems lab	0.4	Fabio Ruggiero	DIETI	University of Naples Federico II
2 <sup>nd</sup>	Game Theory and Network Systems	3		SIDRA 2021	
2 <sup>nd</sup>	Soft Robots	3		SIDRA 2021	
3 <sup>rd</sup>	Workshop on Design, Learning, and Control for Safe Human-Robot Collaboration	1		ICAR 2021	ICAR 2021
3 <sup>rd</sup>	The era of human robot collaboration: Deep sea exploration	0.4	Prof. Oussama Khatib	Stanford University	ITEE
3 <sup>rd</sup>	Guiding with Touch: Objective assessment and haptic cueing to improve surgical performance on virtual and robotic platforms	0.4	Prof. Marcie O'Malley	University of Rice	WPI
3 <sup>rd</sup>	Vine robots: design challenges and unique opportunities	0.2	Nicholas Naclerio	University of California Santa Barbara	ITEE

### Research activities

Cristina Iacono's research contributes to the field of automation in robot-assisted surgical procedure. To implement advanced control strategies to automate surgical processes, multiple areas of robotics research must come together, including robot modeling and control, imaging,

haptics, and AI. The research activity aims to explore the impact of different aspects related to automation in surgical robotics.

**Vision Perception:** The research explores state-of-the-art methodologies and frameworks for enhancing vision perception, focusing on tool localization and tracking, 3D reconstruction and organ localization. Vision perception contributed to develop vision-based control strategies that not only augment the perceptual capabilities of surgical robots but also lay the groundwork for more accurate and context-aware surgical interventions.

**Modeling:** It is crucial to identify the kinematic and dynamic properties of robotic arms to effectively control the robot in an unstructured environment such as a surgical site and estimate external forces. The research contributes to the field making an accurate characterization of the dynamic model of the da Vinci® Research Kit (dVRK) surgical robotic systems.

**Force Feedback:** Most of the currently available robotic surgery systems do not have haptic feedback capability. In addressing this deficiency, research work contributes to demonstrating the capacity of force feedback to reduce unintentional damages and accelerate the learning curve for novice surgeons and providing a comprehensive framework for implementing advanced control algorithms, including impedance control and virtual fixtures.

**Data Collection:** Data collection plays a crucial role in the fields of Artificial Intelligence and robotics. The open access design of the dVRK incentivizes and enables researchers to easily access and collect data. For these reasons, an important part of the thesis contributes to the creation of a dataset based on the suturing task with dVRK that will be used for further research.

## Tutoring and supplementary teaching activities

Tutorship of the course of Robotica Medica (SSD: ING-INF/04):

- 1st Year: 40h of tutorship (12h of teaching assistance, 6h of tutorials, 22h of student assistance),
- 2nd Year: 40h of tutorship (8h of teaching assistance, 10h of tutorials, 22h of student assistance),
- 3rd Year: 2h of tutorship

## Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	28.2	5.4	35	1.6
2 <sup>nd</sup>	12	7.6	40	1.6

3 <sup>rd</sup>	0	2	57	0.08
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## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
3 <sup>rd</sup>	Worcester Polytechnic Institute, Worcester, USA	Prof. Gregory Fisher	05/03/22 – 05/12/22	Attended course on MRI Security and Physics. Attended course on Human Subjects in Biomedical Research Participation to the AccelNet Surgical Robotics Challenge Study on surgical needle localization, developing the automatic task of grasp needle and drive through tissue. Laboratory activity for the realization of the state-of-the-art setup for the dVRK of tge University of Naples Federico II Conducted User study on data collection during surgical suturing

## PhD Thesis

In the PhD Thesis, Cristina Iacono explored the topic of automation of surgical robotics procedures. The closing decades of the 20th century witnessed a profound transformation in the field of surgical procedures, marking the beginning of a technological revolution that continues to reshape the practice of medicine, with a particular focus on reducing invasiveness. The development of surgical robotic systems has addressed some of the limitations of classical open and endoscopic surgery and has improved the overall surgical experience.

The thesis explained the concept of autonomy in the context of surgical robotics, accompanied by a systematic taxonomy designed to classify surgical robots. Subsequently, an overview of the related works in robotic surgery, starting from Level 0 and moving toward Level 5 of autonomy, is presented. The thesis contributed on automation of surgical processed focusing on different aspect, such as vision, haptic feedback, robot modeling and control .Most of the research work has been conducted using the dVRK robotic platform as the hardware setup.

The thesis presents a novel and accurate dynamic model of the dVRK PSMs, that focuses in particular on estimating friction. The proposed model is tested using a residual-based approach for external force estimation acting on the PSM end-effector.

Haptic feedback and impedance control has been used for the development of a control framework for human-robot interaction in medical applications, characterized by an RCM constraint and repulsive VFs constraint.

Haptic feedback has been also used to improve performances in robot-assisted surgical procedures. In particular, a vision-based control frame-work has been developed: it includes impedance control and Forbidden Region Virtual Fixture (FRVF) to avoid the collision between the surgical instruments starting from the endoscopic images. It is demonstrated through a user study how the use of force feedback facilitates the use of the surgical robot for novice surgeons.

The thesis also explores the use of visual perception in robotic surgery, which is of utmost importance since it is the only feedback of surgeons during surgical procedures. Indeed the thesis presents a deep learning-based method for the localization and segmentation of the biliary tract to help the surgeon better visualize the biliary tract without using Indocyanine Green (ICG) during laparoscopic cholecystectomy. A database of laparoscopic images has been constructed and annotated to train the deep learning algorithm.

Lastly the thesis proposes a novel dataset from several surgeons with different skill levels, who performed the suturing task on the dVRK. The dataset includes kinematics, video, interaction force, electromyographic signal and acceleration, angles, and angular velocity of the surgeon's right wrist. The data has been organized by surgical gestures part of the suture procedure.

### Publications

Research results appear in 1 papers published in international journals and 1 under review, 2 contributions to international conferences, 1 contributions to national conferences.

### List of scientific publications

#### International journal papers

R. Moccia, C. Iacono, B. Siciliano, F. Ficuciello

Vision-based dynamic virtual fixtures for tools collision avoidance in robotic surgery,  
*IEEE Robotics and Automation Letters*,  
vol. 5 (2), pp. 1650-1655, 2020, DOI: 10.1109/LRA.2020.2969941.

O. F. Argin, R. Moccia, C. Iacono, F. Ficuciello

da Vinci Research Kit Patient Side Manipulator Dynamic Model using Augmented Lagrangian Particle Swarm Optimization,  
*IEEE Transactions on Medical Robotics and Bionics*,  
(under review)

#### International conference papers

M. Caianiello, C. Iacono, A. Imperato, F. Ficuciello

Exploring the Use of Deep Reinforcement Learning Algorithms for Wound-Approaching Trajectories in Robot-Assisted Minimally Invasive Surgery,  
*International Conference on Advanced Robotics (ICAR)*  
Schedule Code: WeCT2.Abu Dhabi, UAE, Dec. 2023  
(on publication)

## National journal papers

N. Surname1,  
Complete Paper Title,  
*Complete journal name*,  
vol. 62 (4), pp. 1013-1062, 2018, DOI: XX.XXXX/TGRS.2016.XXXXXX.

## National conference papers

C. Iacono, B. Siciliano, F. Ficuciello  
Forbidden Region Virtual Fixtures for Surgical Tools Collision Avoidance,  
*I-RIM 3D: la Tre Giorni di Robotica e Macchine Intelligenti*, Rome, IT, 2020

**Date** 15/01/24

**PhD student signature**

*Cristina Iacono*

**Supervisor signature**

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