



**PhD in Information Technology and Electrical Engineering**

**Università degli Studi di Napoli Federico II**

**PhD Student: Rocco Moccia**

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**XXXIII Cycle**

**Training and Research Activities Report – Second Year**

**Tutor: Prof. Bruno Siciliano – co-Tutor: Fanny Ficuciello, PhD**

## 1. Information

I am Rocco Moccia, Ms.Sc in Mechanical Engineering – La Sapienza, Università di Roma, Department of Mechanical and Aerospace Engineering – January 2017. Master thesis title: “Design and Development of a Haptic Human-Robot Interface to study the effect of Co-Contraction Training on motor control”, developed at Georgia Institute of Technology, in Atlanta, GA, United States of America. Currently PhD student in Information Technology and Electrical Engineering, XXXIII Cycle, at Università degli Studi di Napoli Federico II with a PON fellowship in collaboration with MMI S.p.A and University of Leeds, supervised by Prof. Bruno Siciliano and Fanny Ficuciello, PhD.

## 2. Study and Training activities

### Courses

Lecture/Activity	Type	Credits	Certification	Notes
Data Science and Optimization	Ad Hoc Module	1,2	x	
Machine Learning	Ad Hoc Module	4,2	x	

### Seminars

Lecture/Activity	Type	Credits	Certification	Notes
Issues in Robotic Manipulation of Deformable Objects	Seminar	0,2	x	
Research work in active perception and robot interactive lab in IIT	Seminar	0,2	x	
Robots in Medical applications: an overview of the current Medical Robotics market from the industry's point of view	Seminar	0,4	x	
9 <sup>th</sup> Joint Workshop on New Technologies for Computer/Robot Assisted Surgery	Conference	3,6	x	
Presentazione ADI: vittorie, sfide, obiettivi	Seminar	0,2	x	
Control of Multi-Robot systems: from rendez-vous to long-duration autonomy	Seminar	0,2	x	
The Hamlyn Symposium on Medical Robotics 2019	Conference	7,2	x	
PID Passivity-based Control: Application to Energy and Mechanical Systems	Seminar	0,2	x	
SIDRA 2019 PhD Summer School	Doctorate School	3	x	
Innovation in Medical Robotics and the human-centred paradigm	Seminar	0,2	x	
2019 IEEE/RSJ International Conference on Intelligent Robots and Systems	Conference	9	x	

## 3. Research activity

My primary research activity is the development of innovative control methods in minimally invasive surgery and microsurgery.

The use of surgical robots significantly improves surgeons' technical capabilities, improving the accuracy of tissue manipulation tasks and the quality of surgical procedures. In Minimally invasive surgery, the da Vinci robot is the most used surgical robotic platform. Also, in microsurgical procedures the use of robots significantly enhances the surgeon's performances.

The research activity articulates in three parts:

- The use of computer vision allowing characterizing the surgical scene and track soft-tissues and surgical instruments, using a stereo camera as sensor;
- Development of new control algorithms allowing the surgeon working under less stressful conditions and performing the surgical procedures with more accuracy and safety;
- The development and the integration of new sensors and instruments in surgical robots.

Shared control techniques such as virtual fixtures and active constraints, are identified as a concrete aid for the surgeon to perform precise operation, reducing its physical workload.

I focused on multiple aspects necessary for the development of assistive surgical procedure towards fully autonomy and the surgical robot:

- I. Development of a vision-based method for robot-aided polyp dissection using the da Vinci Research Kit (dVRK). The method defines a technique to constrain the robot to follow an accurate dissection path based on Virtual Fixtures (VF). The VFs are created via specific control points obtained directly from images of the surgical scene and are updated by a vision algorithm. The VF constraints can autonomously adapt themselves to environment changing during the surgical intervention. The work leads to the publication of the following papers: [5], [8], [11].
- II. Development of a surgical tools collision avoidance method that uses Forbidden Region Virtual Fixtures. Tool clashing is avoided by rendering a repulsive force to the surgeon. To ensure the correct definition of the VF, a marker-less tool tracking method, using deep neural network architecture for tool segmentation, is adopted. This work proposes an Extended Kalman Filter for pose estimation which ensures a more robust application of the VF, coupling vision and kinematics information. The proposed method allows avoiding

potential collision between surgical tools that could create serious damages. The work leads to the publication of the following papers: [1], [3].

- III. Definition of a haptic-guided shared-control teleoperation system which aims to avoid encountering kinematic constraints on the da Vinci Research Kit during suturing procedures. The method proposes a vision-based tracking of the suturing needle, defining the chosen grasping pose for immediate starting the suturing procedures. A shared control application guides the surgeon during the reach-to-grasp phase of the needle in the suturing task optimizing the cost of robot joint limits and singularities. The work leads to the publication of the following papers: [6], [9], [10].
- IV. Side activities: work on anthropomorphic smart hand PRISMA Hand II and multifunctional soft hand with force sensors for minimally invasive surgery, MUSHA Hand II. The work leads to the publication of the following papers: [2], [4], [7].

During the second year, I visited the Medical Micro instruments (MMI), S.p.A in Pisa. I studied the hardware and software of the RASM robotic platform developed by MMI. The activity has defined by the following steps:

- I. Acquisition of detailed information about the RASM robot: reference frame definition, component's geometry.
- II. Definition of the kinematic model for the RASM robot.
- III. Test of the developed model in simulation environment.

Finally, I attended the following International conference on Robotics and Automation and Doctorate school:

1. 9<sup>th</sup> Joint Workshop on New Technologies for Computer/Robot Assisted Surgery, Genova, Italy, March 21-22, 2019.
2. Hamlyn Symposium on Medical Robotics, London, England, June 23-26, 2019.
3. SIDRA 2019 PhD Summer School.
4. 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau, China, November 3-8, 2019.

## 4. Products

### Journal Papers

- [1] **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, 2019.
- [2] H.Liu, M.Selvaggio, P.Ferrentino, **R.Moccia**, S.Pirozzi, U.Bracale, F.Ficuciello, “The MUSHA Hand II: A Multi-Functional Hand for Robot-Assisted Laparoscopic Surgery”, IEEE Transactions on Mechatronics, 2019. **(Under Review)**

### Conference Papers

- [3] **R.Moccia**, C.Iacono, B.Siciliano, F.Ficuciello. “Vision-based Dynamic Virtual Fixtures for Tools Collision Avoidance in Robotic Surgery”, 2020 IEEE International Conference on Robotics and Automation, Paris, France, May 31 – June 4, 2020. **(Under Review)**
- [4] P. Ferrentino, D.E. Canbay, H. Liu, **R. Moccia**, S. Pirozzi, B. Siciliano, F. Ficuciello, “An optimized tactile sensing suite for contact force control of the PRISMA Hand II”, to IEEE International Conference on Robotics and Automation 2020, Paris, France, May 31 – June 4, 2020. **(Under Review)**
- [5] **R.Moccia**, M.Selvaggio, L.Villani, B.Siciliano, F.Ficuciello, “Vision-based Virtual Fixtures Generation for Robotic-Assisted Polyp Dissection Procedures”, Proceedings of 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau, China, November 3-8, 2019.
- [6] M.Selvaggio, A.M. Ghalamzan E., **R.Moccia**, F.Ficuciello, B.Siciliano, “Haptic-guided shared control for needle grasping optimization in minimally invasive robotic surgery”, Proceedings of 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau, China, November 3-8, 2019.

### Workshops - Short Papers

- [7] P.Ferrentino, H.Liu, M.Selvaggio, **R.Moccia**, S.Pirozzi, B.Siciliano, F.Ficuciello, “The MUSHA Soft Hand for Minimally Invasive Surgery”, IROS Workshop “Advances in Soft Robots Control”, Macau, China, November 4, 2019.
- [8] **R.Moccia**, M.Selvaggio, L.Villani, B.Siciliano, F.Ficuciello, “Vision-based Virtual Fixtures Generation for Robotic-Assisted Polyp Dissection Procedures”, The 12<sup>th</sup> International Workshop on Human Friendly Robotics, Reggio Emilia, Italy, October 24-25, 2019.

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Rocco Moccia

- [9] **R. Moccia**, M. Selvaggio, F. Ficuciello, “Suturing Needle Tracking for Grasping Optimization in Minimally Invasive Surgery”, at Hamlyn Symposium on Medical Robotics 2019 Workshop, “From BCI to Human Robot Augmentation”, London, England, June 26, 2019.
- [10] **R. Moccia**, M. Selvaggio, F. Ficuciello, “Suturing Needle Tracking for Grasping Optimization in Minimally Invasive Surgery”, Italian Institute of Robotics and Intelligent Machines, Rome, Italy, October 20, 2019.
- [11] **R. Moccia**, M.Selvaggio, B.Siciliano, A.Arezzo, F.Ficuciello. “Vision-based Virtual Fixtures Generation for MIS Dissection Tasks” CRAS 2019 – 9<sup>th</sup> Joint Workshop on New Technologies for Computer/Robot Assisted Surgery, Genova, Italy, March 21-22, 2019.

## 5. Summary of credits

Student: Rocco Moccia <a href="mailto:rocco.moccia@unina.it">rocco.moccia@unina.it</a>		Tutor: Bruno Siciliano <a href="mailto:bruno.siciliano@unina.it">bruno.siciliano@unina.it</a>		Cycle XXXIII																						
	Credits year 1							Credits year 2							Credits year 3							Total	Check			
	Estimated	1	2	3	4	5	6	Summary	Estimated	1	2	3	4	5	6	Summary	Estimated	1	2	3	4			5	6	Summary
<b>Modules</b>	20			3	3		13	19	11	1,2		4,2				5,4	6							0	24	30-70
<b>Seminars</b>	5	3,2	0,4	1			0,2	4,8	5,2	0,2	4,2	7,8	3	0,2	9	24	6							0	30	10-30
<b>Research</b>	35	5	6	6	6	6	6	35	45	6	8	8	8	8	8	46	60							0	81	80-140
	60	8,2	6,4	10	9	6	19	59	61	7,4	12	20	11	8,2	17	76	72	0	0	0	0	0	0	0	135	180

Year	Lecture/Activity	Type	Credits	Certification	Notes
	<b>MODULES</b>				
1	Green Economy and Management in Engineering projects	External Module	3	x	
1	Summer School on Control of Surgical Robots (COSUR 2018)	Doctoral School	3	x	
1	Image Processing For Computer Vision	MS Module	9	x	
1	Geometric Theory of Soft Robots	External Module	4	x	
2	Data Science and Optimization	Ad Hoc Module	1,2	x	
2	Machine Learning	Ad Hoc Module	4,2	x	
	<b>SEMINARS</b>				
1	EIT-Health Matchmaking Event 2018	Conference	3,2	x	
1	The Age of Human-Robot Collaboration	Seminar	0,4	x	
1	IBMQ: Building the First Universal Quantum Computers for Business and Science	Seminar	0,8	x	
1	How Does Mathworks Accelerate the Pace of Engineering and Science?	Seminar	0,2	x	
1	Domains of Attraction and Manifolds in Gear Model	Seminar	0,2	x	
2	Issues in Robotic Manipulation of Deformable Objects	Seminar	0,2	x	
2	Research work in active perception and robot interactive lab in IIT	Seminar	0,2	x	
2	Robots in Medical applications: an overview of the current Medical Robotics market	Seminar	0,4	x	
2	9 <sup>th</sup> Joint Workshop on New Technologies for Computer/Robot Assisted Surgery	Conference	3,6	x	
2	Presentazione ADI: vittorie, sfide, obiettivi	Seminar	0,2	x	
2	Control of Multi-Robot systems: from rendez-vous to long-duration autonomy	Seminar	0,2	x	
2	The Hamlyn Symposium on Medical Robotics 2019	Conference	7,2	x	
2	PID Passivity-based Control: Application to Energy and Mechanical Systems	Seminar	0,2	x	
2	SIDRA 2019 PhD Summer School	Doctoral School	3	x	
2	Innovation in Medical Robotics and the human-centred paradigm	Seminar	0,2	x	
2	2019 IEEE/RSJ International Conference on Intelligent Robots and Systems	Conference	9	x	