PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Giuseppe Andrea Fontanelli

XXXI Cycle

Training and Research Activities Report – First Year

Tutor: Bruno Siciliano

1. Information

Giuseppe Andrea Fontanelli, MS degree in Automation engineering, January 2014 with the thesis “Development of an 8 DOF Omnidirectional mobile robotic platform with integrated torque sensors". Now PhD student XXXI-cycle in Information technology and electrical engineering at the University of Naples Federico II, with a university fellowship, under the supervision of the professor Bruno Siciliano.

2. Study and training activities

During my first year of PhD I attended the following seminars, courses, conference and summer school:

a) Courses:

- The Entrepreneurial Analysis of Engineering Research Projects, (3 CFU)
  Lecturer: Luca Iandoli
- Introduzione a Matlab, (3 CFU)
  Lecturer: Alessandra D’alessio
- Laboratorio di software per l'ottimizzazione (8 CFU)
  Lecturer: Claudio Sterle, Antonio Sforza

b) Seminars

- Armi autonome, problemi etici e decisioni politiche, 01/12/2015 (0.4 CFU)
  Lecturer: Guglielmo Tamburini
- Medical Robot Research at IPR- KIT, 09/06/2015, (0.4 CFU)
  Lecturer: Heinz Worn
- DDoS detection in cloud and campus network, 06/06/2016 (0.3 CFU)
  Lecturer: Jill Jermyn
- The Development of a Fast Pick-And-Place Robot With an Innovative Cylindrical Drive, 16/05/2016 (0.3 CFU)
  Lecturer: Jorge Angles
- Test and diagnosis of integrated circuits, 17/11/2015 (1.2 CFU)

Lecturer: Alberto Bosio

c) Summer school

- SIDRA summer school 2016 held in Bertinoro, (4CFU), http://www.ceub.it
- COSUR summer school 2016 held in Verona, (3 CFU), http://metropolis.scienze.univr.it/altair/events/cosur-2016/

d) Conference

- CRAS 2016 workshop held in Pisa (1.9 CFU), https://www.cras-eu.org/cras-2016
- HFR 2016 workshop held in Genova (1.4 CFU), https://hfr2016.wordpress.com/

3. Research activity

My research field is surgical robotics. Minimally Invasive Robotic Surgery (MIRS) holds a fundamental role in modern surgical procedures. In details, a better sense of visual immersion and comfort for the surgeon, the less post-operative pain and recovery with respect to the classical open or laparoscopic surgery, are just some of the benefits of using robots in minimally invasive procedures.

I had the opportunity to work in collaboration with the Prisma Lab and the new Interdepartmental Centre for Advances in Robotic Surgery ICAROS located in the Policlinico of Naples. I worked strictly with the urologist surgeon and I attended to more than six surgical procedure in the operative room in order to find and evaluate the main problems and the main needs of surgeons. I worked on the Da Vinci robot that is the most used robot in laparoscopic surgery.

During the first phase of studying, in which I had the opportunity to participate in a summer school (COSUR) and a conference (CRAS) on the robotic surgery, I find that one of the most difficult procedure in laparoscopic robotic surgery is the reconstructive phase that consists of suturing the tissues after the organ removal. For example in a radical prostatectomy procedure, the reconstructive phase consists of linking again, with a suture, the urethra to the bladder after the prostate removal.

For this reason, I choose to dedicate my research to the suturing problem in order to improve the speed and the quality of the procedure.

A provisory title of my research could be “Mechatronic design and methods to improve the suturing phase during a robotic surgical procedure”.

I worked in parallel on multiple aspects necessary for the development of an assisted suturing procedure:

a) Development of a Matlab toolbox for the kinematic and dynamic modelling and identification of any multi-chain robot. The toolbox, using the information provided on the robot structure (Denavit and Hartemberg convention), is able to calculate, in symbolic form, all the matrices that define the kinematic and dynamic model of the robot. An LMI-based optimization approach [1] is implemented to identify the dynamical parameters and an optimal trajectory planner is used to calculate the identification trajectory that minimizes the condition number of the dynamical regressor. I choose the LMI-based approach in order to include the physical consistency constraints in the optimization procedure.

b) Tracking of soft objects and simulation of contact between rigid and soft bodies.
I start to study the problem of soft object tracking in collaboration with the post-doc Antoin Petit of the Prisma Lab team. During our collaboration, we developed a real-time tracker for deformable objects using an Asus Xition sensor to reconstruct the point cloud and a FEM model of the object to track the deformations. In particular, the algorithm was used to track a pizza phantom in the RoDyMan project context but it could be used, without any problems, to track the tissues deformation.
Moreover, a collision detection algorithm between rigid and thin objects and soft bodies was be implemented in an open source engine (bullet) in order to simulate the interaction between the needle and the organs. The original algorithm presented by Fukuhara [2] has been extended in order to calculate the collision between soft objects and generic rigid and thin bodies. Furthermore, a haptic interface has been used to allow the surgeon to feel the forces applied on the simulated environments and a nonlinear model for the force interaction was considered.

c) Mechatronic design of new sensors and tools for the da Vinci robot. During this year a firsts prototypes of two tools were developed.
The first one is a new force sensor, which can be mounted on a trocar (the entrance in the patient’s body used for the robotic tools) in order to measure the force applied on the tool tip of the robot, along the axis “x” and “y”. This device is a big improvement respect the state of the art on the force sensors used in robotic surgery because allows the force measure without any modification on robot’s arm. The sensor is developed using a deformable structure realized with 3D printing and use four optical distance sensors in order to measure the structure deformations and reconstructing the force. The first results are promising.
The second one is a new laparoscopic tool for in hand manipulation of a needle during suturing. This tool promises to improve the comfort and the dexterity for the

surgeon during a suturing procedure. A patent for that was written and a submission procedure will start in the next months.

d) Study the state of the art for an optimal trajectory planning for suturing and for force-based virtual fixtures.

The final goal of this research is the development of a real-time trajectory planner for suturing that will be able to minimize the tissues stress. The force sensor and the FEM model could be used to calculate the tissues stress that will be an input for the optimal planner. Moreover, virtual fixtures, applied on the haptic device, can be used to constrain the surgeon motions along this path.

4. Products

a) **Journal paper published:** Antoine Petit, Vincenzo Lippiello, ANDREA FONTANELLI, Bruno Siciliano, "*Tracking elastic deformable objects with an RGB-D sensor for a pizza chef robot*" in Robotics and automation systems, September 2016.

b) **Conference paper:** F. Fazioli, F. Ficuciello, G. A. FONTANELLI, B. Siciliano, L. Villani, *"Implementation of a Soft-Rigid Collision Algorithm in an Open-Source Engine for Surgery Realistic Simulation*". The article was presented as a poster section at the CRAS Workshop 2016 (Pisa 12-14 September) and as a fully presentation at the HFR Workshop 2016 (Genova 29-30 September). Moreover an extended version of that work was submitted, and accepted at the ROBIO conference 2016.

c) **Patent:** An Italian patent for a new laparoscopic tool that allows in hand manipulation of a needle during a suturing procedure was written and will be submitted in the next months.

References

[1] Cristovao D. Sousa, Rui Cortesao, *"Physical Feasibility of Robot Base Inertial Parameter Identication: a Linear Matrix Inequality Approach"*, in The International Journal of Robotics Research · May 2014

[2] Akira Fukuhara et al. "*Proposition and evaluation of a collision detection method for real time surgery simulation of opening a brain fissure"*. In: ROBOMECH Journal 1.1 (2014)

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	20		6			8	7	**21**	10							**0**								**0**	**21**	**30-70**
Seminars	5	1,6	0		1	0	3,3	**5,9**	5							**0**								**0**	**5,9**	**10-30**
Research	35	8,4	4	10	9	2	2	**35**	45							**0**								**0**	**35**	**80-140**
	60	10	10	10	10	10	12	**62**	60	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	**62**	**180**