PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Mario Selvaggio

XXXII Cycle

Training and Research Activities Report – Second Year

Tutor: Bruno Siciliano

1. INFORMATION

NAME: Mario Selvaggio

EDUCATION: M. Sc. Mechanical Engineering – Università degli Studi di Napoli Federico II, department of Industrial Engineering

CURRENT POSITION: XXXII Cycle Ph.D. student at the department of Information Technology and Electrical Engineering – Università degli Studi di Napoli Federico II – MIUR fellowship – supervised by prof. Bruno Siciliano.

2. STUDY AND TRAINING ACTIVITIES

Courses:

Lecture/Activity	Type	Credits	Certification
Geometric Theory of Soft Robots	Ad hoc module	4	
Delay differential equations and their applications	Ad hoc module	3	x
Introduction to modeling and control of mechanical systems with constraints	Ad hoc module	2	x

Seminars:

Lecture/Activity	Type	Credits	Certification
Approssimazione di problemi alle derivate parziali e applicazioni	Seminar	2	x
How does mathworks accellerate the pace of engineering and science	Seminar	0.2	x
A leap into funnctional data analysis: from theory to applications	Seminar	2	x

Summer schools:

Lecture/Activity	Type	Credits	Certification
Control of Surgical Robots Summer School	Doctoral School	4	x

Conferences:

Conference	Papers	Credits	Certification
2018 IEEE/RSJ International Conference on Intelligent Robots and Systems, 1-5 Oct., Madrid, Spain.	2	-	x
Sixth National Congress of Bioengineering	1	-	x

3. RESEARCH ACTIVITY

My primary research topic is haptic-enabled shared-control robotic teleoperation with application in minimally invasive robotic surgery and remote maintenance in hazardous industrial settings. The research activity focuses on the design and development of novel shared-control techniques for complex telerobotic systems operating in non-trivial scenarios.

Teleoperation is one of the oldest robotics fields of application. In recent years, renewed interest has been shown in this field due to its effectiveness and benefits that it brings to the society. Nuclear industry and robotic surgery are two of the most relevant application examples.

However, remotely performed activities are still relatively slow and very difficult to carry out (usually highly skilled human operators are required, e.g. in robotic surgery). The idea of shared control comes here into play: with the aid of sensory feedback, it is possible to endow teleoperation systems with a certain degree of autonomy which alleviates the human operator physical and cognitive workload in accomplishing a difficult task. In this sense, the control of the systems is traded between the human operator and the autonomous controller with the ultimate scope of combining human intelligence and precision/effectiveness of autonomous control.

I dedicated the second year of my PhD to the study and development of shared control techniques to minimally invasive robotic surgery and remote maintenance of nucleal sites. In robotic surgery, the main problem is the difficulty to model the environment in which the robot operates that limits also the development of completely autonomous control strategies. Hence, human inputs and artificial sensory feedback techniques can be used in order to interactively define the task/model. However, this model must be dynamically updated to be effectively exploited. To this end, I developed an “adaptive virtual fixtures” strategy which helps the surgeon to define the task interactively and perform very precise operations while reducing her/his physical and cognitive workload. On one hand, haptic guidance techniques were exploited to provide the user with the needed assistance. On the other hand, the adaptation strategy threatens the stability of the system, so passivity-based control techniques were used to guarantee a stable behaviour for any user/environment interaction. This activity is currently still under development, one paper has been published in the IEEE Robotics and Automation Letters. Future works on this trend will consider the exploitation of advanced vision-based sensing techniques.

On the same line, I recently started a collaboration with Dr. Amir M. Ghalamzan E. from university of Lincoln (UK) in which we aim to investigate the problem of optimally grasping an object to maximize the success of the post-grasping manipulation tasks (a.k.a. task-oriented grasping). This topic finds perfect application in robotic surgery, e.g. to grasp a needle for suturing. The main goal is to devise suitable metrics along the task trajectories for grasping evaluation and haptic guidance techniques that drive the surgeon towards the optimal grasping pose in a shared control fashion.

In this scenario, it would be very useful to use different control strategies based on the currently executed state of the surgical procedure. To this end, task classification techniques must be exploited. Machine learning approaches help to train classifiers that can online decode the surgical tasks. Preliminary results on this topic has been presented in two workshop papers to the 7th Joint Workshop on New Technologies for Computer/Robot Assisted Surgery, held in Montpellier (France) and to the Sixth National Congress of Bioengineering, respectively. This research line is very interesting and attractive and will be further investigated into the next year.

Shared-control methods are often used in combination with haptic guidance techniques: on this topic I established a collaboration with Rainbow team (previously Equipe de Recherche Lagadic), IRISA, INRIA Rennes where I spent a short period in Nov-Dec 2018 under the supervision of Dr. P. Robuffo Giordano. On the continuation of the previous abroad

period (Nov-Dec 2017), this time, I investigated the possible loss of passivity problem that can arise in a shared-control teleoperation system with a redundant slave manipulator. A task-prioritized architecture was adopted to simultaneously accomplish autonomous and user-specified tasks, while a haptic guidance method is used for constraints avoidance (collisions, joint limitations, singularities etc.). The potential loss of passivity was prevented by resorting to an energy tanks passivity-based control technique that was opportunely reformulated for this scope. On this research line one paper has recently been accepted to the 2019 IEEE International Conference on Robotics and Automation.

Moreover, a new research line was identified and is currently under investigation, i.e. the possibility of dynamically balancing an object using a shared controlled manipulator. Usually, shared-control methods consider kinematic control of the manipulator. When an object is not firmly grasped it may fall from the robot end-effector. In this work, we aim to find a controller that automatically prevents the object from falling while accepting human-specified set-point. One paper is in preparation on this topic.

In addition, during the last year I carried out some side activities:

a. Simulation and experimental test of the MUSHA hand (on the account of the project MUSHA whose principal investigator is Fanny Ficuciello), one paper was published in the International Journal of Medical Robotics and Computer Assisted Surgery.
    a. On this activity, our group was also awarded second prize at the “SWITCH 2 PRODUCT INNOVATION IN BIOENGINEERING” organized by the Sixth National Congress of Bioengineering. The award consists in a free consultancy for patent submission.
b. Development of a novel tool for laparoscopic robotic surgery with in-hand rolling capabilities (in collaboration with my colleague Giuseppe Andrea Fontanelli – PhD student XXXI cycle), one journal paper was published in the IEEE Robotics and Automation Letters and one workshop paper was presented to the Hamlyn Symposium on Medical Robotics.
c. Development of a V-Rep simulator for the da Vinci Research Kit robot, in collaboration with University of Rome La Sapienza (prof. M. Vendittelli and Dr. M. Ferro). This work led to two accepted conferences and one journal paper submitted.

All the activities were carried out between PRISMA Lab and ICAROS centre. The abroad period was spent at Rainbow team, IRISA, INRIA Rennes.

Additionally, I was granted from the IEEE Robotics and Automation Society – Technical committee on haptics for the “Innovation in haptics by young researchers” program € 2500, and from the Coinor Unina STAR program L2 for the project “Everte – Eversive Robot Teleoperation” € 9500 (scholarship to spend a 6-months period to University of California Santa Barbara” in 2019.

4. PRODUCTS

Publications:

a. Published:

i. M. Selvaggio, P. Robuffo Giordano, F. Ficuciello and B. Siciliano. “Passive Task-prioritized Shared-Control with Haptic Guidance.” Proceedings of 2019 IEEE International Conference on Robotics and Automation, Accepted, Montreal, Canada, May 20-24, 2019.
ii. M. Ferro, D. Brunori, F. Magistri, L. Saiella, M. Selvaggio, G. A. Fontanelli. “A portable da Vinci simulator in virtual reality.” Proceedings of 3rd IEEE International Conference on Robotic Computing, Accepted, Napoli, Italy, Feb 25-27, 2019.
iii. G. A. Fontanelli, M. Selvaggio, M. Ferro, F. Ficuciello, M. Vendittelli, B. Siciliano. “A V-REP simulator for the da Vinci Research Kit robotic platform." Proceedings of 7th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics, Pages: 1056-1061, Enschede, The Netherlands, August 26-29, 2018.
iv. M. Selvaggio, G. A. Fontanelli, V. R. Marrazzo, U. Bracale, A. Irace, G. Breglio, L. Villani, B. Siciliano, F. Ficuciello. “The MUSHA underactuated hand for robot-aided minimally invasive surgery.” International Journal of Medical Robotics and Computer Assisted Surgery, accepted.
v. F. Chen, M. Selvaggio, D. G. Caldwell. “Dexterous Grasping by Manipulability Selection for Mobile Manipulator with Visual Guidance.” IEEE Transactions on Industrial Informatics, accepted.
vi. M. Selvaggio, F. Abi-Farraj, C. Pacchierotti, P. Robuffo Giordano and B. Siciliano. “Haptic-Based Shared-Control Methods for a Dual-Arm System.” IEEE Robotics and Automation Letters, Vol. 3, no. 4, pages 4249-4256, Oct. 2018.
vii. M. Selvaggio, G. A. Fontanelli, F. Ficuciello, L. Villani and B. Siciliano. “Interactive Generation and Passive Adaptation of Virtual Fixtures in Minimally Invasive Robotic Surgery." IEEE Robotics and Automation Letters, Vol. 3, no. 4, pages 3129-3136, Oct. 2018.
viii. G. A. Fontanelli, M. Selvaggio, L. R. Buonocore, F. Ficuciello, L. Villani and B. Siciliano. “A New Laparoscopic Instrument with In-Hand Rolling Capabilities for Needle Re-Orientation.” IEEE Robotics and Automation Letters, Vol. 3, no. 3, pages 2354-2361, July 2018.
ix. M. Selvaggio, G. A. Fontanelli, F. Ficuciello, L. Villani, B. Siciliano. “A virtual fixture adaptation strategy for MIRS dissection tasks.” 8th Workshop on New Technologies for Computer/Robot Assisted Surgery, -, London, UK, Sep. 2018.
x. M. Selvaggio, G.A. Fontanelli, F. Ficuciello, L. Villani, B. Siciliano. “Enhancing Dexterity with a 7-DoF Laparoscopic Suturing Tool.” The Hamlyn Symposium on Medical Robotics, -, London, UK, June 24-27, 2018.
xi. M. Selvaggio, L. Villani, B. Siciliano, F. Ficuciello. “Physics-based task classification of da Vinci robot surgical procedures.” Sixth National Congress of Bioengineering, -, Milan, Italy, June 25-27, 2018.

b. Submitted:

i. G. A. Fontanelli, M. Selvaggio, M. Ferro, F. Ficuciello, M. Vendittelli and B. Siciliano. “Portable dVRK: an augmented V-REP simulator of the da Vinci Research Kit”, Acta Polytechnica Hungarica, Special Issue on Platforms for Medical Robotics Research.

c. In preparation (titles are provisional)

i. M. Selvaggio, Amir M. Ghalamzan E., F. Ficuciello, B. Siciliano. “Assistive Shared-control for Manipulation with da Vinci”.
ii. M. Selvaggio, F. Abi-Farraj, M.Cognetti, C. Pacchierotti, P. Robuffo Giordano and B. Siciliano. “A Shared-control Method for Dynamic Grasping Tasks”.

Awards:

a. 2nd place at SWITCH 2 PRODUCT INNOVATION IN BIOENGINEERING contest held at the Sixth National Congress of Bioengineering.

Grants:

a. Robotics and Automation Society, Technical Committee on Haptics will fund my proposal "Haptic-guidance methods for robotic surgery" for $2500 during 2019.

b. I have been assigned a scholarship (€9500) from Coinor-Unina within the STAR 2018 program – L2 mobility for young researcher. The funded project "EveRTe: EVErsive Robot TEleoperation" will allow me to spend a 6-months period to University of California Santa Barbara during 2019.

5. Conferences and Seminars

a. IEEE/RSJ International Conference on Intelligent Robots and Systems, 1-5 October 2018, Madrid, Spain.
b. Sixth National Congress of Bioengineering, 25-27 June, Milan, Italy.

6. Abroad Activity

a. 12/10/2018 – 12/12/2018 Rainbow Team, IRISA, INRIA Rennes - Bretagne Atlantique Campus Universitaire de Beaulieu, Rennes, France. Work topic: haptic guidance and shared control teleoperation of a robotic system. One paper in preparation.

7. Summary of credits

Student: Mario Selvaggio									Tutor: Bruno Siciliano								Cycle XXXII									
mario.selvaggio@unina.it									bruno.siciliano@unina.it																	
	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	5	0	0	0	10	4	**19**	10	0	4	9	0	0	0	**13**	0							**0**	**32**	30-70
Seminars	10	0	0.8	8	1.9	0.4	0.4	**12**	5	0	2	0.2	0	0	2	**4.2**	0							**0**	**16**	10-30
Research	30	5	5	5	5	5	5	**30**	45	10	4	3	10	10	8	**45**	60							**0**	**75**	80-140
	60	10	5.8	13	6.9	15	9.4	**61**	60	10	10	12	10	10	10	**62**	60	0	0	0	0	0	0	**0**	**123**	180

Year	Lecture/Activity	Type	Credits	Certification	Notes
	MODULES				
1	Modelling, simulation and control of collective behaviour	Ad hoc module	2	x	
1	Introduction to artificial and computational intelligence	External Module	3	x	
1	Port-Hamiltonian modelling and passivity-based control of physical systems. Theory and applications	Doctoral School	4	x	
1	Analisi e controllo di reti e sistemi complessi	MS Module	6	x	
1	Machine Learning	Ad hoc module	4	x	
2	Geometric Theory of Soft Robots	Ad hoc module	4		
2	Delay differential equations and their applications	Ad hoc module	3	x	
2	Introduction to modeling and control of mechanical systems with constraints	Ad hoc module	2	x	
2	Control of Surgical Robots Summer School	Doctoral School	4	x	
	SEMINARS				
1	Icelandic centre of neurophysiology: aims, projects and opportunities for biomedical engineers student	Seminar	0.4	x	
1	Assessment, monitoring, prediction and decision making: different application from multimodal analysis	Seminar	0.4	x	
1	7th Joint Workshop on new Technologies for Computer/Robot Assisted Surgery	Conference	1.9	x	
1	Summer school on soft manipulation	External Seminar	8	x	summer s
1	From control to interaction in multi-robot systems	Seminar	0.4	x	
1	Dynamic control: mathematical challenges and applications	Seminar	0.4	x	
2	Approssimazione di problemi alle derivate parziali e applicazioni	Seminar	2	x	
2	How does mathworks accellerate the pace of engineering and science	Seminar	0.2	x	
2	A leap into funnctional data analysis: from theory to applications	Seminar	2	x	