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 – Third 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 Electrical Engineering and Information Technology – Università degli Studi di Napoli Federico II – MIUR fellowship – supervised by prof. Bruno Siciliano.

2. STUDY AND TRAINING ACTIVITIES

Courses:

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Seminars:

Lecture/Activity	Type	Credits	Certification
The age of human-robot collaboration: deep sea exploration	Seminar	0.3	x
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

Summer schools:

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Conferences:

Conference	Papers	Credits	Certification
2019 IEEE International Conference on Robotics and Automation, Montreal, Canada, May 20th – 24th 2019	1	-	x
58th IEEE Conference on Decision and Control - Nice, France - December 11th -13th 2019	-	-	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 third 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 deformable environment, in which the robot operates, is the most influent limiting factor to the development of completely autonomous control strategies. Hence, human intelligence and decision-making capabilities are essential to effectively carry out the tasks. However, autonomous control techniques can be used to aid the user instead of providing the system with full autonomy. To this end, haptic guidance techniques can be opportunely designed. This activity led to two papers published in the 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems. In both papers, advanced vision-based sensing techniques were used to design the assisting haptic guidance in the form of forces rendered through the master robotic interface. Optimal needle grasping (which allows avoiding post-grasping constraints) and precise polyp dissection tasks were considered as use cases. The work was carried out in collaboration with university of Lincoln (UK) and was granted by the IEEE Robotics and Automation Society technical committee on haptics under the “Innovation in Haptics by Young Researchers” program.

Haptic-based shared-control methods can be used for remote maintenance of nuclear sites: this research topic was addressed in collaboration with Rainbow team at IRISA, INRIA Rennes (established in the previous years). On the continuation of the previous abroad periods, we investigated the development of a shared-control teleoperation architecture with a redundant slave manipulator. A task-prioritized control architecture was adopted to simultaneously accomplish autonomous and user-specified tasks, while a haptic guidance method was used for constraints avoidance (collisions, joint limitations, singularities etc.). The potential loss of passivity, which can arise in such a devised system was prevented by resorting to an energy tanks passivity-based control technique that was opportunely designed for this scope. On this research line, one paper was presented to the 2019 IEEE International Conference on Robotics and Automation.

A telerobotic framework may use a soft robot as a slave system. Soft robots can exhibit large-scale deformations and high compliance which let them to safely interact with the environment. Compared to their traditional rigid-bodied counterparts, they bring benefits in applications in constrained environments, requiring unavoidable interaction with the surroundings. However, the development of effective semi-autonomous teleoperation strategies for soft robots should incorporate reliable robot-environment interaction models and planning strategies. This topic was addressed during the 6-months abroad period spent at the Mechanical Engineering department of University of California Santa Barbara. The abroad period was funded by COINOR UniNa under the “STAR Linea 2 – mobilità giovani ricercatori” program. This work led to a conference publication at the 2020 IEEE International Conference on Robotics and Automation.

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

a. Design, simulation and control of the MUSHA hand (for the project MUSHA whose principal investigator is Fanny Ficuciello), one paper on this topic is currently under evaluation.

b. Development of a simulation environment 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 the publication of one journal paper.

All the activities were carried out between PRISMA Lab and ICAROS centre. The abroad period was spent at University of California Santa Barbara.

4. PRODUCTS

Publications:

a. Published:

i. M. Selvaggio, L. A. Ramirez, B. Siciliano, E. W. Hawkes, “An obstacle-interaction planning method for navigation of actuated vine robots”, 2020 IEEE International Conference on Robotics and Automation, Paris (France), accepted.
ii. G. Notomista, S. Mayya, M. Selvaggio, M. Santos, C. Secchi, “A set-theoretic approach to multi-task execution and prioritization”, 2020 IEEE International Conference on Robotics and Automation, Paris (France), accepted.
iii. 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”, 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau (China), pp. 3617-3623, Nov. 2019, DOI: 10.1109/IROS40897.2019.8968109.
iv. R. Moccia, M. Selvaggio, L. Villani, B. Siciliano, F. Ficuciello, “Vision-based Virtual Fixtures Generation for Robotic-Assisted Polyp Dissection Procedures”, 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau (China), pp. 7934-7939, Nov. 2019, DOI: 10.1109/IROS40897.2019.8968080.
v. M. Selvaggio, P. Robuffo Giordano, F. Ficuciello, B. Siciliano, “Passive task-prioritized shared-control teleoperation with haptic guidance”, 2019 IEEE International Conference on Robotics and Automation, Monteal (Canada), pp. 430-436, May 2019, DOI: 10.1109/ICRA.2019.8794197.
vi. M. Ferro, D. Brunori, F. Magistri, L. Saiella, M. Selvaggio and G. A. Fontanelli, "A Portable da Vinci Simulator in Virtual Reality," 2019 Third IEEE International Conference on Robotic Computing (IRC), Naples, Italy, 2019, pp. 447-448. DOI: 10.1109/IRC.2019.00093.
vii. G. A. Fontanelli, M. Selvaggio, M. Ferro, F. Ficuciello, M. Vendittelli, B. Siciliano, “Portable dVRK: an augmented V-REP simulator of the da Vinci Research Kit”, Acta Polytechnica Hungarica, vol. 16 (8), pp. 79-98, 2019, DOI: 10.12700/APH.16.8.2019.8.6.
viii. 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, vol. 15 (3), pp. 1013-1062, 2019, DOI: 10.1002/rcs.1981.

b. Submitted:

i. 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/ASME Transactions on Mechatronics (submitted).

Grants:

a. Robotics and Automation Society, Technical Committee on Haptics grant for the project "Haptic-guidance methods for robotic surgery".

b. COINOR Unina scholarship within the STAR 2018 program – L2 mobility for young researcher. The funded project "EveRTe: EVErsive Robot TEleoperation" allowed me to spend the 6-months period to University of California Santa Barbara during 2019.

5. Conferences and Seminars

a. IEEE International Conference Robotics and Automation, May 20th - 24th 2019, Montreal, Canada.
b. 58th Conference on Decision and Control, December 11th -13th 2019, Nice, France
c. Invited talk at University of Modena and Reggio Emilia, May 10th 2019, Reggio Emilia, Italy

6. Abroad Activity

a. 01/06/2019 – 01/12/2019 University of California Santa Barbara. Work topic: eversive robot teleoperation.

7. Summary of credits

	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	0	0	0	0	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	0.3	0.4	0	0	0	0	**0.7**	**16**	10-30
Research	30	5	5	5	5	5	5	**30**	45	10	4	3	10	10	8	**45**	60	9	8	10	10	10	10	**57**	**132**	80-140
	60	10	5.8	13	6.9	15	9.4	**61**	60	10	10	12	10	10	10	**62**	60	9.3	8.4	10	10	10	10	**58**	**180**	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	x	
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	
3	The age of human-robot collabotation: deep sea exploration	Seminar	0.3	x	
3	Issues in robotic manipulation of deformable objects	Seminar	0.2	x	
3	Research work in active perception and robot interactive lab in IIT	Seminar	0.2	x	