Mario Selvaggio

Tutor: Bruno Siciliano

XXXII cycle - I year presentation

Shared-Control teleoperation for Mininimally Invasive Robotic Surgery

Background

Past experiences and education

PAST EXPERIENCES

Nov. 2017 Dec. 2017	**Visiting student** at Équipe de Recherche Lagadic (now Rainbow Team) - IRISA, INRIA Rennes - Bretagne Atlantique Campus Universitaire de Beaulieu, Rennes (France). Work topic: haptic guidance and shared control teleoperation of a dual arm robotic system.
Oct. 2015 Sep. 2016	**Intern** at ADVanced Robotics department, Istituto Italiano di Tecnologia, Genova (Italy). Member of the AutoMAP team working on the EU FP7 EuRoC project. Work topic: haptic feedback teleoperation for robotic mobile manipulation.
Apr. 2014 Sep. 2014	**Master thesis student** at department of Interactive Engineering Technologies, Fraunhofer IGD, Darmstadt (Germany). Thesis topic: modeling and simulation of kinematic chains for deformable bodies' animation.

EDUCATION

Jan. 2013 Apr. 2015	**MSc in Mechanical Engineering** at Università degli Studi di Napoli Federico II, department of Industrial Engineering. Dissertation: Interactive simulation of kinematic and dynamic chains and their coupling with deformable bodies.
Sep. 2009 Jan. 2013	**BSc in Mechanical Engineering** at Università degli Studi di Napoli Federico II, department of Industrial Engineering. Dissertation: L'espressione dell'incertezza nella misura.

Background

Current position

CURRENT POSITION

Ph.D candidate at Università degli Studi di Napoli Federico II, department of Information Technology and Electrical Engineering, PRISMA Lab and ICAROS center. Supervisor: Prof. Bruno Siciliano.

Research interests: shared control teleoperation for robotic surgery, robotic manipulation modeling and control, port-Hamiltonian modeling and passivity-based control.

Problem

Telerobotics overview

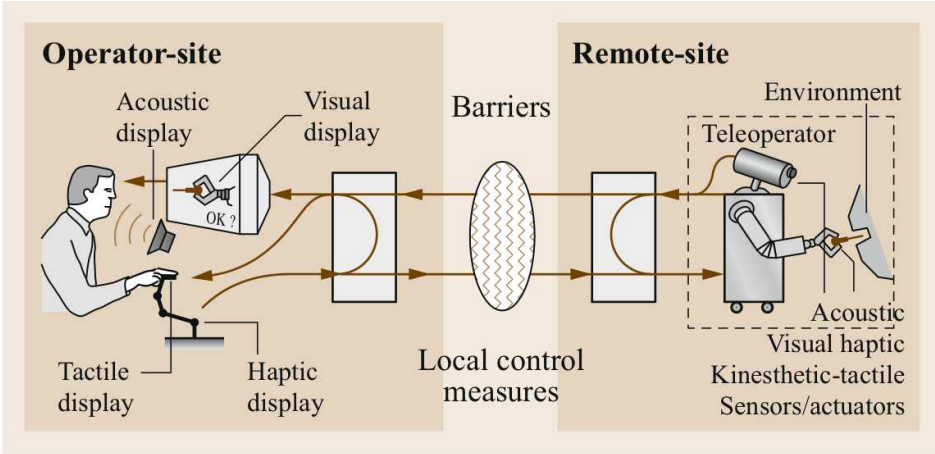

Figure: Overview of a telerobotic system

- a master side: human operator + master interface
- a slave side: slave teleoperator + environment
- a communication channel: bandwidth, time delay

Problem

Force feedback

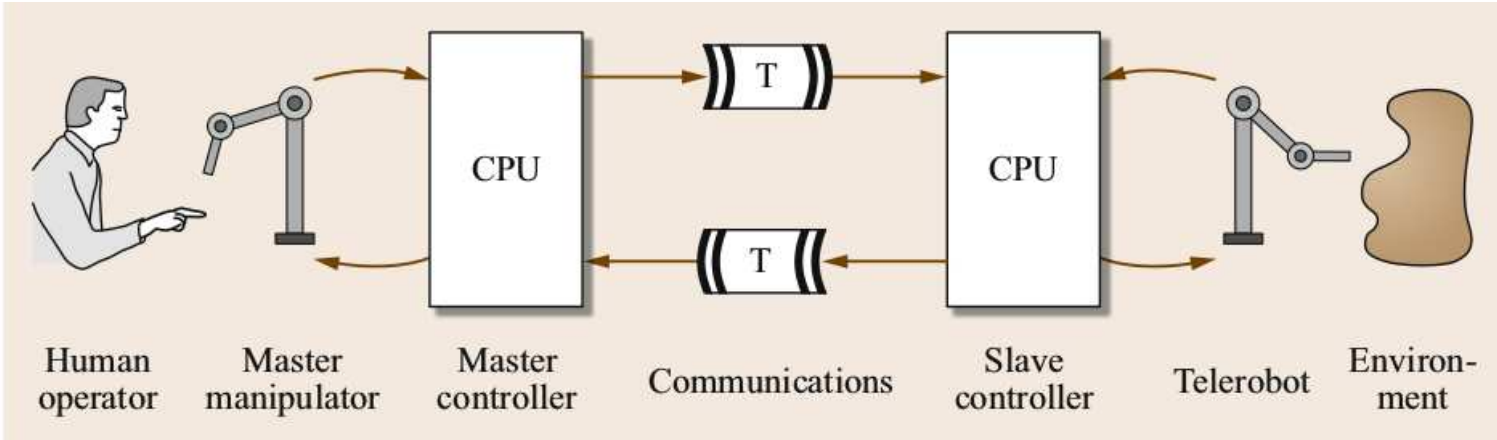

Figure: A tipical bilateral teleoperator

In the past decades...

- improve transparency: fidelity of force feedback
- guarantee stability: time delay, disturbances
- best architecture: position-force, force-force etc.

Problem

Control architectures

- Direct control: the user is controlling the motion of the robot directly
- Supervisory control: user's commands and feedback occur at a very high level and the robot requires substantial intelligence or autonomy
- Shared control: between the two extrema

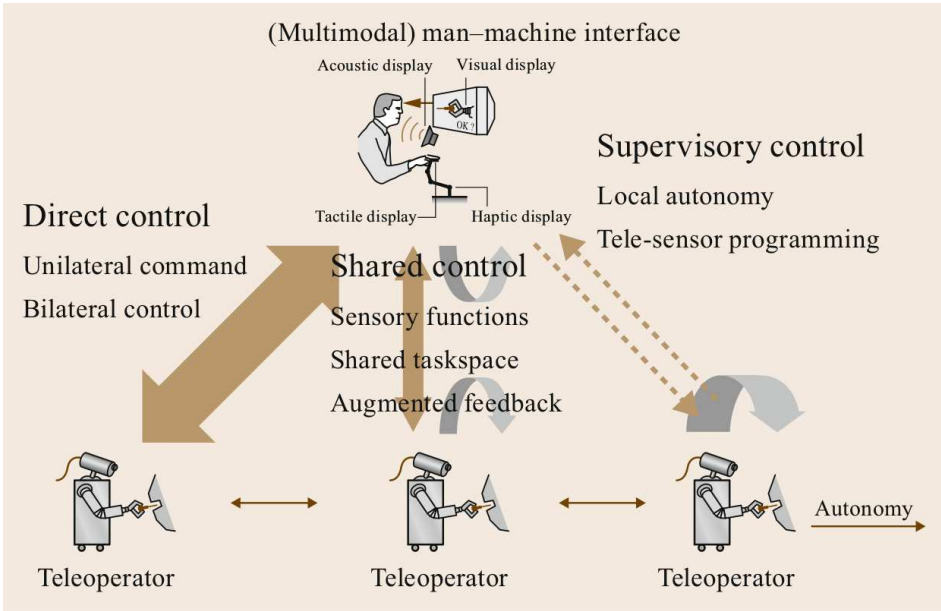

Figure: Different telerobotics control architectures

Problem

Shared control in robotic surgery

Robots are more precise but not yet intelligent/robust enough for complete autonomy

Different levels of assistance

- Tremor filtering
- Motion compensation
- Virtual fixtures
- Shared autonomy

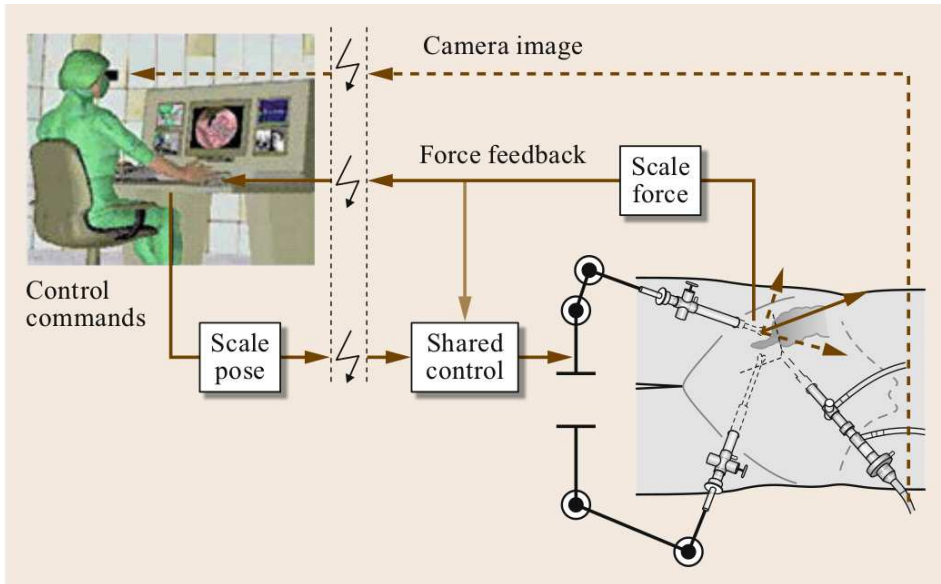

Figure: An example of shared control in telerobotic surgery

Problem

Shared control in robotic surgery

Open points:

(1) How to systematically split control tasks into teleoperative and autonomous control?

(2) How to adapt to different environmental condition and update the control modality?

(3) How to assign and determine the role of the human-in-the-loop?

(4) What is the best form of human interface (or haptic feedback) shared-control telerobotics and how to complement the interface with other modality (e.g., visual feedback)?

Problem

Shared control in robotic surgery

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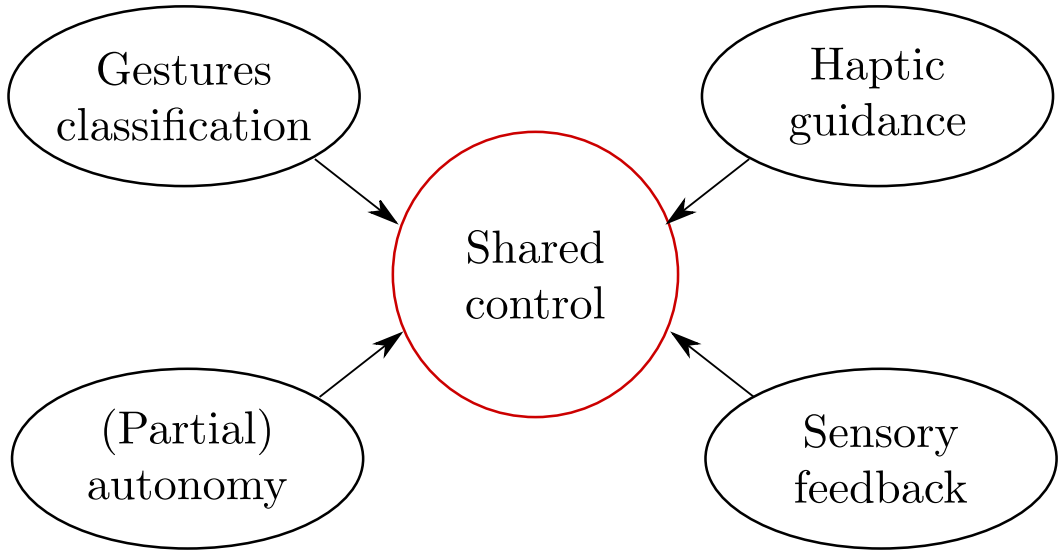
Research activities

Idea & methodology



Gestures classification allows the development of task dependent control
Haptic guidance can be provided through virtual fixtures
Autonomy reduces user cognitive workload
Sensory feedback allows augmentation of user awareness

Research activities

Developments

Gestures classification

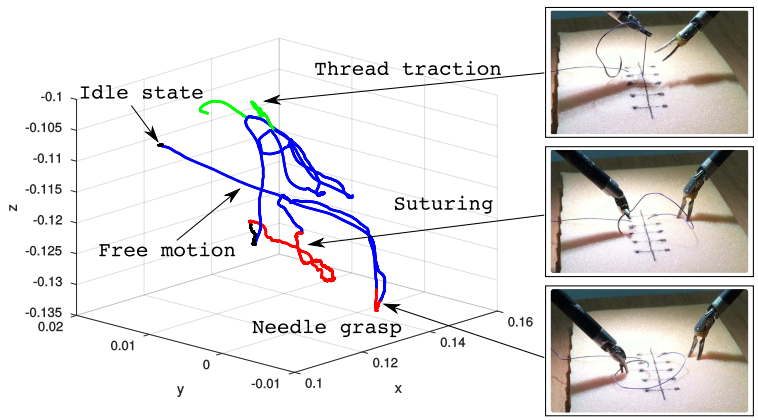


Figure: Suturing segmentation

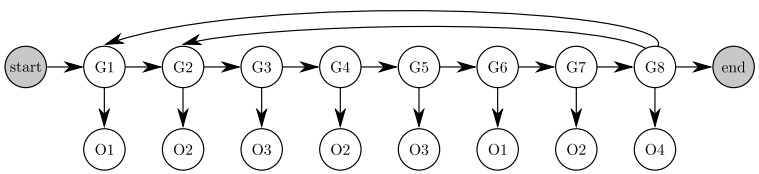


Figure: Suturing Hidden Markov Model

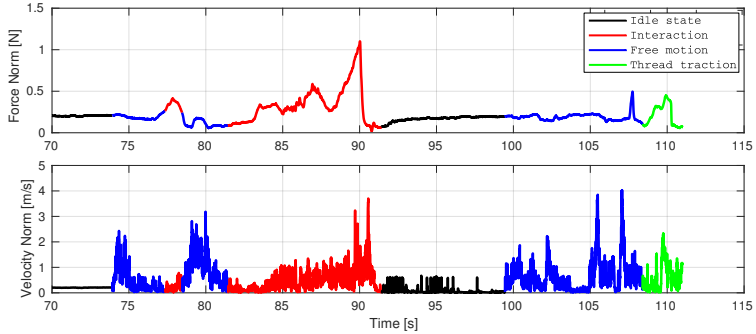


Figure: GMM clustering

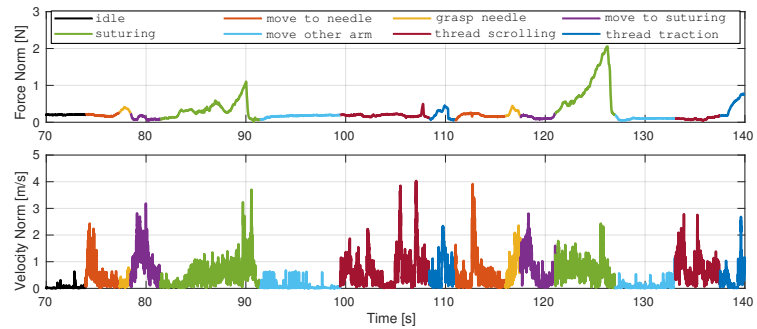


Figure: GMM+HMM gesture decoding

[1] M. Selvaggio, G. A. Fontanelli, F. Ficuciello and B. Siciliano, "Force-based Task Classification of Robotic Surgical Re-Constructive Procedures", CRAS 2017.

Research activities

Developments

Haptic guidance: virtual fixtures adaptation

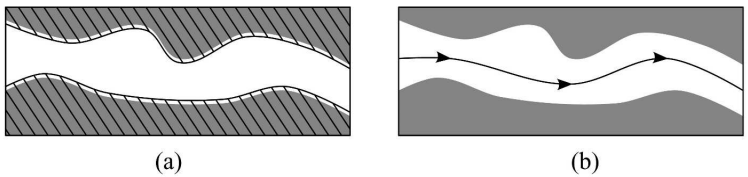


Figure: Forbidden regions (a) and guidance (b) virtual fixture

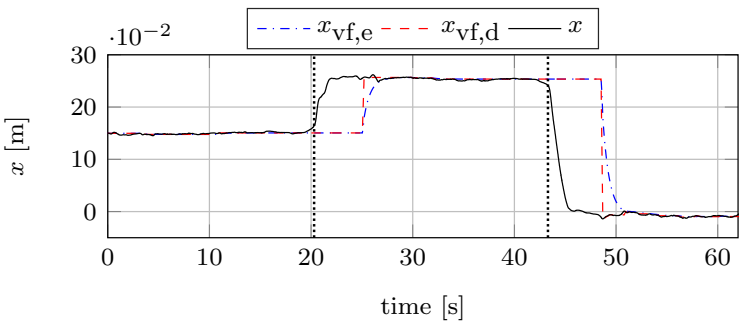


Figure: Virtual fixture adaptation

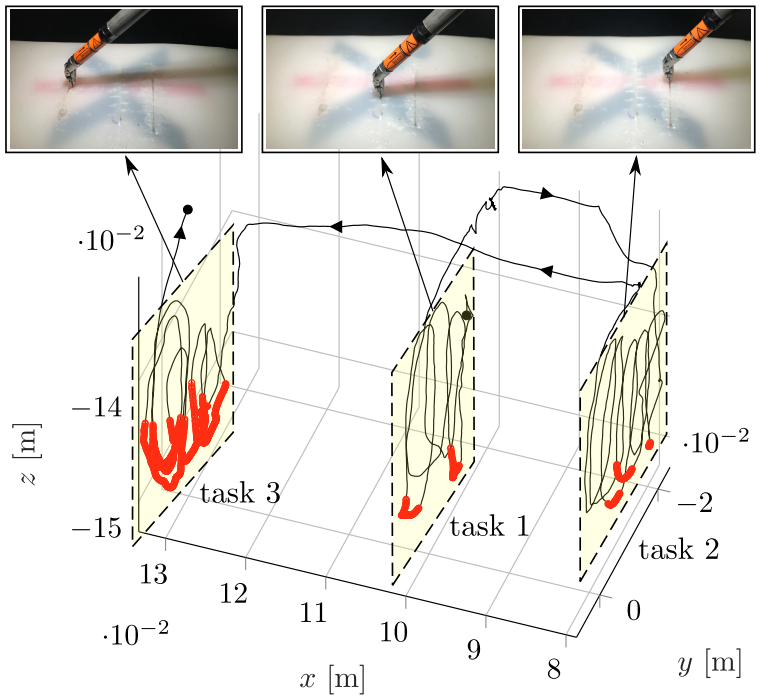


Figure: Surgical tasks

[1] M. Selvaggio, G. A. Fontanelli, F. Ficuciello, L. Villani and B. Siciliano, "A Passive Guidance Virtual Fixtures Adaptation Strategy", in preparation.

Research activities

Developments

Shared autonomy with haptic guidance

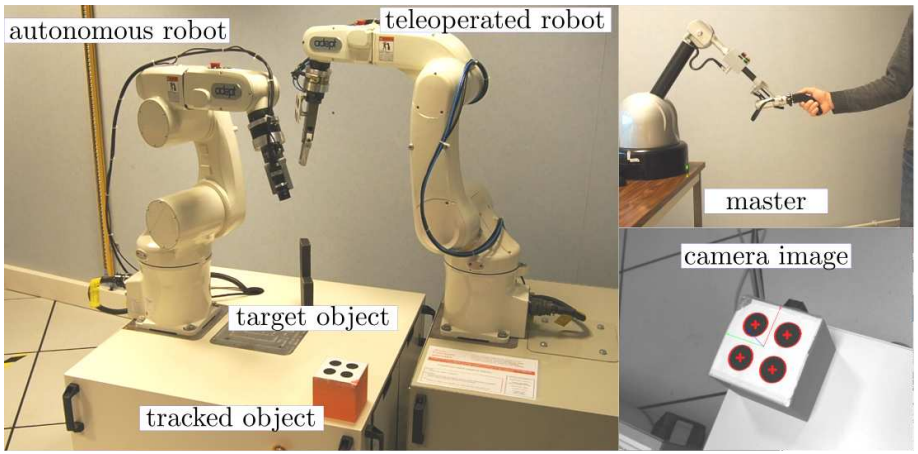


Figure: Experimental setup

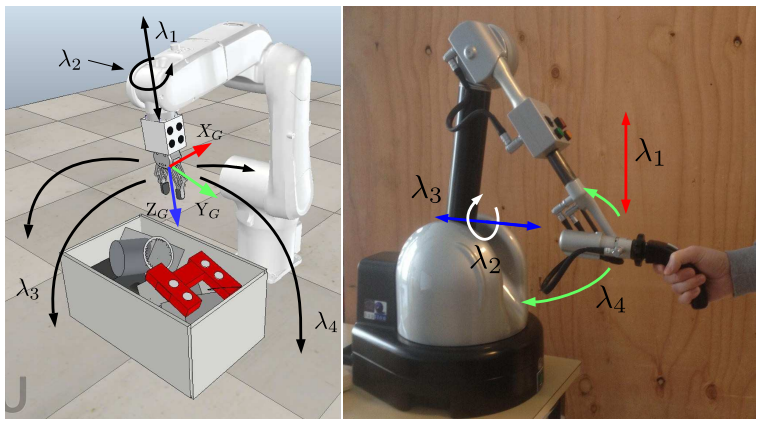


Figure: Shared control exploiting sensory feedback

- Autonomous orientation control towards target object
- Haptic feedback about collisions, joint limits and singularities

[1] M.Selvaggio, F. Abi-Farraj, B. Siciliano, C. Pacchierotti, and P. Robuffo Giordano, "Constraints avoiding and shared control architecture for dual arm teleoperation", in preparation.

Research activities

Side activities

Surgical tool for in-hand rolling

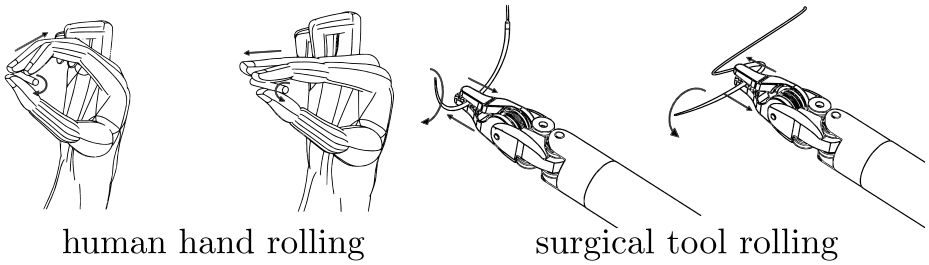


Figure: Human hand inspiration

Figure: CAD design

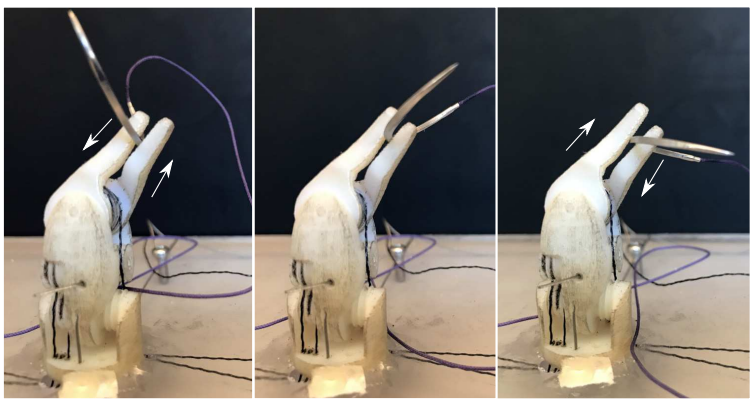


Figure: Prototype testing

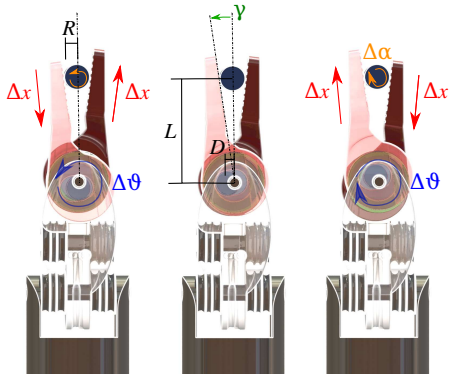


Figure: Modeling working principles

[1] G. A. Fontanelli, M. Selvaggio, L. R. Buonocore, F. Ficuciello, L. Villani, and B. Siciliano, "A New Laparoscopic Tool with In-Hand Rolling Capabilities for Needle Reorientation", accepted RAL 2018.

Research activities

Side activities

MUSHA hand

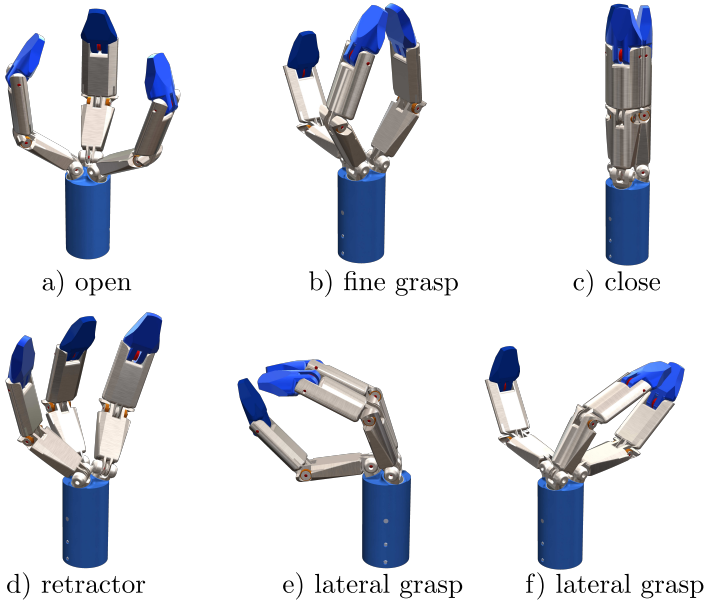


Figure: Multifunction smart hand for MIRS

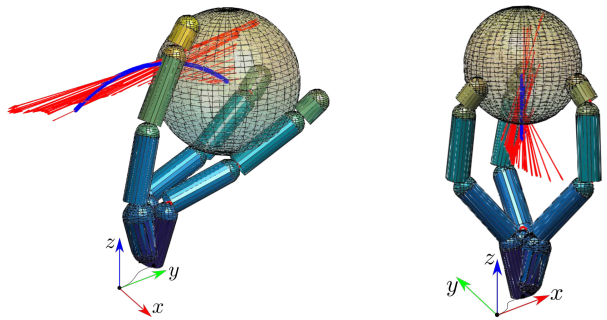


Figure: Simulation

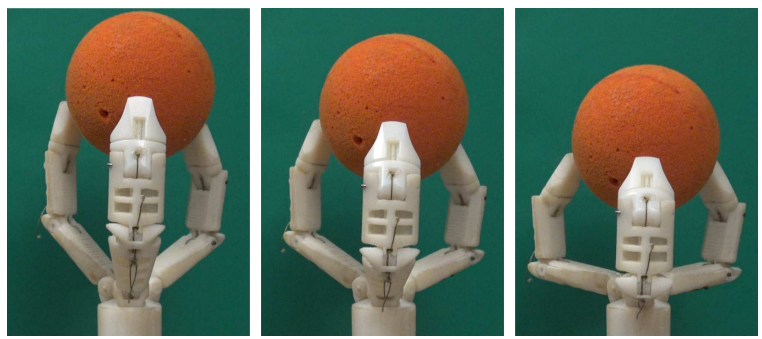


Figure: Prototype testing

[1] M. Selvaggio, G. A. Fontanelli, U. Bracale, L. Villani, B. Siciliano, and F. Ficuciello "The MUSHA underactuated hand for robot-aided minimally invasive surgery", in preparation.

Products

Publications

Previous (selected)

1. **M. Selvaggio**, S. Grazioso, G. Notomista, F. Chen "Towards a Self-Collision Aware Teleoperation Framework for Compound Robots." Proceedings of 2017 IEEE World Haptics Conference, Pages: 460 - 465, Fürstenfeldbruck (Munich), Germany, June 6-9, 2017.
2. **M. Selvaggio**, G. Notomista, F. Chen, B. Gao, F. Trapani, D. Caldwell. "Enhancing Bilateral Teleoperation using Camera-Based Online Virtual Fixtures Generation.âĂİ Proceedings of 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems, Pages: 1483 - 1488, Daejeon, Korea, October 9-14, 2016.
3. **M. Selvaggio**, F. Chen, B. Gao, G. Notomista, F. Trapani, D. Caldwell. "Vision Based Virtual Fixture Generation for Teleoperated Robotic Manipulation.âĂİ Proceedings of 2016 IEEE International Conference on Advanced Robotics and Mechatronics, Pages: 190 - 195, Macau, China, August 18-20, 2016.

Published

1. **M. Selvaggio**, G.A. Fontanelli, F. Ficuciello, L. Villani, B. Siciliano. "Task Classification of Robotic Surgical Reconstructive Procedures using Force Measurements." CRAS 2017 - 7th Joint Workshop on New Technologies for Computer/Robot Assisted Surgery, Montpellier, France, September 14-15, 2017.
2. 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*, Accepted.

Products

Publications

In preparation (titles are provisional)

1. **M.Selvaggio**, F. Abi-Farraj, B. Siciliano, C. Pacchierotti, and P. Robuffo Giordano, "Constraints avoiding and shared control architecture for dual arm teleoperation", in preparation.
2. **M.Selvaggio**, G. A. Fontanelli, F. Ficuciello, L. Villani and B. Siciliano, "A Passive Guidance Virtual Fixtures Adaptation Strategy", in preparation.
3. **M.Selvaggio**, G. A. Fontanelli, U. Bracale, L. Villani, B. Siciliano, and F. Ficuciello "The MUSHA underactuated hand for robot-aided minimally invasive surgery", in preparation.

Next years

I year credits

Student: Name Surname mario.selvaggio@unina.it

Tutor: Name Surname bruno.siciliano@unina.it

Cycle XXXII

	Credits year 1								Credits year 2								Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	20	5				10	4	**19**	10							**0**								**0**	**19**	30-70
Seminars	10		0.8	10		0.4	0.4	**12**	10							**0**								**0**	**12**	10-30
Research	30	5	5	5	5	5	5	**30**	40							**0**								**0**	**30**	80-140
	60	10	5.8	15	5	15	9.4	**61**	60	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	**0**	**61**	180

Modules and seminars

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	
	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 sc
1	From control to interaction in multi-robot systems	Seminar	0.4	x	
1	Dynamic control: mathematical challenges and applications	Seminar	0.4	x	