PhD Course in
ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Healthcare and Wellness of Persons

Research themes

The main goal of the curriculum “Robotics and Intelligent Machines for Healthcare and Wellness of Persons” is to contribute to improve people wellness and quality of life, as well as preventing risk of injuries or professional pathologies. This curriculum tackles the following challenges:

1. New algorithms for human-robot interaction in application including: diagnosis, therapy, rehabilitation, assistance, and support to healthcare personnel;
2. Increasing role of robots in the overall process involving prevention, diagnosis, therapy, recovery and home assistance, to increase social participation and involvement of people, reducing social isolation, monitoring daily activities and identify emergency situations;
3. New methods and techniques for human-machine interfaces, including bidirectional human-machine communication;
4. Innovative solutions per health, through integration of mechatronic devices, new materials and tissues;
5. Innovative solutions to improve efficiency and safety of medical personnel to reduce healthcare costs;
6. Innovative solutions to foster adoption of robotic solutions in the workplace, for prevention and reducing risks of work-related pathologies;
7. New methods for physical and social human-robot interaction, for wellness of people in various contexts, including education.

Projects in the curriculum will develop and experimentally validate methods, conventional, biomimetic and bio-inspired models, components, subsystems, systems and intelligent strategies for information analysis and telemedicine for:

- Medical robotics with imaging support;
- Rehabilitation robotics;
- Assistive robotics and functional replacement;
- Robotics for health and safety in the workplace;
- Innovative medical devices
- Human-robot interaction

The quality of research and its impact will be evaluated through specific indicators monitoring:

- Scientific Excellence;
- Industrial impact;
- Economic impact;
- Social Impact;
- Improvement to people health and wellbeing

The ideal candidates are students with a Master (or equivalent/higher) STEM (Science, Technology, Engineering, and Mathematics) degree and possibly a specific background in Robotics.

The students will perform their research project at the hosting institution (as described in the research project sheet). Interested applicants are encouraged to contact the tutors and/or the Unit's Principal Investigators for clarifications before submitting their application.

International applications are encouraged and applicants will receive logistic support with visa issues, relocation, etc.

1. AI-based neuromodulation for controlling neuronal activity - Univ. Genova

Curriculum

Healthcare and wellness of persons

Hosting Institution

Università degli Studi di Genova

Department:

DIBRIS, University of Genova, Genova, www.dibris.unige.it

Tutor(s):

Michela Chiappalone, Paolo Massobrio

Description:

Nervous system disorders have become a significant socio-economic burden. Among the different diseases, a growing number of patients can benefit from therapies using electrical stimulation. Nevertheless, they still present limitation in their usability, mostly due to the fact that the current technologies do not allow a truly personalized stimulation strategy. Within this PhD project, the goal is to test novel neuromodulatory strategies on different experimental models at an increasing structural complexity: from 2D to 3D in vitro cultures up to in vivo animal models. Neuromodulation will be tested in healthy preparation as well as pathological ones. The core of the neuromodulation system will be a closed-loop system initially based on a simple activity-dependent paradigm, based on the detection of peculiar events, such as spikes or their combination (e.g. network bursts). The system will be improved by leveraging on AI/machine learning techniques to deliver the most effective stimulation policies to reliably entrain network activity and to achieve online/real-time 'intelligent' stimulation. A test-train-validate learning paradigm will be exploited to on-line identify an activity pattern and deliver an appropriate electrical stimulation to arrest, prevent or 'rectify' the pathological electrical discharges. A data analysis suite will be also developed to be used on the collected data and to provide an easy and fast comparison with the literature results, also in humans study. To this end, focus will be placed on: i) electrophysiological patterns (both Single/Multi Unit Activity and Local Field Potentials); ii) connectivity-related metrics (global measures such as modularity, dynamical richness, small worldness), to facilitate comparisons among the different experimental models.

Requirements:

Applicants are expected to have a background in (bio)engineering or mathematics or computer science; proficient programming skills: experience with Matlab/Simulink, C and/or Python for data analysis. Experience on data analysis of neural signals (MUA or LFP recordings) is recommended. Previous Lab experience is a plus

References:

- Averna A et al. (2020). *Cerebral Cortex*, 30(5), 2879-2896.
- Buccelli S et al. (2019). *IScience*, 19: 402-414
- Brofiga M et al. (2022) *Cerebral Cortex* 32 (9), 1866-1881.

Company name and link (for industrial projects): n.a.

Number of positions available:

1

Main Research Site: https://dibris.unige.it/

Contacts: michela.chiappalone@unige.it; paolo.massobrio@unige.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

2. Study and development of a highly ergonomic wearable device for movement and posture assessment in rehabilitation, work, and sports - SWHARD-Univ. Genova

Curriculum: Healthcare and wellness of persons

Hosting Institution: Università di Genova

Department: DIBRIS

Tutor(s):

M. Casadio, C. Pierella

Description:

The proposed research is focused on the design and development of a highly ergonomic wearable device for movement and posture assessment. Recent studies show that between 60% and 90% of people in Europe suffer from low back disorders at some point in their life. In most cases patients make a full recovery from an episode of low back pain, but this still adds up to a very large amount of lost time from work. In addition, the recurrence rate for low back disorders is very high. The PhD candidate will develop a new wearable device to monitor, during all day, the body movement and posture, focusing in particular on the back but also other body district or limbs can be included. The device will also provide some sensory feedback to encourage and guide the users toward correct posture and movements pattern. The device can extend the one already developed by SWHARD to monitor the shoulder movement, or design and develop a completely new one, depending on the scientific and technical convenience. The main field of application of this innovative device will be healthcare and rehabilitation, including prevention, but possible extension to physically demanding work and sports can be addressed. The device has to be properly designed to be wore in ecological conditions, such as working places, home, or sport activity site, in terms e.g., of wearability, battery life, data storage, data transfer and communication. A set of indicators related to correct posture and movement will be prepared, and the data obtained from the sensors will be analysed and compared with the selected indicators. Finally, a dedicated test campaign will be carried on by the candidate, to assess the device outcome.

Requirements:

Applicants are expected to have a master's degree in a technical field (e.g., engineering, information technology, physics), a good background in programming and basic knowledge in data analysis

References:

- R. Stanzani, P. Dondero, A. Mantero and M. Testa, "Measurement Accuracy of an Upper Limb Tracking System Based on Two Hillcrest Labs BNO080 IMU Sensors: An Environmental Assessment," in IEEE Sensors Journal, vol. 20, no. 17, pp. 10267-10274, 1 Sept.1, 2020, doi: 10.1109/JSEN.2020.2992733.
- Dingenen, B., Blandford, L., Comerford, M., Staes, F., and Mottram, S. (2018). The assessment of movement health in clinical practice: A multidimensional perspective. Physical Therapy in Sport, 32:282–292.
- Job, M., Dottor, A., Viceconti, A., and Testa, M. (2020). Ecological Gait as a Fall Indicator in Older Adults: A Systematic Review. The Gerontologist, 60(5):e395–e412.

Company name and link (for industrial projects):

SWHARD S.R.L. (www.swhard.it)

Number of positions available:

1

Main Research Sites

C/O BIC - Via Greto di Cornigliano 6R, 16152, Genova

Contacts:

Email: maura.casadio@unige.it, Igor.ingegnosi@swhard.it, alfonso.mantero@swhard.it

Funding scheme: This industrial doctorate grants is co-funded by the proponent research institution, company and by the Italian Ministry of Research, under law D.M. 352/2022.

3. Virtual reality and robotic integration to assess human vestibular performance - MOVENDO-Univ. Genova

Curriculum: Healthcare and wellness of persons

Hosting Institution: Università di Genova

Department: DIBRIS

Tutor(s):

M. Casadio, V. Squeri

Description:

Uncompensated loss of vestibular function results in postural instability, imbalance, visual blurring during head movements, and dizziness. Therapeutic exercises specifically designed to target vestibular deficits have been shown to decrease dizziness, improve postural stability, reduce fall risk, and improve visual acuity during head movements [1].

To date, there are several assessment techniques allowing to differentiate the sensory, motor, and central adaptive impairments in balance control. The most common techniques for assessment rely on exposure to sensory conflict arising when two (or more) sensory modalities provide different and contrasting information. To create this conflict, a system is necessary providing reliable and realistic inputs to different sensory modalities. The used techniques quantify vestibular contribution to balance control and highlight the adaptive response of the central nervous system to diagnostically determine balance impairments [2].

The objective of the present project is to develop a novel system to quantitatively assess the vestibular deficits during postural task. The system will integrate an immersive virtual reality for enhancing the visual stimulus for postural control during evaluations and interventions. The virtual reality will also influence the visual system allowing for the conflicting situation previously mentioned. The developed device will include all the hardware and software necessary to provide a realistic and immersive experience into one or more real-life scenarios that would otherwise be difficult to reproduce in a clinical setting. The system will allow for an improved evaluation of balance impairments and will provide a more engaging balance training.

The immersive VR could operate in standalone or be integrated with a robotic platform [3] augmenting the system with the measurement of postural control in sitting or standing position, both in steady or perturbed conditions.

The candidate will develop a system prototype:

- to design and implement an assessment protocol for detecting vestibular impairments;
- to plan and develop data driven training scenarios based on the measured impairments and adapting to the user's improvements

The novel set up will be validate in clinical scenario with at least two different neurological populations. .

Requirements:

Applicants are expected to carry on independent research and implementation of prototypes to showcase and test new technology. The research project is offered in collaboration with a company so ability to coordinate the project with a larger team is also required.

Useful Technical / Programming skills: immersive reality, 3D programming, C/C++, Python

Other useful skills: data analysis and statistical analysis; ability to design and conduct a clinical experiment.

References:

[1] Hall CD, Herdman SJ, Whitney SL, Cass SP, Clendaniel RA, Fife TD, Furman JM, Getchius TS, Goebel JA, Shepard NT, Woodhouse SN. Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Evidence-Based Clinical Practice Guideline: FROM THE AMERICAN PHYSICAL THERAPY ASSOCIATION NEUROLOGY SECTION. J Neurol Phys Ther. 2016 Apr;40(2):124-55. doi: 10.1097/NPT.0000000000000120. PMID: 26913496; PMCID: PMC4795094.

[2] https://www.bertec.com/clinical

[3] Saglia JA, De Luca A, Squeri V, Ciaccia L, Sanfilippo C, Ungaro S, De Michieli L. Design and Development of a Novel Core, Balance and Lower Limb Rehabilitation Robot: hunova®. IEEE Int Conf Rehabil Robot. 2019 Jun; 2019:417-422. doi: 10.1109/ICORR.2019.8779531. PMID: 31374665.

Company name and link (for industrial projects):

Movendo Technology (https://www.movendo.technology)

Number of positions available:

1

Main Research Sites

Movendo Technology s.r.l. – calata Cattaneo 15 – Genova

DIBRIS – Via All'Opera Pia,13 - Genova

Contacts:

Email: maura.casadio@unige.it, valentina.squeri@movendo.technology

Funding scheme: This industrial doctorate grants is co-funded by the proponent research institution, company and by the Italian Ministry of Research, under law D.M. 352/2022.

4. Advanced computer-vision techniques in body machine interfaces for rehabilitation and assistance of people with neurological diseases - MOVENDO-Univ. Genova

Curriculum: Healthcare and wellness of persons

Hosting Institution: Università di Genova

Department: DIBRIS

Tutor(s):

M. Casadio, F. Odone, T. Falchi Delitala

Description:

Infrared marker-based systems are considered the gold standard in motion-tracking, including clinical application [1] and, in general, in accurate tracking of human motion. However, these approaches have limitations such as high cost, cumbersome setup/calibration and interference on the naturalness of the motion which makes them unsuitable for everyday clinical outside research labs.

Recent advances on markerless pose estimation algorithms, based on computer vision and deep neural networks, are opening the possibility of adopting efficient methods for extracting motion information starting from common video data [2]. Recent studies show how markerless, ML-based solutions can offer results comparable with maker-based systems in critical clinical applications, such as gate analysis [3] or stroke [6].

Recent industrial and research projects have made available powerful open-source ML algorithms to extract and measure human-pose from videos (e.g. Google's Pose [4], OpenPose library by CMU [5]). Those libraries offer general-purpose software toolkits that can run on relatively modest hardware, however their usability and accuracy when used on a neurologically impaired population is yet to be verified.

The aim of the thesis is to develop a prototype of a novel human-machine interface based on new or improved ML models that can:

- extract and quantify kinematic and dynamic parameters from RGB video;
- assess the level of impairment of people with neurological conditions from the extracted parameters;
- guide the user through a set of exercises (involving interaction with objects from their everyday life) with the aim of rehabilitating defective functional areas
- run on mobile devices or be suited for home use.

The system must require minimal setup and calibration to meet the needs of users without technical knowledge and suffering from neurological conditions. Outside the home environment the system may also be interfaced with a rehabilitation robot to provide additional measurements and challenge the user with additional stimulation.

The system and its measurement will be evaluated in various clinical scenarios to test its usability and validate the extracted measurements.

Requirements:

Applicants are expected to carry on independent research and implementation of prototypes to showcase and test new technology. The research project is offered in collaboration with a company so ability to coordinate the project with a larger team is also required.

Useful Technical / Programming skills: mobile programming, HW accelerated Neural Networks, computer vision, Python, C/C++.

Other useful skills: data analysis, ability to design and conduct a clinical experiment.

References:

[1] Colyer, S.L.; Evans, M.; Cosker, D.P.; Salo, A.I. A review of the evolution of vision-based motion analysis and the integration of advanced computer vision methods towards developing a markerless system. Sport. Med.-Open 2018, 4, 1–15

[2] Zheng, C.; Wu, W.; Yang, T.; Zhu, S.; Chen, C.; Liu, R.; Shen, J.; Kehtarnavaz, N.; Shah, M. Deep learning-based human pose estimation: A survey. arXiv 2020, arXiv:2012.13392.

[3] M. Moro, G. Marchesi, F. Hesse, F. Odone, and M. Casadio, “Markerless vs. Marker-Based Gait Analysis: A Proof of Concept Study,” Sensors, vol. 22, no. 5, p. 2011, Mar. 2022, doi: 10.3390/s22052011.

[4]On-device, Real-time Body Pose Tracking with MediaPipe BlazePose (https://ai.googleblog.com/2020/08/on-device-real-time-body-pose-tracking.html)

[5] Cao, Zhe, et al. "Realtime multi-person 2d pose estimation using part affinity fields." Proceedings of the IEEE conference on computer vision and pattern recognition. 2017.

[6] Moro M., G Marchesi G., OdoneF., Casadio M., “Markerless gait analysis in stroke survivors based on computer vision and deep learning: a pilot study”. Proceedings of the 35th Annual ACM Symposium on Applied Computing, 2097-2104

Company name and link (for industrial projects):

Movendo Technology (https://www.movendo.technology)

Number of positions available:

1

Main Research Sites

Movendo Technology s.r.l. – calata Cattaneo 15 – Genova

DIBRIS – Via All'Opera Pia,13 - Genova

Contacts:

Email: maura.casadio@unige.it, tommaso.falchi@movendo.technology

Funding scheme: This industrial doctorate grants is co-funded by the proponent research institution, company and by the Italian Ministry of Research, under law D.M. 352/2022.

5. Diversity-Aware Social Robots for Education and Social Assistance - Scuola di Robotica-Univ. Genova

Curriculum: Healthcare and wellness of persons

Hosting Institution

University of Genova, Genova

Department:

DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering

Tutor(s):

C. Recchiuto, M. Casadio, A. Sgorbissa, E. Micheli

Description:

According to a broadly accepted definition, "diversity is about what makes each of us unique and includes our backgrounds, personality, life experiences and beliefs, all of the things that make us who we are. (...) Diversity is also about recognising, respecting and valuing differences based on ethnicity, gender, age, race, religion, disability and sexual orientation. (...) Inclusion occurs when people feel, and are valued and respected regardless of their personal characteristic or circumstance (...) Equal opportunity means that every person can participate freely and equally in areas of public life (...) without disadvantage or less favourable treatment due to their unique attributes." [1].

Social Robotics has, among the others, the purpose of developing companion robots that may assist people in their everyday life. Examples range from assistance to older people in care homes to educational applications for children. Social robots have been customised for populations with unique needs, ranging from older people with dementia to autistic children. Cultural factors that can make the robot more or less acceptable to people of different cultures have been investigated [2]. However, none of the previous approaches defined a general conceptual framework to make a robot capable of adapting its way of interacting with people to value diversity (e.g., ethnicity, physical or cognitive skills, age, religion, sex, gender identity).

This research will introduce a crucial innovation in social robotics by making robots able to re-configure their behaviour to recognize and value the uniqueness of the person they interact with to promote respect for diversity, inclusion, and equal opportunities. This groundbreaking objective in human centered and "post human centered" design will include exploring innovative methods for:

- storing knowledge about different persons and their characteristics, both acquired *a priori* through interviews and focus groups with diverse target populations and learned in real-time during the interaction to avoid stereotyped representations [2];
- conversing with the person about diverse topics and providing suggestions for different activities, tuning the interaction style to the person's unique characteristics [2];

- moving autonomously between different areas of the house, approaching and sharing space with the person, ensuring the safety and comfort of persons with diverse cognitive and physical abilities [3];
- processing sensor data to detect the most relevant objects, places, or activities, taking into account the specificity of the person and the environment to ensure a higher perception accuracy and robustness [4];
- exhibiting a Theory of Mind (ToM), i.e., the ability to attribute independent mental states to self and others, to the end of reasoning about the person's beliefs, goals, and intentions [5].

The Ph.D. candidates will have to address some of the previous aspects to develop social robots with unprecedented skills to interact with different target populations. We will consider the most popular platforms used for social interaction, including Pepper and NAO by SoftBank Robotics. Moreover, thanks to the vast portfolio of robotic solutions available at Scuola di Robotica, other robotic platforms will be explored depending on the investigated aspects.

Company name and link (for industrial projects):

Scuola di Robotica, Via Riccardo Banderali 1/2, 16121 Genova, Italy, an association founded in 2000 to promote the conscious use of robotics and new technologies (https://www.scuoladirobotica.it/en/home-eng/)

Requirements:

Applicants are expected to have good programming skills and an interest in study and cutting-edge research in social robotics application and human centered design. Previous experience with Artificial Intelligence solutions and/or impact of robotics on people is not mandatory but will be appreciated.

When applying for the Ph.D. scholarship, the student will be encouraged to propose solutions to address one or more of the abovementioned aspects.

References:

[1] The Victorian Government commitment to diversity and inclusion (D&I), https://bit.ly/3DbTzlJ

[2] Bruno, B., Recchiuto, C.T., …, R., Sgorbissa, A. Knowledge Representation for Culturally Competent Personal Robots: Requirements, Design Principles, Implementation, and Assessment (2019) Int. J. of Social Robotics, 11 (3), pp. 515-538.

[3] Kruse, T., Pandey, A.K., Alami, R., Kirsch, A. Human-aware robot navigation: A survey (2013) Robotics and Autonomous Systems, 61 (12), pp. 1726-1743.

[4] Wang, J., Chen, Y., Hao, S., Peng, X., Hu, L. Deep learning for sensor-based activity recognition: A survey (2019) Pattern Recognition Letters, 119, pp. 3-11.

[5] Scassellati, B. (2002). Theory of mind for a humanoid robot. Autonomous Robots, 12(1), 13-24.

Number of positions available:

1

Main Research Site

The research will be partially performed in the "Laboratorium/Social Robotics Lab" at DIBRIS, a fully equipped facility with aerial ground robots (quadruped and wheeled), humanoid robots for social applications. In addition, research will be carried out at Scuola di Robotica, offering strong expertise in a vast portfolio of robotic solutions for a maximum of 18 months.

Contacts:

Email: carmine.recchiuto@dibris.unige.it, maura.casadio@unige.it, antonio.sgorbissa@unige.it, micheli@scuoladirobotica.it

Funding scheme: This industrial doctorate grants is co-funded by the proponent research institution, company and by the Italian Ministry of Research, under law D.M. 352/2022.

6. Legal issues of Robotics and Intelligent machine in medicine and healthcare - Univ. Genova

Curriculum:

Healthcare and wellness of persons

Hosting Institution

Università degli Studi di Genova

Department:

Dipartimento di Giurisprudenza
www.giurisprudenza.unige.it

Tutor(s):

Prof. Valentina Di Gregorio

Description:

The new technologies in the field of Robotics and intelligent machines have opened scenarios on the legal subjectivity of machines, on civil liability, on the protection of confidentiality, on information security, making it necessary to proceed with the reconstruction of the regulatory processes of technological innovation. The topic includes the study of private law, evaluating, in the light of recent EU Resolutions, the opportunity to identify a new system of rules capable of offering an adequate way to prevent and provide protection against damage caused by devices and robots in the medical and healthcare fields.

Requirements:

Candidates must have excellent skills in private law, with particular regard to civil liability in the fields of medicine and e-health. They must be able to use multilevel legal sources focusing on new technologies such as robotics and artificial intelligence, while respecting the internal legal system and the EU regulatory framework.

References:

- Valentina Di Gregorio, Intelligenza artificiale e responsabilità civile: quale paradigma per le nuove tecnologie?, in Danno e responsabilità, 2022, 51;
- Valentina Di Gregorio, Robotica e intelligenza artificiale: profili di r.c. in campo sanitario, in Resp. medica, 2019, 433.

Number of positions available:

1

Main Research Site

Università di Genova, Dipartimento di Giurisprudenza www.giurisprudenza.unige.it

Contacts:

E-mail: valentina.digregorio@unige.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

7. Design and Operation Methodologies for Upper-Limb Exoskeletons - Univ. Calabria

Curriculum: Healthcare and wellness of persons

Hosting Institution

Universita' della Calabria

Department:

Department of Mechanical, Energy, and Management Engineering

https://www2.unical.it/portale/strutture/dipartimenti_240/dimeg/

Tutor(s):

Prof. Giuseppe Carbone, Prof. Domenico Mundo

Description:

In our modern societies, it is extremely relevant that people can exercise to stay active and quickly recover if they suffer physiological impairments. This PhD topic aims at the design and operation methodologies for innovative upper-limb exoskeletons. The proposed approach is expected to involve users to achieve an effective, cost-oriented, and user-friendly solution for limb exercising. The PhD candidate is expected to develop proper high-fidelity biomechanical models of the upper limb as well as models of the integrated limb-exoskeleton system to properly analyze and predict the interconnected behavior of the human upper limb when wearing an exoskeleton. The proposed models will be integrated into proper optimal design methodologies as well as into operation approaches for safely and reliably executing various collaborative exercising and rehabilitation tasks while monitoring and steering the motions and intentions of a user.

Requirements:

Applicants are expected to have good skills in the following areas: applied mechanics, robot design, mechatronics. Furthermore, good attitude for experimental work is mandatory. The candidates must have good programming skills with different languages (including Matlab/Simulink/optimization toolbox); confidence with electronic hardware and be capable to conduct experiments; attitude to problem solving and be strongly motivated for team working.

References:

- Ben Hamida, I., Laribi, M. A., Mlika, A., Romdhane, L., Zeghloul, S., & Carbone, G. (2021). Multi-objective optimal design of a cable driven parallel robot for rehabilitation tasks. Mechanism and Machine Theory, 156 doi:10.1016/j.mechmachtheory.2020.104141
- Curcio, E. M., & Carbone, G. (2021). Mechatronic design of a robot for upper limb rehabilitation at home. Journal of Bionic Engineering, 18(4), 857-871. doi:10.1007/s42235-021-0066-3
- Tucan, P., Vaida, C., Plitea, N., Pisla, A., Carbone, G., & Pisla, D. (2019). Risk-based assessment engineering of a parallel robot used in post-stroke upper limb rehabilitation. Sustainability (Switzerland), 11(10) doi:10.3390/su11102893

Research abroad: a period of minimum 6 months abroad will be planned at a partner university

Number of positions available: 1

Main Research Site

DIMEG, Department of Mechanical, Energy, and Management Engineering

Universita' della Calabria, Via Bucci Cubo 45C, Arcavacata di Rende (CS)

https://www2.unical.it/portale/strutture/dipartimenti_240/dimeg/

Contacts:

Prof. Giuseppe Carbone, Giuseppe.carbone@unical.it - Prof. Domenico Mundo, domenico.mundo@unical.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

8. Social robot assistant for intelligent health care - Univ. Palermo

Curriculum:

Healthcare and wellness of persons

Hosting Institution

University of Palermo (Università degli Studi di Palermo)

Department:

Department of Engineering

Tutor(s):

Chella Antonio, Seidita Valeri, Sorbello Rosario, Fagiolini Adriano

Description:

Context. Improving citizen's health, care and lifestyle is one of the main goals of our society. The last years of the 21st century have seen an increase in average age and chronic diseases. Today's society in Europe is made of more over-60s than under-5, and according to WHO estimates, the World population is growing at an accelerating rate. Most people will reach and exceed the age of 60 by 2050. A serious consequence is less time and resources available to cope with the effects of population growth from the perspective of health services. Indeed, the main health problems are age-related and chronic diseases (from declining cognitive and motor skills to diabetes, cancer, and Alzheimer's). Economic pressure on national health systems is increasing. They are overburdened due to lack of staff, budget constraints imposed by public health, emergency, or exceptional events, such as the situation we have been experiencing during the last 2 year due the COVID-19 pandemic.

Another problem is the lack of doctors and nurses or, even more challenging, the presence of changing contexts i.e., cases where patients with the same disease but placed in different family or social contexts have different characteristics and needs. Probably no single medical protocol can be applied in these cases, but doctors must be able to decide on a case-by-case basis.

Within this context, three main factors can be identified that explain the crisis in the health care sector: the gradual decrease in the number of physicians, the aging population, and the increased demand for care for chronic diseases. Providing adequate treatment and care to the population may become almost impossible, generating tragic consequences and domino effects on the economy and society. Investing in prevention is a strategy that could bring excellent results in the long term, but in the short and medium terms one solution is to invest in how to provide services to patients in a way that improves affordability and efficiency of care. An efficient health care system depends on accessibility, quality, availability of professionals and services. In today's scenarios, doctors can no longer rely solely on themselves to provide patients with quality diagnosis and care and in an acceptable time frame. It is necessary for the health care system to be supported and complemented by intelligent and (semi-) autonomous systems to support both the doctors and the patients. As EU documents show the urgent need for intelligent systems for healthcare should not be underestimated. Investigating the importance of AI and Robotics in health care is the current challenge for scientists and doctors.

Activities. The new digital technologies covered in this research will play a major role in the transformation of health and care systems. Robotics and Artificial intelligence can potentially transform health and care facilities in all their functions, from the clinical aspects (screening and

prevention, diagnosis, treatment, surgical support) to the organizational and the logistical ones. The results of this research project will contribute in the future to transforming traditional healthcare systems into a data-driven, experience-driven, patient-centered model that is more collaborative, distributed, and personalized and that can be cross-cutting across the various domains of healthcare.

The proposed Ph.D. project aims at investigating and analyzing how an intelligent system can help a doctor, or nurse, make decisions, even in dynamic contexts and support a patient during his or her care journey. The doctoral research activity will be carried out mainly in the Robotics Laboratory of the Department of Engineering. The idea is to create an intelligent system that can continuously interact with users (doctors, nurses, patients) and an often-changing environment. An intelligent system that can self-adapt to changing situations and decide the best action to take even in the complete or partial absence of input data from doctors or patients. All these aspects include the design of systems that can plan and adapt at runtime and at the same time provide the right level of reliability, acceptability, and transparency (closely related to the concepts of Trustworthiness and Human in the loop that underlie the well-known Explainable AI).

Two main activities will be pursued over the three-year PhD program:

1) Intelligent and Adaptive Support for Healthcare Professionals. This activity aims to create intelligent support to respond in a timely and efficient manner to the changing and sudden needs of patients and the environment. Support is also configured in the management of human-computer interaction. During this activity, techniques for creating autonomous, adaptive, and self-conscious systems will be explored from both a design and implementation perspective. The solution adopted to achieve this goal will lead to reduced costs and, most importantly, increased efficiency in cases of overloaded healthcare facilities.

2) Advanced patient monitoring. The objective of this activity is the analysis and implementation of techniques suitable for patient monitoring and support. To do this, robots and IoT devices can be used to constantly monitor the patient in care facilities, or at the same time a set of patients. For example, at the entrance of triage, to capture in real time all useful data to be sent to the intelligent system. By useful data, we mean data that can be used to formulate a diagnosis or treatment hypothesis. Another key element of patient monitoring is the support of all activities during the stay in the healthcare facility. The outcome will be the improvement of the patient's quality of life, in fact, the system will adapt to the patient's needs, for example, it will make suggestions on how to take medication or complete a therapy. At any time, the monitoring system will alert the doctor or nurses of any abnormality in the patient's status or behavior.

Expected results. The proposed PhD program promotes the design and development of tools for ameliorating, modernizing the current public health with a specific goal to overcome the effects of the current crisis and its social consequences and to prepare for a green, digital, and resilient recovery of the economy. The doctoral track aims at fostering the creation of new knowledge and new technologies for the improvement of patient diagnosis, treatment and quality of life can find its natural verticalization in combating the health, social and economic effects of COVID-19.

The results and impact of the PhD project will be directly measured through KPI indicators such as scientific excellence and industrial impact. Regarding scientific excellence, the publications produced in the three years of the doctoral program will be considered, in relation to the internal regulations of the doctoral host university and the regulations of the doctoral program itself. Bibliometric indicators will be mainly used, and reference will be made to the SCOPUS and/or WOS databases.

On the other hand, as far as industrial impact is concerned, the spin-off in terms of the production of software prototypes, within the company that will host the doctoral student, for the realization of the intelligent system to support doctors and patients will be considered.

Requirements:

Applicants are expected to have a general background in robotics, artificial intelligence, expert systems, control theory.

References:

- Lanza, F., Seidita, V. and Chella, A., 2020. Agents and robots for collaborating and supporting physicians in healthcare scenarios. Journal of biomedical informatics, 108, p.103483
- Sorbello, R., Tramonte, S., Giardina, M.E., La Bella, V., Spataro, R., Allison, B., Guger, C. and Chella, A., 2017. A human–humanoid interaction through the use of BCI for locked-in ALS patients using neuro-biological feedback fusion. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 26(2), pp.487-497
- Seidita, V., Lanza, F., Pipitone, A. and Chella, A., 2021. Robots as intelligent assistants to face COVID-19 pandemic. Briefings in Bioinformatics, 22(2), pp.823-831
- Spataro, R., Sorbello, R., Tramonte, S., Tumminello, G., Giardina, M., Chella, A. and La Bella, V., 2015. Reaching and grasping a glass of water by locked-in ALS patients through a BCI-controlled humanoid robot. Journal of the Neurological Sciences, 357, pp.e48-e49
- Dindo, H., Presti, L.L., La Cascia, M., Chella, A. and Dedić, R., 2017. Hankelet-based action classification for motor intention recognition. Robotics and Autonomous Systems, 94, pp.120-133
- M. Trumić, K. Jovanović, and A. Fagiolini, "Decoupled nonlinear adaptive control of position and stiffness for pneumatic soft robots," International Journal of Robotics Research, vol. 40, no. 1, pp. 277–295, 2021

Number of positions available:

1

Main Research Site

RoboticsLab (http://diid.unipa.it/roboticslab/)

MIRPALab (https://www.mirpalab.it/)

Viale delle Scienze, University of Palermo

Contacts:

antonio.chella@unipa.it, valeria.seidita@unipa.it,

rosario.sorbello@unipa.it, adriano.fagiolini@unipa.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PA).

9. Robot assisted rehabilitation for older adults after strokes or traumatic events - Univ. Trento

Curriculum: Healthcare and wellness of persons

Hosting Institution

Robotics and Intelligent Machines for healthcare and wellness of persons

Department:

Università degli Studi di Trento

Tutor(s):

Luigi Palopoli, Marco Roveri, Daniele Fontanelli

Description:

The rehabilitation for older adults after strokes or traumatic events is attracting a growing interest in recent times. This is partly due to the catastrophic events (first and foremost the COVID19 pandemic) that put a heavy strain on hour NHS and exposed the importance of adequate policies for reducing the days of hospital admission for older adults affected by strokes/traumatic events (e.g., hip fracture) and to facilitate their recovery of (at least) partial autonomy in the midterm. In this context, rehabilitation is key starting from a few days (even hours) after surgery or adverse events, but this requirement is in clear contrast with the limited (and shrinking) availability of human resources. As usual, a proper level of robotic automation can come to the rescue in increasingly critical situations. Specifically, many rehabilitation devices have been developed, ranging from smart walkers to exoskeletons, which could contribute to scaling up the possibility of intervention of small teams of doctors and physiotherapists.

In order for a rehabilitation device to be effective, it has to be well accepted by the patient, it has to collect information on the health state of the patient and offer it to the physician in an intelligible form, and it has to enable the creation of personalised rehabilitation plan for the different patients.

The University of Trento has been the coordinator of a successful research project (www.ict-acanto.eu) on a new generation of robotic rehabilitation devices (a modified form of a smart walker) and for their interconnection. The recent medical literature and the outcome of the project have shown smart walkers can be very effective rehabilitation tools for the type of physical support that they offer to the patient, for the familiarity of their form factor, and for their ability to easily host a capable sensing platform along with large computing power. Smart walkers support the patients without giving the impression of "forcing" their behavior, but they can suggest movements to the patients and suggest paths that do not cause injuries or dangers to the patient themselves and to other people moving around.

In this project, we aim to take a leap forward by two developments of the greatest relevance: 1. collecting diagnostic evidence and suggesting therapeutic actions of proven medical efficacy, 2. enabling a limited number of devices to take care of multiple patients. In a sentence, we aim to maximise both the effectiveness of the devices and the efficiency of their use. To achieve the latter goal, we will need to develop proper orchestration and scheduling mechanisms, considering the type of patient treated, the condition of the battery, the current position, and the use of each device.

Requirements:

Applicants are expected to work in collaboration with robotic researchers and doctors to develop rehabilitation protocols that can be implemented in crowded environments and in small spaces (e.g., hospital rooms). This will require a collection of requirements and a development phase based on the constant integration of user requirements (human-centered development). In addition, to guarantee the efficient use of these resources, the applicants are also expected to use AI-based techniques (both machine learning and planning and scheduling or combinations of them taking into account, if needed, probabilistic aspects). Similar techniques are expected to be used also to achieve the right level of autonomy for the designed smart walkers. Moreover, the applicants are expected to show good programming skills and acquire proper knowledge of the typical programming frameworks widely adopted by the robotic community (e.g. ROS, Matlab, and all the related simulation infrastructure). The expected outcome of the PhD program will be a list of high-quality publications (including patents), along with a set of prototype software tools developed with suitable programming languages to achieve the required performances (e.g., C and C++). The PhD candidate will have to work side-by-side with hardware developers to optimise the sensing and processing ability embedded within the smart walkers.

References:

- Francesco Ferrari, Stefano Divan, Cristina Guerrero, Fabiano Zenatti, Roberta Guidolin, Luigi Palopoli, Daniele Fontanelli: Human-Robot Interaction Analysis for a Smart Walker for Elderly: The ACANTO Interactive Guidance System. Int. J. Soc. Robotics 12(2): 479-492 (2020)I. Me, Y. Myself and H. I. “Towards the creation of a great Genoa C.F.C”. Robotics and Autonomous Systems 69(16): 293–308, 2215.
- Paolo Bevilacqua, Marco Frego, Luigi Palopoli, Daniele Fontanelli: Activity Planning for Assistive Robots Using Chance-Constrained Stochastic Programming. IEEE Trans. Ind. Informatics 17(6): 3950-3961 (2021)
- Andrea Traldi, Francesco Bruschetti, Marco Robol, Marco Roveri, Paolo Giorgini: Real-Time BDI Agents: a model and its implementation. CoRR abs/2205.00979 (2022)
- Marco Bozzano, Alessandro Cimatti, Marco Roveri: A Comprehensive Approach to On-board Autonomy Verification and Validation. ACM Trans. Intell. Syst. Technol. 12(4): 46:1-46:29 (2021)

Company name and link (for industrial projects): N/A

Number of positions available:

1

Main Research Site

via Sommarive, 9 - 38123, Trento (TN), Italy

Contacts:

Email: daniele.fontanelli@unitn.it, marco.roveri@unitn.it, luigi.palopoli@unitn.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

10. Robotics enhanced by IoT and AI for healthcare 4.0 - Univ. Campus Bio-Medico Roma

Curriculum: Healthcare and wellness of persons

Hosting Institution

Università Campus Bio-Medico di Roma

Department:

The BioRobotics Institute

Tutor(s):

Loredana Zollo and Nevio L. Tagliamonte

Description:

Healthcare 4.0 is a collective term for concepts derived from Industry 4.0 like data-driven digital health technologies, smart health, mobile health, wireless health, e-health, online health, medical IT, telemedicine, digital medicine, health informatics, pervasive health, and the health information system [1]. The new approach to the delivery of care is expected to enhance the quality and effectiveness of healthcare services, paving the way for a more direct relationship between providers and patients as well as clinical operators [2]. Moreover, the analysis of Healthcare 4.0 implications reveals that the effects of the technological revolution are progressing in both medicine itself and in the management of healthcare organizations, especially in hospitals, which are the foundation of the healthcare system [3].

Despite several efforts have been already made to increase the efficiency of care in hospitals and to improve patients' satisfaction, substantial organizational restructuring is still possible leveraging on innovative enabling technologies [4]. Medical robotics, together with other novel technologies such as Internet of Things (IoT), and Artificial Intelligence (AI) but also wearable sensors, big data, extended reality, and 3D printing, are spanning the digital transformation of health and healthcare, by radically transforming the way users access and interact with hospital services. Using robotics in the healthcare field has been recently demonstrated to enable a high level of patient care, efficient processes in clinical settings, and a safe environment for patients and workers. Healthcare organizations often rely on robotics because of their ability to assist with critical needs such as disinfection, telepresence, and delivery of medication and medical supplies, creating safe environments while freeing up staff to spend more time with patients.

Historically, robotic systems have been used in hospitals for surgical assistance. Over the years, AI-enabled computer vision and data analytics have transformed medical robots, expanding their capabilities into many other areas of healthcare. Indeed, robots can now be employed also in clinical settings to support healthcare workers and enhance patient assistance. Medical robots support customized and frequent monitoring for patients with chronic diseases, intelligent therapeutics, and social engagement for elderly patients.

Autonomous mobile robots simplify routine tasks, reduce the physical demands on human workers, and ensure more consistent processes. These robots can address staffing shortages and challenges by keeping track of inventory and placing timely orders to help make sure supplies, equipment, and medication are in stock where they are needed. Streamlined workflows and risk reduction provided by robotics offer value in many areas. For example, robots can also help with cleaning and disinfection by using UV light, hydrogen peroxide vapors, or air filtration to reduce infection and to sanitize reachable places in a uniform way. Cleaning and disinfection robots enable hospital rooms to

be sanitized and ready for incoming patients quickly, allowing workers to focus on value-driven work and helping limit person-to-person contact in infectious disease wards. Moreover, hospitals are recently deploying robots to help reduce exposure to pathogens during the COVID-19 pandemic [5]. Robots with AI-enabled medicine identifier software reduce the time it takes to identify, match, and distribute medicine to patients in hospitals.

To help keep healthcare workers safe, autonomous and service robots are used to transport supplies and linens in hospitals, also in case of pathogen exposure, and to relieve the daily burden on healthcare workers by handling routine logistical tasks. Many of these robots function autonomously and can send a report when they complete a task. These robots set up patient rooms, track supplies and file purchase orders, restock medical supply cabinets, and transport bed linens to and from laundry facilities. Having some routine tasks performed by service robots gives healthcare workers the opportunity to focus on immediate patient needs and can help with increasing job satisfaction. Autonomous robots can self-navigate towards patients allowing clinicians to interact with them remotely. Potentially, robots could eventually evolve in terms of autonomy until ideally being able to perform certain tasks entirely on their own. As a result, since robots alleviate workloads, medical doctors, nurses, caregivers and other healthcare workers will be able to spend more time providing direct patient care and focus on more delicate activities and can offer patients more empathy and human interaction, which can promote long-term well-being.

Within this research theme the PhD candidate will work to deliver, in novel smart hospitals, advanced robotic solutions, augmented by IoT and enhanced by extensible specialized AI with the final goal to reduce the effort of the clinical staff, by overcoming some practical difficulties in the wards, and to improve the comfort perceived by the patients during hospital care.

In particular, this research theme is grounded around the use of robotic mobile robots, equipped with AI and connected with IoT devices in the environment and worn by patients, in different use cases to support healthcare workers in their activity and improve patients' care experience. Use cases might include:

- Robot-aided support for logistics and patients experience, with particular focus on the automatic meal delivery to patients and to the monitoring of food assumption to prevent undernutrition. The ultimate goal is to monitor and support the delivery of the meal, to improve safety for the patients and to increase hospital efficiency and workflow;
- Robot-aided rehabilitation, with particular focus on the prevention from loss of mobility of hospitalized patients. The ultimate goal is to improve patients' health conditions, provide support to the clinical staff during rehabilitation, increase hospital efficiency;
- Robot-aided therapy monitoring, with particular focus on the supervision of oxygen therapy to prevent hypoxia complications. The ultimate goal to optimize oxygen assumption, verify that the prescribed rules for the oxygen therapy are met and provide support to the clinical staff.

Requirements:

Basic qualifications:

- MS in the area of Robotics and Mechatronics Engineering, Biomedical Engineering, Computer Engineering or Computer Science;
- Proficiency in different high-level programming languages (C++), multi-threading and object oriented programming;
- Fluency in English.

Appreciated plus:

- Knowledge of middleware for robotics applications (ROS) and Python;

- Knowledge of DevOps development methodology, ability to review software architecture, identify bugs and perform software quality checks;

Past experience in similar relevant activities.

References:

- Herrmann, M., Boehme, P., Mondritzki, T., Ehlers, J. P., Kavadias, S., & Truebel, H. (2018). Digital transformation and disruption of the health care sector: internet-based observational study. Journal of medical internet research, 20(3), e9498.
- Cavallone, M., & Palumbo, R. (2020). Debunking the myth of industry 4.0 in health care: insights from a systematic literature review. The TQM Journal.
- Unterhofer, M., Rauch, E., & Matt, D. T. (2021). Hospital 4.0 roadmap: an agile implementation guideline for hospital manager. International Journal of Agile Systems and Management, 14(4), 635-656.
- B. Djulbegovic and G. H. Guyatt, 'Progress in evidence-based medicine: a quarter century on', Lancet Lond. Engl., vol. 390, no. 10092, pp. 415-423, 22 2017, doi: 10.1016/S0140-6736(16)31592-6.
- Tamantini, C., di Luzio, F. S., Cordella, F., Pascarella, G., Agro, F. E., & Zollo, L. (2021). A robotic health-care assistant for COVID-19 emergency: A proposed solution for logistics and disinfection in a hospital environment. IEEE Robotics & Automation Magazine, 28(1), 71-81.

Number of positions available:

1

Main Research Site

The BioRobotics Institute, Pontedera (PI), Italy

Contacts:

Email: l.zollo@unicampus.it ; n.tagliamonte@unicampus.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

11. Magnetic multi-robot system control - Scuola Sup. S. Anna Pisa

Curriculum: Healthcare and wellness of persons

Hosting Institution

Sant'Anna School of Advanced Studies, Pisa

Department:

The BioRobotics Institute

Tutor(s):

A. Menciassi

Description:

Robots are still often regarded as large machines with links, gears, and electric motors, autonomously interacting with the surrounding environment. Despite the great research efforts in robotics and human-robot interaction (HRI), the way we design, use, and control robots has not fundamentally changed in the past 20 years.

We see in small-scale wireless multi-robot systems and cognitive HRI a revolutionary answer to nowadays robots limitations. Instead of large, tethered machines, that are difficult for the human user to control, we propose an innovative set of AI-powered, modular, microsized swarms of robots. They are wirelessly steered by electromagnetic fields as well as able to react to other external stimuli, and then naturally controlled by humans through intuitive dexterous interfaces and interaction techniques. Taking advantage of AI multi-robot control strategies, these robots can team up and collaborate to fulfill complex tasks in a robust and unprecedented flexible way.

The candidate will deal with the design of a magnetic multi-robot control strategy and with the design of a millimeter scale carrier able to release, control and stimulate a swarm of nanorobots responsible for task execution.

The candidate will carry on this research project in the framework of a European Project (REGO – Cognitive robotic tools for human-centered small-scale multi-robot operations – 101070066) with the possibility to collaborate and interact both with academic partners (University of Twente, Centre hospitalier universitaire de Rennes) research centers (CNRS, Italian Institute of Technology, Helmholtz-Zentrum Dresden Rossendorf) and companies (Haption).

Requirements:

Applicants are expected to have a background in control, mechatronics, mechanical, biomedical engineering or related fields.

References:

- Ciuti, G., Valdastri, P., Menciassi, A., & Dario, P. (2010). Robotic magnetic steering and locomotion of capsule endoscope for diagnostic and surgical endoluminal procedures. *Robotica*, *28*(2), 199-207.
- Iacovacci, V., Ricotti, L., Sinibaldi, E., Signore, G., Vistoli, F., & Menciassi, A. (2018). An intravascular magnetic catheter enables the retrieval of nanoagents from the bloodstream. *Advanced Science*, *5*(9), 1800807.

Number of positions available:

1

Main Research Site

The BioRobotics Institute, Pontedera (PI), Italy

Contacts:

Email: Arianna.menciassi@santannapisa.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

12. Intelligent Microscale Robots - Scuola Sup. S. Anna Pisa

Curriculum: Healthcare and wellness of persons

Hosting Institution

Sant'Anna School of Advanced Studies, Pisa

Department:

Microscale Robotics Laboratory, The BioRobotics Institute

Tutor(s):

Stefano Palagi

Description:

Microrobots are microscopic, mobile, and untethered robotic devices envisioned to revolutionize minimally invasive medicine. They are expected to enable highly targeted and localized delivery of drugs, thus minimizing the side effects of drug-based therapies. Whereas most current microrobots are microstructures moved by external fields (e.g.: magnetic fields), we aim at developing *intelligent* microscale robots that can move autonomously inside soft body tissues. To do so, we take inspiration from immune cells and aim at endowing microrobots with the ability to move and change shape, locomote in complex 3D environments, harvest energy, perceive chemo-physical stimuli, and navigate autonomously in unknown environments. This research is funded by the European Research Council (CELLOIDS: Cell-inspired particle-based intelligent microrobots, GA: 948590).

Requirements:

Applicants are expected to be passionate about pursuing frontier interdisciplinary research at the intersection of autonomous robotics, swarm intelligence, and the natural sciences, within a multidisciplinary and diverse research team.

References:

Palagi, S., & Fischer, P. (2018). Bioinspired microrobots. *Nature Reviews Materials*, *3*(6), 113-124.

Number of positions available:

1

Main Research Site

The BioRobotics Institute, Pontedera (PI), Italy

Contacts:

Email: stefano.palagi@santannapisa.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

13. Sensing for Medical Robotics - Scuola Sup. S. Anna Pisa

Curriculum: Healthcare and wellness of persons

Hosting Institution

Sant'Anna School of Advanced Studies, Pisa

Department:

The BioRobotics Institute

Tutor(s):

Arianna Menciassi, Calogero Maria Oddo

Description:

Sensors are an essential component for robots to gather a representation of the environment so to act and interact in complex dynamic scenarios and to cooperate with humans and other agents. This doctoral project is dedicated to the development and integration of sensors and information processing strategies, including artificial intelligence solutions, within medical robots such as machines to be used for diagnostic or surgical purposes. Targeted applications will include tasks such as the identification and remote reproduction of tissues and their biomechanical characteristics within medical scenarios.

Requirements:

Applicants are expected to have a background in electronic, control, mechatronic, biomedical, mechanical, electronic, or computer engineering or related fields. However, this is not limiting, and other MSc degrees could be considered.

References:

- Massari, L., Schena, E., Massaroni, C., Saccomandi, P., Menciassi, A., Sinibaldi, E., & Oddo, C. M. (2020). A machine-learning-based approach to solve both contact location and force in soft material tactile sensors. *Soft robotics*, *7*(4), 409-420.
- Massari, L., Bulletti, A., Prasanna, S., Mazzoni, M., Frosini, F., Vicari, E., Pantano, M., Staderini, F., Ciuti, G., Cianchi, F., Messerini, L., Capineri, L., Menciassi, A., & Oddo, C. M. (2019). A mechatronic platform for computer aided detection of nodules in anatomopathological analyses via stiffness and ultrasound measurements. *Sensors*, *19*(11), 2512.
- Dupont, P. E., Nelson, B. J., Goldfarb, M., Hannaford, B., Menciassi, A., O'Malley, M. K., Simaan, N., Valdastri, P., & Yang, G. Z. (2021). A decade retrospective of medical robotics research from 2010 to 2020. *Science Robotics*, *6*(60), eabi8017.

Number of positions available:

1

Main Research Site

The BioRobotics Institute, Pontedera (PI), Italy

Contacts:

Email: arianna.menciassi@santannapisa.it calogero.oddo@santannapisa.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

14. Robotics for healthcare - Politecnico Torino

Curriculum:
Healthcare and wellness of persons

Hosting Institution:

Politecnico di Torino

Department:

Department of Mechanical and Aerospace Engineering

Tutor(s):

Giuseppe Quaglia, Carmen Visconte

Description:

The research program aims to widen the application of enabling robotics and digital technologies in healthcare, and in particular in the National Health Service, to ensure greater effectiveness and efficiency, and cost-reduction. An applied and multidisciplinary research activity will be required.

The project envisages, in a first phase, the selection of a certain number of activities that can benefit from the use of robotic technologies, starting from the real needs of healthcare personnel and patients, and considering the specificity and variety of the environments and of the operational and organizational conditions characterizing the application.

Although several tasks can only be performed by human staff, many others can be delegated to properly conceived and instrumented robotized agents.

The services that the machines should be able to provide clearly depend on the application and on the served subjects. With such a wide design premises, it turns straightforward that a sharp modular approach must feature in the research and design activity since its primary steps.

Innovative robotic devices will be addressed to some of the following tasks:

- handling and transport of small objects: consumables, medical records, samples to be analyzed. This basic functionality could be used to move material within the structure without having to employ qualified personnel;
- transport and mobility of patients;
- autonomous systems for waste management, aimed at increasing the efficiency of the recovery and reuse of materials, at a higher environmental sustainability of hospitals and at increasing the safety of operators and patients in the case of contaminated materials;
- remote monitoring, especially addressed to increase the monitoring frequency and/or for patients who are in a condition of precautionary isolation;
- rehabilitation devices;
- robotic technologies for telemedicine.

Requirements:

The candidate must exhibit a prominent interest in the field of design of innovative robotic applications, which by nature declines into complex mechatronic systems. Thus, he/she must confidently handle all the involved aspects:

- Mechanical design skills are of uttermost importance, in particular, a marked proneness to strictly defined methodological design processes, made necessary by both the modularity at the base of the project and the plurality of non-trivial engineering issues involved.
- Electrical, mechatronic, and control basic skills are required, for a proficient and effective interaction with the specialists working on software and high-level control design
- Data processing and analysis: experimentation remains of course of paramount importance in the research process. Ability to collect and critically observe numerical and phenomenological results is mandatory.

At last, it is worth remarking that such a transversal project requires a plurality of soft skills essential to guarantee an advantageous cooperation with the work-team, as well as the dissemination of the research results.

References:

- On the Suspension Design of Paquitop, a Novel Service Robot for Home Assistance Applications / Tagliavini, Luigi; Botta, Andrea; Cavallone, Paride; Carbonari, Luca; Quaglia, Giuseppe. - In: MACHINES. - ISSN 2075-1702. - ELETTRONICO. - 9:3(2021), pp. 1-16. [10.3390/machines9030052]
- Paquitop.arm, a Mobile Manipulator for Assessing Emerging Challenges in the COVID-19 Pandemic Scenario / Colucci, Giovanni; Tagliavini, Luigi; Carbonari, Luca; Cavallone, Paride; Botta, Andrea; Quaglia, Giuseppe. - In: ROBOTICS. - ISSN 2218-6581. - ELETTRONICO. - 10:3(2021), pp. 102-114. [10.3390/robotics10030102]

Number of positions available:

1

Main Research Site

Politecnico di Torino

Contacts:

Email: giuseppe.quaglia@polito.it, carmen.visconte@polito.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PA).

15. Bio-inspired friction-based self-locomoting soft microbot - Univ. Salento

Curriculum: Healthcare and wellness of persons

Hosting Institution

University of Salento

Department:

Engineering for Innovation

Tutor(s):

M. Scaraggi, M. De Vittorio, S. Gorb (Kiel University)

Description:

The research activities are finalized to the theoretical investigation by means of direct and mean field simulations, supported by ad hoc experimentation including (but not limited to) tribological testing and microfabrication, of soft bio-inspired microbots with locomotion based on frictional anisotropy. Locomotion is envisaged in soft unstructured wet environments, such as biological tissues, whereas microfabrication will target biocompatible/digestible electromechanical materials.

Requirements:

Applicants are expected to exceptionally hold a Master's Degree in Engineering, Physics or related disciplines, with strong background in continuum mechanics and in modelling the dynamics of fluid and structure, as well as experience in mechatronics design and preparation/microfabrication of soft materials. Good communication skills and ability to cooperate (creative, proactive and collaborative attitude), as well as proficiency in English language (written and oral) are required.

References:

- Ma, S. H., Scaraggi, M., Yan, C. Y., Wang, X. L., Gorb, S. N., Dini, D., Zhou, F., Small 2019, 15, 1802931.
- Lamanna, L., Rizzi, F., Guido, F., Algieri, L., Marras, S., Mastronardi, V. M., Qualtieri, A., De Vittorio, M., Adv. Electron. Mater. 2019, 5, 1900095.
- Tramsen, H.T., Heepe, L., Homchanthanakul, J., Wörgötter, F., Gorb, S.N., Manoonpong, P., Appl. Phys. A 2021, 127, 389

Number of positions available:

1

Main Research Site

University of Salento, Monteroni-Lecce, 73100, Italy; CBN-IIT, Arnesano (LE), 73010, Italy.

Contacts:

Email: michele.scaraggi@unisalento.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

16. Sensorimotor interfaces and control for human-robot collaboration - Univ. Siena

Curriculum: Healthcare and wellness of persons

Hosting Institution

University of Siena

Department:

Department of Information Engineering and Mathematics

Tutor(s):

Domenico Prattichizzo

Description:

The concept of human-robot collaboration has opened to innovative applications of robot manipulators in industrial and service contexts. Several works have investigated the use of collaborative robots in industrial applications (e.g., assembly), but also novel application fields are recently emerging. Co-bots can be used, for example, as assistants of doctors, surgeons, and dentists, or to help people with limited mobility in activities of daily living. Notwithstanding the envisaged application, it is paramount to develop suitable human-robot interfaces that enable the mutual understanding between the human and robot partners. In other words, the robot must interpret/recognize/predict human actions while the human must be aware of “what” the robot is doing, and possibly “why”.

In this doctoral project, we propose to develop robot perception and control strategies as well as sensorimotor interfaces that enable human-robot mutual awareness. Interfaces will be designed to give control inputs to collaborative manipulators as well as to provide the human user with feedback on the robot and/or task state. We will primarily focus on tactile feedback, which is still under-exploited in the field, possibly comparing and combining it with other feedback modalities (visual, audio). The main envisaged applications are in the healthcare domain, with a focus on interfacing collaborative robot arms with users that need assistance in manipulation tasks.

Requirements:

Applicants are expected to have good skills in the following areas: software development, robot control, robot programming, mechatronics. Furthermore, a good attitude for experimental work is fundamental. The candidates must have: good programming skills with different languages (e.g., C/C++, Python, Matlab/Simulink); attitude to problem solving, and be strongly motivated for team working.

References:

- A. Casalino, C. Messeri, M. Pozzi, A. M. Zanchettin, P. Rocco, D. Prattichizzo. Operator awareness in human-robot collaboration through wearable vibrotactile feedback. IEEE Robotics and Automation Letters,, 3(4):4289-4296, October 2018.
- Riccardo Maderna, Maria Pozzi, Andrea Maria Zanchettin, Paolo Rocco, Domenico Prattichizzo. Flexible scheduling and tactile communication for human-robot collaboration. Robotics and Computer-Integrated Manufacturing, 73, 2022.
- Domenico Prattichizzo, Maria Pozzi, Tommaso Lisini Baldi, Monica Malvezzi, Irfan Hussain, Simone Rossi, Gionata Salvietti. Human augmentation by wearable supernumerary robotic limbs: review and perspectives. Progress in Biomedical Engineering, 3(4), September 2021.

- C. Pacchierotti, S. Sinclair, M. Solazzi, A. Frisoli, V. Hayward, D. Prattichizzo. Wearable haptic systems for the fingertip and the hand: taxonomy, review, and perspectives. IEEE Transactions on Haptics, 10(4):580-600, 2017.

Number of positions available:

1

Main Research Site

University of Siena,
Department of Information Engineering and Mathematics,
Via Roma 56,
53100 Siena (SI), Italy
https://www.diism.unisi.it/it

Contacts:

Email: dprattichizzo@unisi.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

17. Sensorimotor interfaces and control for human-robot augmentation - Univ. Siena

Curriculum: Healthcare and wellness of persons

Hosting Institution

University of Siena

Department:

Department of Information Engineering and Mathematics

Tutor(s):

Domenico Prattichizzo

Description:

Human-robot sensorimotor augmentation refers to the enhancement of human physical capabilities, typically in manipulation and locomotion tasks. This is achieved through Supernumerary Robotic Limbs, i.e., wearable or grounded robotic devices which add artificial degrees of freedom to the human body and are under the direct control of the user.

The main idea underlying this doctoral project is to study how to integrate humans and AI-powered supernumerary robotic limbs (mainly wearable fingers and grounded robot arms) to perform complex manipulation tasks with both biological and artificial limbs. The user gains control over the robot limbs through wearable sensorimotor interfaces which are the enabling core technology of the human-robot interplay. Sensorimotor interfaces establish a connection between the human sensorimotor system and the system of actuators and sensors of the robot, allowing for reciprocal awareness, trustworthiness, and mutual understanding. The objective is to develop interfaces that will i) capture signals from human body motion or muscle activation to be mapped onto commands for the robot limbs, and ii) provide haptic feedback to the user to convey information on the robot state and on the executed task. Different types of cutaneous cues (e.g., skin stretch, vibrations, and temperature changes) will be investigated.

Human-robot sensorimotor augmentation finds its natural application in the assistance of people with upper limb disabilities, who, thanks to a supernumerary robotic limb could regain independence in daily living and social activities.

Requirements:

Applicants are expected to have good skills in the following areas: software development, robot control, robot programming, mechatronics. Furthermore, a good attitude for experimental work is fundamental. The candidates must have: good programming skills with different languages (e.g., C/C++, Python, Matlab/Simulink); attitude to problem solving, and be strongly motivated for team working.

References:

- Domenico Prattichizzo, Maria Pozzi, Tommaso Lisini Baldi, Monica Malvezzi, Irfan Hussain, Simone Rossi, Gionata Salvietti. Human augmentation by wearable supernumerary robotic limbs: review and perspectives. Progress in Biomedical Engineering, 3(4), September 2021.
- G. Dominijanni, S. Shokur, G. Salvietti, S. Buehler, E. Palmerini, S. Rossi, F. De Vignemont, A. d'Avella, T. R. Makin, D. Prattichizzo, S. Micera. The neural resource allocation problem

when enhancing human bodies with extra robotic limbs. Nature Machine Intelligence, 3(10):850-860, 2021.
- G. Salvietti, I. Hussain, D. Cioncoloni, S. Taddei, S. Rossi, D. Prattichizzo. Compensating Hand Function in Chronic Stroke Patients Through the Robotic Sixth Finger. Transaction on Neural System and Rehabilitation Engineering, 25(2):142-150, 2017.
- C. Pacchierotti, S. Sinclair, M. Solazzi, A. Frisoli, V. Hayward, D. Prattichizzo. Wearable haptic systems for the fingertip and the hand: taxonomy, review, and perspectives. IEEE Transactions on Haptics, 10(4):580-600, 2017.

Number of positions available:

1

Main Research Site

University of Siena,
Department of Information Engineering and Mathematics,
Via Roma 56,
53100 Siena (SI), Italy
https://www.diism.unisi.it/it

Contacts:

Email: dprattichizzo@unisi.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.

18. Human-robot coexistence and interaction in robot-assisted medical procedures - Univ. Roma La Sapienza

Curriculum:

Healthcare and wellness of persons

Hosting Institution

Sapienza University of Rome

Department:

Department of Computer, Control and Management Engineering (DIAG)

Tutor(s):

Alessandro De Luca, Marilena Vendittelli

Description:

The introduction of robots in the medical domain is radically changing the standard of care. However, despite their early adoption in mid 80's, the clinical practice lacks examples of robots that autonomously execute a complete medical task in contact with the patient, collaborate with the medical operators, and safely coexist with humans and devices populating a classical operating room. In short, a robot that interacts with its working environment is lacking in the medical domain. Physical safety is, naturally, the most relevant concern to be addressed to allow the deployment of interacting robots in this context. Research on human-robot physical interaction, that has already enabled a step change in the industrial production paradigms, finds unique challenges in medical applications.

Relying on the results obtained at the DIAG Robotics Laboratory [1-4] on safe human-robot interaction, this thesis work will address these challenges with reference to robot-assisted superficial hyperthermia treatments. The company supporting this PhD project has recently developed, in collaboration with the DIAG Robotics Laboratory, a technology demonstrator [5,6]. The thesis work will address the many issues and open problems that still remain for guaranteeing safe coexistence and physical interaction with collaborating (the staff) and non-collaborating (the patient) humans, minimally invasive integration in the operating room, significant improvement in therapy delivery and clinical outcomes. The ultimate goal of the project is to integrate the safe physical interaction algorithms developed in the thesis with methods for estimating the actually delivered dose of therapy. This will lead to the development of "treatment servoing" algorithms that allow a feedback control on therapy delivery. The generation of the feedback information is the subject of another, ongoing, PhD work.

The role holder will therefore operate on these stimulating and challenging topics in a multidisciplinary context, working with experts in Robotics, Computer Science, Biomedical Engineering, and Medicine.

Requirements:

We look for applicants with a master's degree in Control Engineering, Artificial Intelligence and Robotics, or Computer Science. Different backgrounds will be taken also into account, provided that the candidate has received basic education in modeling and control of dynamic systems and in robotics. Applicants are also expected to possess programming skills in the most common languages (C++, MATLAB, Python), familiarity with standard development software (like, e.g.,

Microsoft Visual Studio) and knowledge of robotic simulation environments. Preferred qualifications include experience in designing and developing software solutions to interconnect and integrate heterogeneous systems and/or that implement basic human-robot physical interaction control methodologies on real robot platforms.

References:

[1] M. Khatib, K. Al Khudir, A. De Luca, "Human-robot contactless collaboration with mixed reality interface," *Robotics and Computer-Integrated Manufacturing*, vol. 67, 102030, February 2021

[2] E. Magrini, F. Ferraguti, A.J. Ronga, F. Pini, A. De Luca, F. Leali, "Human-robot coexistence and interaction in open industrial cells," *Robotics and Computer-Integrated Manufacturing*, vol. 61, 101846, February 2020.

[3] C. Gaz, E. Magrini, A. De Luca, "A model-based residual approach for human-robot collaboration during manual polishing operations," *Mechatronics* (Special Issue on Human-Robot Collaboration in Industrial Applications), vol. 55, pp. 234-247, 2018

[4] S. Haddadin, A. De Luca, A. Albu-Schäffer, "Robot collisions: A survey on detection, isolation, and identification," *IEEE Transactions on Robotics*, vol. 33, no. 6, pp. 1292-1312, 2017.

[5] ROBHOT - DIH-HERO technology demonstrator .

[6] Demo at The European SocieTy for Radiotherapy and Oncology Congress (ESTRO 2022).

Company name and link (for industrial projects):

MedLogix (https://albahyperthermia.com/)

Number of positions available:

1

Main Research Site

DIAG Robotics Laboratory, MedLogix

Contacts:

Email: alessandro.deluca@uniroma1.it, marilena.vendittelli@uniroma1.it

Funding scheme: This industrial doctorate grants is co-funded by the proponent research institution, company and by the Italian Ministry of Research, under law D.M. 352/2022.

19. Artificial Intelligence methods and Robotic Assistance in Surgical Procedures - Univ. Modena e Reggio Emilia

Curriculum: Healthcare and wellness of persons

Hosting Institution

Università di Modena e Reggio Emilia

Department:

Dipartimento di Scienze e Metodi dell'Ingegneria

Tutor(s): Federica Ferraguti

Description:

In the operating room, surgeons must always be precise when making incisions or performing other surgical tasks. The repetitive tasks are challenging. To assist surgeons, the medical field is using the advancements of Artificial Intelligence and robotics. The research aims at the development and implementation of Artificial Intelligence and machine learning algorithms to be applied in surgical robotics. In particular, the research activity deals with the development and application of machine learning and deep learning algorithms to implement advanced control systems for surgical robots. The developed systems will be exploited in teleoperation systems, in control systems for autonomous robots and in robotic systems to provide assistance to the surgeon during the execution of the surgical task.

During the research period, the PhD candidate will study the most advanced solutions from state of the art and develop novel strategies for:

- Action recognition in surgical robotics: detection of the behavior of the surgeon, prediction of future movements and actions, surgical phase recognition, surgical scene segmentation
- Robotic assistance to the surgeon and to the trainees: solutions for reducing the learning curve of trainees, minimization of the error that can be performed by the surgeon, thanks to the implementation of novel control algorithms based on virtual fixtures, variable admittance control, repulsive fields.
- Error detection, prevention, and correction: strategies to detect the errors that are currently being performed by the surgeon during the procedure and implementation of automatic corrective actions.
- Scene understanding: automatic understanding of the surgical scene, thanks to advanced Artificial Intelligence based algorithms and automatic execution of surgical actions.
- Teleoperation of surgical robots: implementation of strategies for providing the best performance of the teleoperation system, while guaranteeing the stability.

Requirements:

Applicants are expected to have a strong attitude to research and team working. Knowledge of topics related to robotics and surgical robotics are appreciated.

Applicants should hold a Master Thesis in Engineering (preferably Mechatronics, Computer Science, Management).

References:

- Panesar, Sandip; Cagle, Yvonne; Chander, Divya; Morey, Jose; Fernandez-Miranda, Juan. Artificial Intelligence and the Future of Surgical Robotics, Annals of Surgery: August 2019 - Volume 270 - Issue 2 - p 223-226
- G. De Rossi et al., "A First Evaluation of a Multi-Modal Learning System to Control Surgical Assistant Robots via Action Segmentation," in IEEE Transactions on Medical Robotics and Bionics, vol. 3, no. 3, pp. 714-724, Aug. 2021
- F. Ferraguti, N. Preda, A. Manurung, M. Bonfè, O. Lambercy, R. Gassert, R. Muradore, P. Fiorini and C. Secchi. An Energy Tank-Based Interactive Control Architecture for Autonomous and Teleoperated Robotic Surgery. IEEE Transactions on Robotics (T-RO). 2015. 31(5), pp. 1073-1088.

Number of positions available: 1

Main Research Site

Laboratorio ARSControl, Tecnopolo di Reggio Emilia, Piazzale Europa 1, 42122 Reggio Emilia, Italy

Contacts:

federica.ferraguti@unimore.it

Funding scheme: This doctorate grant is co-funded by the proponent research institutions and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

20. Motion and action prediction for human-robot collaboration facilitated by body signals and context - Univ. Bolzano

Curriculum: Healthcare and wellness of persons

Hosting Institution:
Free University of Bolzano

Department:
Science and Technology

Tutor(s):
Angelika Peer
Renato Vidoni

Description:

For achieving seamless human-robot interaction, proper prediction capabilities play a major role. In this project, we aim at developing a robotic architecture capable of predicting human motions and actions based on a multimodal approach combining movement information, EMG, EEG and eyetracking information as well as context. While lots of literature focuses on action recognition that requires observing the full action, we aim for developing algorithms for motion and action prediction to facilitate the early triggering of proper assistive/collaborative robot behaviors. The resulting motion and action prediction capabilities will not only allow to enhance human-robot collaboration in scenarios involving sequential actions to be performed in alternation of human and robot, but also scenarios involving parallel actions with physically coupled bodies as typically found in exoskeleton or orthoses applications. More specifically, we aim at investigating how eye-tracking information, EMG and EEG signals as well as context (e.g. objects located in the environment, their type and affordances as well as knowledge about plans) can contribute next to human motion tracking to motion and action prediction. To be able to handle context more easily and to allow for its incorporation into a computational approach, we will investigate its transformation into different latent spaces. We aim for testing the developed algorithms with healthy subjects in applications involving an active lower-limb exoskeleton in the laboratory as well as in the field.

Specifically the work will involve:

- recording datasets with typical activities by incorporating motion tracking, EMG, EEG and eyetracking information
- developing a multimodal approach for motion and action prediction
- evaluating the performance of the proposed algorithm based on the recorded dataset and investigate the contribution of the individual modalities and context
- validating the approach in real-time robotic assistive experiments

Requirements:

Applicants are expected to have strong interests in multidisciplinary research and should ideally come with previous experience in processing body signals as well as strong programming skills in C++, Python and Matlab.

References:

- Y. Zheng, Y. Yang, K. Mo, J. Li, T. Yu, Y. Liu, K. Liu, L.J. Guibas, GIMO: Gaze-Informed Human Motion Prediction in Context, arXiv:2204.09443v1, 2022
- E.A. Kirchner, M. Tabie, A. Seeland, Multimodal Movement Prediction - Towards an Individual Assistance of Patients, Plos One, 9, 2014.
- M.S. AL-Quraishi, I. Elamvazuthi, S.A. Daud, S. Parasuraman, A. Borboni, EEG-Based Control for Upper and Lower Limb Exoskeletons and Prostheses: A Systematic Review, Sensors, 18, 3342, 2018.

Number of positions available:

1

Main Research Site

Free University of Bolzano, NOI Techpark, Via Volta 13, 39100 Bolzano

Contacts:

Email: angelika.peer@unibz.it

Funding scheme: This doctorate grant is fully funded by the proponent research institutions.