I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Curriculum: Robotics and Intelligent 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 improving people's wellness and quality of life, as well as preventing the risk of injuries or professional pathologies.

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 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. Assistive Robots for Alzheimer's Disease – Università degli Studi di Genova

Curriculum: Healthcare and wellness of persons	
Hosting Institution Università degli Studi di Genova	
Department: DIBRIS: https://dibris.unige.it/ RICE lab: https://rice.dibris.unige.it/	
Tutor(s): Carmine Recchiuto	

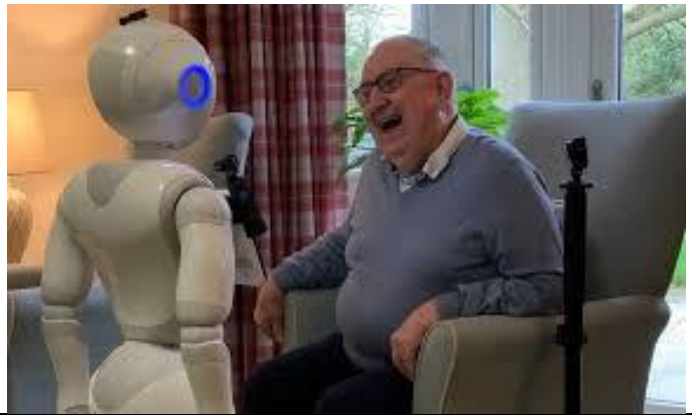
Description:

May an opportunely programmed social robot be able to assist individuals with dementia and ease the burden of their caregivers, by a) showing emotional intelligence, b) providing practical help with Activities of Daily Life, and c) being extremely reliable so as to be used for long-term interaction?

The question, up to now only partially answered by related scientific literature [1, 2], comes with different technical issues to be addressed. Indeed, emotional intelligence, even when coupled with cutting-edge techniques in computer vision and language processing, is still a big challenge in social robotics, in particular, if the robot should behave autonomously and with adaptive capabilities. On the other hand, assistive robots able to practically help persons suffering from Alzheimer's to perform ADLs have received only limited attention, due to similar technical challenges and real-life complexity. Finally, long-term interaction requires autonomous robots that are able to deal with unexpected situations, are controlled by reliable software.

This PhD program project aims at tackling all or some of these aspects by developing a new generation of assistive robots able to provide emotional engagement with persons affected by Alzheimer's, by adapting to the user's identity and emotional state, expressing proper emotions in response to that state, while also helping the user to perform simple activities. In particular, the work performed during the PhD will allow for defining guidelines for social assistive robots interacting with people suffering from Alzheimer's and designing software architecture and modules able to interact with the user in the proper way, also adapting to the user's specific needs.

The project will be based on existing work in social robotics, psychology (e.g, affect theory, appraisal theory, existing cognitive architecture for robotics), but the student will also benefit from the experience acquired by the RICE lab in the CARESSES project [3] and its future evolutions, where cultural- and diversity-aware social robots have been developed for elderly care assistance and long-term interaction. Experimental tests with real end-users are also foreseen for the last phase of the project.



The project will be performed at the DIBRIS department in the "RICE Lab," a fully equipped facility for software development with different humanoid robots for socially assistive applications (Pepper, Nao, Navel, Buddy)

Requirements:
Applicants are expected to have good programming skills (C++, Java, or Python) and a profound interest in cutting-edge research in autonomous robotics and socially assistive robotics. Previous experience with Artificial Intelligence techniques and Human-Robot Interaction strategies will be considered.
When applying for the Ph.D. scholarship, the student will be encouraged to propose solutions to address one or more of the aspects described in the proposal.

References:

1. Góngora Alonso, Susel, et al. "Social robots for people with aging and dementia: a systematic review of literature." Telemedicine and e-Health 25.7 (2019): 533-540.
2. Ghafurian, Moojan, Jesse Hoey, and Kerstin Dautenhahn. "Social robots for the care of persons with dementia: a systematic review." ACM Transactions on Human-Robot Interaction (THRI) 10.4 (2021): 1-31.
3. Carmine T. Recchiuto, and Antonio Sgorbissa. "A feasibility study of culture-aware cloud services for conversational robots." IEEE Robotics and Automation Letters 5.4 (2020): 6559-6566.

Company name and link (for industrial projects):
-

Number of positions available:
1

Main Research Site
Università degli Studi di Genova, DIBRIS, RICE lab, via all'Opera Pia 13, 16145, Genova

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Funding Scheme: This doctorate grant is fully funded by the Alzheimer's Association Project ARIA, Proposal number: 24AARG-NTF-1200708. CUP

Scolarship Amount:
- Fascia 4: 19,500 €/year

2. Design of customized low-cost hand prosthesis and orthosis – Università Campus Bio-Medico di Roma

Curriculum: Healthcare and wellness of persons

Hosting Institution
Università Campus Bio-Medico di Roma

Department:
Facoltà dipartimentale di ingegneria

Tutor(s):
Fabrizio Taffoni; Loredana Zollo

Description:
In 2017, the World Health Organization reported that around 0.5% of the world population requires prosthetic and orthotic services due to the loss of a limb or a hand functional deficit [1].
Amputations are frequently caused by trauma but also by congenital limb deficiency, vascular pathologies or cancer [2]. About 38.7% of the cases reported in [1] regards the upper limb: 19.6% unilateral, 19.1% bilateral. The impact on the quality of life of the person with an upper limb amputation strongly depends on the amputation level. In the case of a total hand amputation, as in trans-radial or trans-humeral amputations, a huge amount of Activities of Daily Living (ADLs) are impossible [3]. Several neurological and orthopedic pathologies as well as injuries [4] may also cause severe functional hand deficits.
Robotic hand prostheses and orthoses can restore some of these functionalities mitigating the impact of hand amputation or functional deficits on patient's life. Unfortunately, the majority of hand exoskeletons are used for rehabilitative purposes, and only few of them are available for ADL assistance as research prototypes [5]. Moreover, the abandonment rate of robotic hand prostheses is still very high [6]-[9]. In a survey on 92 upper limb amputees, Datta and colleagues [6] point out how the main reasons of prosthesis abandonment are in the level of functionality (i.e., the number of ADLs they allow to restore), the level of cosmesis, and in the weight, frequently judged excessive by patients.
Several approaches have been pursued to support the design of custom devices, mainly focused on prostheses. They can be grouped in: discrete sizing and continuous scaling methods. In the first method, a set of different sizes are predefined according to the population distribution [10]. The prosthetic model is selected as the one closest to the anthropometric characteristics of the user. The second method can be implemented by using a uniform scaling of the 3D model [12]-[14] or by introducing a parametric modeling of the CAD which allows to scale the size of the prosthesis according to specific rules (*i.e.*, non uniform scaling) [15]-[16]. In both cases the shape of the prosthesis is predefined and not directly derived from the patient morphology. 3D scanning technologies may represent a possible source of information to be integrated in the customization process.
Within this research line the PhD candidate will explore the use of patient kinematic modeling, 3D scanning, and additive manufacturing techniques [17]-[20] to setup and validate a development workflow enabling production of low-cost customized hand prostheses and orthoses for both adult and pediatric patients (since 3 years of age). In particular, this research is grounded around the design and development of mechanical/mechatronic components for custom hand prostheses and orthoses for

functional substitution/assistance. The research will tackle with one of more of these activities:

- Biomechanical modelling of human hand
- Mechanical design for human robotics
- Digital manufacturing and system integration
- Development of proof-of-concept mechanical/mechatronic prototypes and of advanced devices.

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/C++; MATLAB and/or Python);
- Knowledge of mechanical and electronic CAD tools;
- Fluency in English.

Appreciated plus:

- Past experiences in the use of Inventor professional and/or Fusion 360; Altium Designers;
- Past experience in the use of Code Composer Studio and/or MPLAB for microcontrollers and processors embedded code development;
- Electronic and software debugging skills;
- Past experience in similar relevant activities.

1. **References:**

2. C. L. McDonald, S. Westcott-McCoy, M. R. Weaver, J. Haagsma, and D. Kartin, “Global prevalence of traumatic non-fatal limb amputation,” Prosthetics and orthotics international, p. 0309364620972258, 2021.
3. J. R. Zenie, “Prosthetic options for persons with upper-extremity amputation,” Orthotics & Prosthetics in Rehabilitation, pp. 795–813, 2013.
4. W. R. Frontera and J. K. Silver, Essentials of Physical Medicine and Rehabilitation E-Book: Musculoskeletal Disorders, Pain, and Rehabilitation. Elsevier Health Sciences, 2018.
5. M. Giustini, A. d. Leo, A. L. Acciaro, G. Pajardi, C. Mamo, F. Voller, F. Fadda, G. Fondi, and A. Pitidis, “Incidence estimates of hand and upper extremity injuries in italy,” Annali dell’Istituto superiore di sanita`, vol. 51, pp. 305–312, 2015.
6. Noronha and D. Accoto, "Exoskeletal Devices for Hand Assistance and Rehabilitation: A Comprehensive Analysis of State-of-the-Art Technologies," in IEEE Transactions on Medical Robotics and Bionics, vol. 3, no. 2, pp. 525-538, May 2021, doi: 10.1109/TMRB.2021.3064412.
7. D. Datta, K. Selvarajah, and N. Davey, “Functional outcome of patients with proximal upper limb deficiency–acquired and congenital,” Clinical rehabilitation, vol. 18, no. 2, pp. 172–177, 2004.
8. S. Ritchie, S. Wiggins, and A. Sanford, “Perceptions of cosmesis and function in adults with upper limb prostheses: a systematic literature review,” Prosthetics and orthotics international, vol. 35, no. 4, pp. 332–341, 2011.
9. F. Cordella, A. L. Ciancio, R. Sacchetti, A. Davalli, A. G. Cutti, E. Guglielmelli, and L. Zollo, “Literature review on needs of upper limb prosthesis users,” Frontiers in neuroscience, vol. 10, p. 209, 2016.

10. E. A. Biddiss and T. T. Chau, “Upper limb prosthesis use and abandonment: a survey of the last 25 years,” Prosthetics and orthotics international, vol. 31, no. 3, pp. 236–257, 2007.
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12. “i-limb quantum,” available on line. [Online]. Available: https://www.ossur.com/it-it/protesi/arto-superiore/i-limb-quantum
13. J. Zuniga, D. Katsavelis, J. Peck, J. Stollberg, M. Petrykowski, A. Carson, and C. Fernandez, “Cyborg beast: a low-cost 3d-printed prosthetic hand for children with upper-limb differences,” BMC research notes, vol. 8, no. 1, pp. 1–9, 2015.
14. M. King, B. Phillips, M. Shively, V. Raman, A. Fleishman, S. Ritter, and K. Mehta, “Optimization of prosthetic hand manufacturing,” in 2015 IEEE Global Humanitarian Technology Conference (GHTC). IEEE, 2015, pp. 59–65.
15. J. L. Parry-Hill and D. L. Ashbrook, “Challenges and opportunities in dfo-at: A study of e-nable,” 2016.
16. J. L´azaro-Guevara, R. Gondokaryono, L. Gonz´alez, K. Garrido, N. Sujumnong, A. Wee, and J. Miscione, “A graphic user interface (gui) to build a cost-effective customizable 3d printed prosthetic hand,” bioRxiv, pp. 2020–03, 2020.
17. D. Lim, T. Georgiou, A. Bhardwaj, G. D. O’Connell, and A. M. Agogino, “Customization of a 3d printed prosthetic finger using parametric modeling,” in International Design Engineering Technical
18. M. B. Burn, A. Ta, and G. R. Gogola, “Three-dimensional printing of prosthetic hands for children,” The Journal of hand surgery, vol. 41, no. 5, pp. e103–e109, 2016.
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20. J. Ten Kate, G. Smit, and P. Breedveld, “3d-printed upper limb prostheses: a review,” Disability and Rehabilitation: Assistive Technology, vol. 12, no. 3, pp. 300–314, 2017.
21. M. Lapresa, A. Ceccarelli, F. Taffoni, N. L. Tagliamonte, L. Zollo, and F. Cordella, “Analysis of hand intra-finger couplings during flexion movements in the free space,” IEEE Access, 2023.

Company name and link (for industrial projects):

Number of positions available:
1

Main Research Site
Università Campus Bio-Medico di Roma - Via Álvaro del Portillo 21, 00128 Roma (RM).

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Funding Scheme: This doctorate grant is fully covered by the PR23-PAS-P3 - 3Daid++ project “Protesi di mano ed ausili robotici esoscheletrici a basso costo per bambini e adulti”, funded the Istituto Nazionale per l’Assicurazione contro gli Infortuni sul Lavoro (INAIL).

Scholarship Amount:

Fascia 1: 16,500 €/year

3. Social robot assistant for intelligent health care – Università degli Studi di Palermo

Curriculum: Healthcare and wellness of persons	
Hosting Institution University of Palermo (Università degli Studi di Palermo)	
Department: Department of Engineering	
Tutor(s): Seidita Valeria Fagiolini Adriano Chella Antonio	

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.
Another problem is the lack of doctors and nurses, the staff dropouts due to burnout and work-related stress 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:

- 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.
- 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 challenges.

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:

1. 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
2. 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
3. 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
4. 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.e 48-e49
5. 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
6. 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 adriano.fagiolini@unipa.it
Funding Scheme: This doctorate grant is fully funded by "Fondi di Ateneo" of UNIPA.
Scholarship Amount: 16,500 €/year

4. Intelligent end-effector embodiments and autonomous manipulation principles for impaired upper limb robot assistance

Curriculum:
Healthcare and wellness of persons

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid and Human Centred Mechatronics Research line (https://hhcm.iit.it/)

Tutor(s):
Nikos Tsagarakis, nikos.tsagarakis@iit.it

Description:
The realization of effective manipulation skills has strong dependencies on the robot end-effector mechatronics including the articulated kinematics, the actuation and the sensing principles of the end-effector module. This research topic targets to develop kinematically minimalistic end-effector modules that are equipped with intrinsic adaptation as well as multi-modal sensing capabilities to facilitate the manipulation robustness as well as the realization of autonomous grasping and manipulation skills. The end-effector device will be realized with different articulation topologies to serve the grasping requirements of various target manipulation tasks. The mechatronic design and the engineering of the end-effector modules will explore the instrumentation of the grippers with integration of visual and haptic sensing that will provide the cues for implementing autonomous grasping and manipulation functionalities. Proprioceptive feedback will be employed for the regulation of the grasping forces and for their adaptation through reflex controllers tuned using model and machine learning based techniques. Control methodologies and a set of autonomous manipulation skills will be explored and implemented to enable the execution and adaptation of grasping actions within the EU project HARIA targeting to develop a assistive robotic manipulation system for people with upper limb impairments (http://haria-project.eu/).

Requirements:
We are seeking for highly motivated candidates with a background in Mechanical and Control engineering, Physical Sciences or Robotics. Candidates should have competencies in mechanical design, robot dynamics, learning and control. (Mechanical design 40%, Control %60). The applicants should be fluent in English and team players.

References:

- Barrett E., Ren Z., Tsagarakis N.G., Grasping with Embedded Synergies through a Reconfigurable Electric Actuation Topology, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2021, pp6131-6138.
- Ren Z, Kashiri N., Zhou C., Tsagarakis N.G., Heri ii: A robust and flexible robotic hand based on modular finger design and under actuation principles, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2018, pp 1449-1455.

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- Y. Bekiroglu, J. Laaksonen, J. Alison Jorgensen, V. Kyrki, D. Kragic, Assessing Grasp Stability Based on Learning and Haptic Data, IEEE Transactions on Robotics, 2011, Vol. 27, Issue 3.

Number of positions available: 1

Main Research Site
Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

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Funding Scheme: This doctorate positions are funded by Horizon Europe Programme project HARIA (http://haria-project.eu/) CUP: J53C22002260006

Scolarship Amount:
Fascia 4: 19,500 €/year