NUS National University of Singapore | Department of Mechanical Engineering
College of Design and Engineering

You are cordially invited to our

DEPARTMENT SEMINAR

Three Seminars in Rehabilitation Robotics

Date: **Thursday, 28 September 2023**

Time: **10.00am to 11.30am**

Venue: **Seminar Room EA-06-02**
Block EA, Level 6, College of Design & Engineering, NUS
(Click here for location map.)

Host: **Prof Cecilia Laschi**

Soft Wearable Robotics: Artificial Intelligence and Control Strategies for Augmented Human Performance and Rehabilitation

Speaker: **Lorenzo Masia**
Professor Dr (W3), Chair in "Biorobotics and Medical Technology"
Institut für Technische Informatik (ZITI)
Heidelberg University, Germany

Transcending the paradigm of wearing a robot - The MusculoSkeletal Expansion

Speaker: **Leonardo Cappello**
Assistant Professor, Head of the Textile Robotics Lab
The Biorobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy

Sensory-based Neurorehabilitation of the Hand

Speaker: **Eleonora Vendrame**
PhD Candidate in Biorobotics
The Biorobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy

ABSTRACT

Soft Wearable Robotics: Artificial Intelligence and Control Strategies for Augmented Human Performance and Rehabilitation

Soft wearable exosuits have been introduced in the last decade as possible candidates to overcome the limitations from devices using rigid structures: the exoskeletons.
Despite the Exosuits initially promised tangible improvements, yet their soft wearable architecture presents strong drawbacks, placing this technology more in a complementary position rather than on a higher step of the podium respect to their predecessors. During my speech I will introduce the

progress from our research on soft wearable exosuits for assistance and augmentation, by presenting novel solutions on mechanical design, novel implementation of control strategies based on machine learning and artificial vision to master the exosuis´non-linear behaviours, improving flexibility and controlling such devices symbiotically. I will discuss in detail how using bio-signals by means of a realtime techniques based on musculoskeletal dynamics to provide a symbiotic interface between the exosuit and the user and introduce also our latest results in clinical applications and performance augmentation.

In this work, we present a novel approach for predicting the perception performance of an optical aerial surveillance system. We outline our use case in multi-target tracking motivating this work before giving some background on related work in sensor performance estimation. After explaining the reasoning behind selecting a Bayesian network against other machine learning classifiers, we present relevant underlying concepts of sample-based inference and parameter learning in probabilistic graphical models. We present the modular architecture of our performance estimator and reason through the model input nodes based on system, object, and scene parameters. Further, we describe the extensive flight experiment performed using a crewed ultralight aircraft equipped with a state-of the-art aerial surveillance gimbal to collect imagery of target vehicles under carefully specified conditions. We describe the implemented post-processing of the recorded data, the method used to sample a reasonably sized dataset for learning, the criteria followed while labeling the dataset, and the technique used to learn a usable model based on a Bayesian network. Next, we analyze the classification performance of the model on an independent validation dataset and compare it against two additional machine-learning classifiers trained on the same dataset. We discuss the limitations of the proposed model and the presented validation. We wrap up by giving an outlook on various opportunities for possible future improvements to enhance the prediction performance of our network. Finally, we present other use cases benefitting from a similarly structured sensor performance prediction model, such as search planning and optimization during the design of new sensor platforms.

Transcending the paradigm of wearing a robot - The MusculoSkeletal Expansion

People that suffer from severe muscle weakness of the (upper) limb following neurological disorders still struggle to find assistive technologies able to help them in their daily life. The most advanced technologies consist of wearable exoskeletons, either rigid or soft, that promise to support the wearer during daily living. Despite their great potential, the widespread adoption of exoskeletons where they are most needed – i.e., for continuous daily home assistance – is prevented by several flaws: limited efficiency, controllability, and lack of reliable ways to connect them to the user. With my project MUSE (MusculoSkeletal Expansion) I aim to abandon the paradigm of wearing an exoskeleton to develop and clinically assess soft external muscles (exomuscles) intimately connected and naturally controlled by the user. The core objective is to develop innovative efficient exomuscles to support people with severe muscle weakness. They will be developed by combining the extreme portability of pneumatic actuators made of textiles with the energy efficiency and promptness of non-linear elastic structures. They will be reliably connected to the user through fixtures implanted on the bones, which will grant the excellent mechanical stability of osseointegration, widely adopted in dental prosthetics and increasingly explored in limb prosthetics, but still unexplored in exoskeletons. This approach will unlock the potential of eliciting osseoperception, i.e., sensory feedback – necessary to control motion – through bone conduction. MUSE will benefit all those in need of sensorimotor augmentation, as it can be extended to all kinds of exoskeletons (from upper to lower limbs, from assistive to augmenting devices).

Sensory-based Neurorehabilitation of the Hand

The loss of sensitivity of the upper limb due to neurological injuries (e.g., stroke) severely limits the ability to manipulate objects, hindering personal independence. Nowadays, strategies to promote motor recovery following stroke mainly focus on repetitive voluntary movements, usually forgetting that the planning and execution of voluntary movement requires also a correct integration of the sensory information. Sensory therapy is rarely targeted and is seldom functional. We believe that functional augmented feedback (i.e., sensory stimuli combined with motor rehabilitation) would promote neural plasticity and motor re-learning, allowing for both short- and long-term benefits. Thus, we are developing wearable devices for restoring sensorimotor hand functions delivering vibrational stimuli synchronously with the relevant mechanical events of manipulation. They rely on piezoelectric sensors for the recognition of touch-events, exploiting miniaturized vibrotactors for the delivery of the feedback. Preliminary tests with healthy and injured volunteers proved the effectiveness of the devices, encouraging further developments.

ABOUT THE SPEAKER

Lorenzo Masia graduated in Mechanical Engineering at "Sapienza" University of Rome in 2003 and in 2007 He accomplished his PhD in "Mechanical Measurement for Engineering" at the University of Padua.
He started his path in robotics, spending

- two years as *Researcher* at the Mechanical Engineering Dept. of the Massachusetts Institute of Technology (MIT) (from Jan- 2005 to Dec 2006) working at the Newman Lab for Biomechanics and Human Rehabilitation.
- he was then *Team Leader* at the Italian Institute of Technology (IIT) in the Robotics Brain and Cognitive Sciences Department
- and he started his academic path as *Assistant Professor* at the School of Mechanical & Aerospace Engineering (MAE) at Nanyang Technological University (NTU) of Singapore (2013-2018).
- He was *Associate Professor* in Biodesign at the Department of Biomechanical Engineering of the University of Twente (The Netherlands) from June 2018 to March 2019.

Now, since April 2019, He is *Full Professor* in *Biorobotics & Medical Technology* at **Heidelberg University** (Germany) at the Institute of Computer Engineering or Institut für Technische Informatik (ZITI), leading the **ARIES Lab** (Assistive Robotics and Interactive ExoSuits).

International Awards
Prof Masia and his team were awarded multiple times in the leading conferences in Biorobotics and Robotic Rehabilitation winning

- two IEEE Best Paper Awards (IEEE ICORR2011 and IEEE BIOROB 2022),
- two IEEE Best Student Paper Awards (IEEE ICORR2015 and IEEE Biorob2016),
- one best presentation award at IEEE BIOROB 2020
- finalists of "Best Human-Robot Interaction (HRI) Paper Award" at IEEE ICRA 2017 and finalist IEEE RAL Best Paper Award in 2022.

Prof Masia is Associate Editor for the following journals

- Wearable Technologies, Cambridge Press (2021-present)
- IEEE RAL Robotics and Automation Letters (2019-present)
- IEEE Transaction on Neural Systems and Rehabilitation Engineering (2019-present)
- Journal of NeuroEngineering and Rehabilitation (2019-present)

High responsibility roles in International Conferences
Prof Masia has been appointed:

- three times Program Chair for the IEEE International Conference in Rehabilitation Robotics (ICORR) 2015, IEEE International Conference on Biomedical Robotics and Biomechatronics (BIOROB) 2016 and International Conference on Neurorehabilitation (ICNR 2018).
- He served as Chairman for Workshop/Tutorial for the IEEE International Conference on Robotics and Automation (IEEE ICRA 2017),
- and He was the Co-Program Chair of IEEE ICORR 2017 (London, UK), and Co-Program Chair, Editor in Chief and Editor of Publication for IEEE BIOROB 2018.

He will be **General Chair for IEEE BIOROB 2024** the leading conference in Biomedical Robotics and Biomechatronics hosted in Heidelberg.

Leonardo Cappello graduated in Mechanical Engineering (BS) in 2009 and in Biomedical Engineering (MS) in 2011 at the University of Florence, Italy. In 2016 he accomplished his PhD in “Robotics, Cognition and Interaction Technologies” at the Italian Institute of Technology, advised by Prof. Lorenzo Masia. During his PhD, he was visiting student at the Nanyang Technological University, Robotics Research Centre, Singapore (2014 - 2015).
He was Postdoctoral Researcher at Harvard University and the Wyss Institute for Biologically Inspired Engineering, in the team lead by Prof. Conor Walsh, where he worked on soft wearable robots for upper limb sensorimotor restoration (2016 - 2017). He was then Postdoctoral Researcher at the BioRobotics Institute - Scuola Superiore Sant'Anna (Italy) - investigating advanced robotic prostheses and prosthetic techniques for the upper extremities, working closely with Prof. Christian Cipriani and Prof. Marco Controzzi (2017-2022).
Leonardo Cappello started his academic path in 2022 as Assistant Professor at the BioRobotics Institute - Scuola Superiore Sant'Anna (Italy), where he funded the Textile Robotics Laboratory and where he works on the design of textile-based robotic wearables for human sensorimotor restoration and augmentation. His research interests include haptics, assistive and rehabilitation robotics, prosthetics and orthotics, and motor neurosciences.
He was recently awarded with the European Research Council Starting Grant (ERC StG) for the project MUsculoSkeletal Expansion (MUSE). He also obtained the Best Student Paper Award at the IEEE International Conference on Rehabilitation Robotics (ICORR) in 2015, held in Singapore.

Eleonora Vendrame is a PhD candidate in Biorobotics at Scuola Superiore Sant’Anna. She is currently working in the Artificial Hands Area of the Biorobotics Institute. Her research is focused on sensory-based rehabilitation techniques for individuals suffering from central or peripherical neuropathies. Relying on the physiological models of sensory feedback integration into motor control, her work endeavours to biomimetically restore tactile information in humans.
She received her master's degree in Biomedical Engineering from Politecnico di Milano (Milan, Italy) in 2020, with a thesis titled “A Multi-Channel Rule-Based Control System for Gait Assisted by Functional Electrical Stimulation”. She is co-author of 3 scientific papers in international peer reviewed journals and of 4 contributed papers for international conferences of Robotics and Biomedical Engineering. Her research interests include wearable technologies for assistance and rehabilitation, sensory feedback and perception.

ALL ARE WELCOME TO ATTEND.