Academic Corner
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In this issue, we are pleased to feature an interview with IEEE SMC member Dr. Marta Lorenzini. She is a Senior Technician at the Human-Robot Interfaces and Physical Interaction lab at Istituto Italiano di Tecnologia (IIT). She received her B.S., M.S., and Ph.D. in the Department of Electronics, Information, and Bioengineering from Politecnico di Milano, Milano, Italy, in 2014, 2016, and 2020, respectively. She was involved in the EU-FP7 STREP ICT CoDyCo, the Horizon-2020 project SOPHIA, the ERC project ErgoLean and the National Institute for Insurance against Accidents at Work (INAIL) Bando Ricerche in Collaborazione (BRiC) 2022 project LABORIUS. She is currently involved in the Fondo Italiano per la Scienza (FIS) 3 project EPIC, the INAIL VIVA project, the INAIL BRiC PROMETEO, and she is the principal investigator of the INAIL BRiC TEC4DPI. She is also active in a technology transfer initiative with several industrial partners, the JOiiNT lab at Kilometro Rosso Innovation District. She was the winner of the Solution Award 2019 (Premio Innovazione Robotica at MECSPE2019), the KUKA Innovation Award 2018, and the IEEE Italy Section 2021 Ph.D. Thesis Award by ABB - New Challenges for Energy and Industry. She is currently the chair of the IEEE Robotics and Automation Society (RAS) Young Reviewers Program and a co-chair of the IEEE RAS Technical Committee on Human-Robot Interaction. Her research interests include human physical and cognitive ergonomics estimation, human movement assessment, feedback interfaces, physical human-robot interaction, and assistive robotics for healthcare.

(1) Please tell us a bit about yourself and your academic/professional background. How did your path from biomedical engineering and human dynamics research lead you to human-robot interaction, ergonomics, and collaborative robotics?
I chose biomedical engineering because I have always been fascinated by the study of the human body, and particularly by human movement from an engineering perspective. For my Master's thesis, I worked on human dynamics estimation in a robotics laboratory, which gave me the opportunity to enter a field quite different from my previous background. That experience made me realize how much human biomechanics and robotics can inform each other, an aspect that fascinates me and has paved the road of my career so far. In human-robot interaction, understanding human behaviour and both physical and cognitive states is essential to make collaboration not only efficient, but also ergonomic, safe, and ultimately acceptable to the user.

(2) A major theme of your research is real-time estimation of human kinodynamic states. What information about the human body is most important for a robot to understand during collaboration, and what are the main challenges in estimating it reliably outside highly controlled laboratory conditions?
One of the biggest challenges is capturing the variability of human behaviour. We can identify common patterns and group people according to similar behaviours, but there will always be individuals who do not fit those generalizations. And given that our datasets are necessarily limited (and can still be biased despite our efforts to avoid it), building a model that represents the whole human population is simply unrealistic. This is why I have recently been focusing more on a combination of a general human model with subject-specific tuning, often driven by data collected from the individual. As for what a robot needs to understand, it really depends on the application. If a human and a robot are, for example, collaboratively carrying a heavy object, coordination is crucial: the robot needs to track and anticipate how the person is moving, infer their intentions, and estimate their physical load to eventually mitigate it. On the other hand, in repetitive and complex human-robot collaborative tasks involving lighter objects, physical load may be less important than understanding the person's mental

state. In that case, detecting increasing cognitive workload could tell the robot to slow down the pace or adapt the way the task is performed.

(3) Your work on ergonomic human-robot collaboration aims not only to assess human physical load but also to use that information to improve the interaction. How can robots move from passive ergonomic assessment toward truly adaptive assistance that responds to an individual user in real time?
It is precisely the ability to continuously estimate online a person's physical and cognitive load that enables the robot to actively respond to their state. The goal is to find a balance between productivity and efficiency on one side, and the person's well-being on the other. This is important because accumulated physical or mental overload can lead to fatigue, accidents, errors, and ultimately health and safety issues. In tasks where full autonomy is not feasible or desirable, human-robot collaboration can create a real synergy between the two. The robot can take over the more physically demanding or repetitive parts of a task, reducing the load on the human and the risk of musculoskeletal problems. At the same time, it can adapt its path, speed, or even its role in the task based on the person's state.

(4) Recent work from your research line explores physics-informed learning, markerless whole-body kinematics monitoring, gait anomaly detection and normative models, and anticipatory fall detection. How do you see data-driven AI and biomechanical knowledge complementing each other in future human-centred robotic systems?
This connects closely to what I mentioned before: every person is different, and analytical models based on predefined assumptions about human behaviour and characteristics cannot always capture that variability. Data-driven approaches are extremely powerful in this sense because learning from large datasets that capture human states and actions can help identify patterns and individual differences that would be otherwise difficult to model analytically. At the same time, I think purely data-driven approaches can be risky, especially when they are used in systems that physically interact with people. We need some form of grounding in physics and biomechanics to constrain the solutions and avoid unpredictable or uncontrollable outcomes. This is why the research line I work in focuses on hybrid approaches. We are exploring, for example, neural networks that can identify deviations from normative movement patterns using loss functions based on biomechanical principles, computer-vision-based systems for markerless whole-body motion monitoring while remaining consistent with human anthropometry, and collaborative and assistive robots that adapt their controllers in real time based on data collected from the interaction with the human and the environment. Data-driven AI can capture the complexity and diversity of human behaviour, while biomechanics can provide the constraints we need to make these systems reliable and trustworthy.

(5) You are involved in research and technology-transfer activities spanning projects such as EU ErgoLean, INAIL (National Institute for Insurance against Accidents at Work) VIVA, PROMETEO and TEC4DPI, and the JOiiNT innovation ecosystem. What are the biggest challenges in translating human-robot collaboration and ergonomic technologies from research prototypes into solutions that can be trusted and adopted in real workplaces?
I think that the interaction between researchers and end users needs to start much earlier. In the lab, we often start from the literature and build an idea of what, for example, workers, older adults, or patients might need. But when we actually engage with them, we sometimes realize that their real needs are different, or simply much more nuanced than we initially understood. This is why human-centred design is, in my opinion, fundamental. In our recent projects, we have been trying to define the requirements of a technology not only from a scientific and engineering perspective, but also by working closely with the people who will eventually use it. This can help avoid having to rethink fundamental aspects of a system when we reach the technology-transfer stage. Ultimately, the challenge is to find a solution that works for everyone involved. Different users have different needs,

working environments have their own constraints, and companies have to consider productivity and sustainability as well. So, once again, I think personalization is key: rather than looking for a one-size-fits-all solution, we need technologies that can adapt to different people and contexts.

(6) You have also been active in the IEEE Community, including the Young Reviewers Program, the Technical Committee on Human-Robot Interaction, and workshop activities. How has this community engagement influenced your career, and what advice would you give to early-career researchers?

I have been very fortunate to be involved in all these initiatives, and I genuinely believe they have been, and continue to be, fundamental experiences for my career. The main reason is that they give me the opportunity to interact with a remarkably diverse community: researchers and industry professionals, senior experts with decades of experience and people who have just started their careers, members of prestigious laboratories as well as smaller research groups, from all over the world. Being exposed to such different perspectives is incredibly valuable. You can discuss your ideas with people who may have completely different approaches from yours, learn from experiences you would never encounter within your own research environment, and get inspired by people working in fields you had never considered. I think this kind of cross-pollination is really at the core of research. So, especially for early-career researchers, I would encourage getting out of the lab whenever possible: to meet people, see different environments, talk to end users, and see how the problems we study actually look in the real world.