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PREFACE

Designing for People in Human-Robot Collaboration

This special issue contains contributions that investigate ways of Designing for People in Human-Robot Collaboration (HRC). HRC is a subset of Human-Robot Interaction (HRI) where people and robots work together in various configurations towards a shared goal. As robots become increasingly more intimate with people, working in close proximity or becoming social companions, the methods for investigating and developing them should follow, including explorations of human-centred [5] and design-led approaches [6] as well as the impact this may have on the ways people collaborate [3]. Design-led research and methods are taking up an increasing amount of space at robotics venues, e.g., with the introduction of a design track at the ACM/IEEE Conference for Human-Robot Interaction in 2015 [1]. This turn has previously been termed "designerly HRI" [4], and it encompasses a large variety of research methods and domains. This shift mirrors a broader shift of adopting relational or entangled perspectives in complement to technology as utility.

The transdisciplinary intersections of HRC between engineering, design, psychology, and many industries [2] offers opportunities to examine what designing for people means from various perspectives. The papers within this special issue illustrate that we can bring together concepts and methods from different disciplines together successfully in the endeavour to emphasise people in HRC. These findings presented in these papers show that design is inherently non-neutral, shaping either positive or negative outcomes for people. In addition, the socio-economic dimensions of HRC are particularly relevant, as the design and integration of collaborative robots in various sectors can affect stakeholder perceptions and acceptance [7], [8]. For example, architectural configurations of space for HRC in industries such as healthcare, education, or manufacturing can either enhance or inhibit accessibility, inclusivity, and safety. Through interdisciplinary collaboration, we can leverage the strengths of each discipline and shape the future of HRC.

The selected papers in this special issue offer both systematic reviews and empirical studies on designing, developing, and enhancing HRC. Traditionally, HRC has highlighted physical safety when interacting with collaborative robots, and while this remains a crucial element, this special issue broadens the scope of safety during HRC using a human-centred approach. Specifically, the works in this issue emphasise various types of robots, i.e., cobots and social robots, and their capabilities to improve creativity, mental safety, psychological and ethical risks, and human wellbeing. Key contributions include conceptual frameworks, design principles, as well as robotic prototypes. The research spans diverse domains including industrial settings, creative,

architectural, everyday public environments, and law enforcement, illustrating the breadth of HRC.

For this special issue, Laurianne Sitbon, Saminda Balasuriya and Alicia Mitchell have contributed the paper “Inclusively Designing for People in Human-Robot Collaboration” [9]. In the paper, they reflect on research in which they have involved adults with intellectual disabilities in the co-design of social and collaborative robots by using a human-rights approach. This means that the research intends to promote respect, inclusion, and autonomy. The authors present three studies in which participants’ strengths and wishes have been the core of the research through applying adapted co-design methods. Some examples of findings include (1) the authors’ emphasis that the involvement of support networks, e.g., caregivers, is essential for adoption and meaningful engagement with technology and (2) that to account for the perspectives of participants, research should go beyond relying on verbal contributions (often via proxy), but instead engage participants with working prototypes, thereby ensuring their perspectives are considered. The paper provides a useful guide for robotics researchers engaging with adults with intellectual disabilities. Furthermore, in a broader perspective, the paper may serve as inspiration for robotics researchers who want to support inclusion.

Human-robot collaboration must prioritize the human experience, not just physical safety and efficiency. In “To Safety and Beyond! A Scoping Review of Human Factors Enriching the Design of Human-Robot Collaboration”, the authors Jasper Vermeulen, Glenda Caldwell, Mu¨ge Belek Fialho Teixeira, Alan Burden, and Matthias Guertler present a scoping review on human factors that enhance Human-Robot Collaboration (HRC) [10]. Moving beyond the traditional focus on physical safety, the authors explore cognitive ergonomics, including worker well-being, stress, and workload. Their rigorous methodology identifies 66 relevant articles. They highlight that HRC benefits vary across environments due to differences in collaboration design. While HRC can improve physical conditions, it may also increase worker stress and mental fatigue. The authors recommend designing collaborative robots with bi-directional communication, anthropomorphic elements, and respect for human autonomy. Their proposed conceptual framework outlines key factors influencing HRC, such as physical, cognitive, external, and robot-related aspects and user acceptance, guiding future HRC design.

Designing human-robot collaboration systems means considering also the psychological and ethical dimensions of worker well-being. The paper titled “Design Principles for Safe Human Robot Collaboration” by the authors Laura Tomidei, Matthias Guertler, Nathalie Sick, Gavin Paul and Marc Carmichael explores the emerging framework of human-robot collaboration with a focus on integrating collaborative robots (cobots) into industrial settings [11]. While physical hazards in HRC have been widely addressed, the paper highlights the often-overlooked psychological and ethical risks to worker wellbeing. Through a systematic literature

review and expert interviews, the authors develop holistic, human-centred design principles that emphasise both physical and mental safety. These principles aim to mitigate not only physical risks but also address the cognitive and organisational factors affecting workers. The paper calls for expanding current safety guidelines to include a broader range of cobot applications and work environments, marking a shift towards more comprehensive and safe human-robot collaborative systems.

Integrating sculptural principles into social robot design reveals new pathways for enhancing expressive capabilities and fostering more empathetic human-robot interactions. In the paper "Rethinking Bodily Expression in Human-Robot Communication: Insights from Sculpture", the authors Belinda Dunstan and Guy Hoffman explore the potential of incorporating sculptural principles into the design of social robots to enhance their expressive capabilities beyond movement [12]. The paper outlines three key principles derived from the field of sculpture: (a) the exposure and protection of emotional pivot points, (b) weight distribution, and (c) the use of flexible skins to reveal movement mechanisms and tension. These principles are demonstrated through an interactive design environment and a robot prototype using a flexible fabric skin. The authors argue that such a transdisciplinary approach could improve the readability of robot intent and emotional expression, thereby ultimately fostering more intuitive and empathetic human-robot interactions even in static positions.

Designing for people in human-robot collaboration also means designing for designers. In "Design Considerations for AR-Enabled Human-Robot Collaboration in Fabrication-Centric Architectural Design Process: A Co-design Approach", Wei Win Loy, Anthony Franze, Jared Donovan, Müge Fialho Leandro Alves Teixeira, Matt Adcock and Markus Rittenbruch focus on ways that collaborative robots can support architects in fabrication processes [13]. While robots are typically valued for making processes safer and more precise, there are still open questions on how these technologies can complement human creativity and maintain the designer's role. The authors engaged five architectural professionals in co-design workshops and found that Augmented Reality (AR) can help overcome challenges when integrating robots into creative workflows. Specifically, AR can address the limitations of physical prototyping, which is often time-consuming and costly, while allowing designers to explore rapid variations and alternatives. The authors argue that AR can seamlessly integrate digital experimentation and physical prototyping, supporting both designerly approaches and the benefits of robotics in architectural design.

Human-robot collaboration can play an important role in trauma-sensitive contexts. In the paper "An Exploration of a Social Robot as a Digital Shield for Law Enforcement Interviews: Designing a Prototype," the authors Cryston Sahae, Shuyue Gu, Lige Yang, Elin A. Bjorling, and Nichelle Song address the challenges sexual assault (SA) victims face when reporting to law enforcement, including retraumatization and mistrust [14]. The authors propose using social robots to provide a non-judgmental support platform during the reporting process. Prior research suggests victims share more information

with autonomous systems than human interviewers. Using an iterative design process, the authors developed a dual-screen robot (IRA) paired with an emotional support robot (Pup). A small user study (N=5) showed promising results, indicating that such robots can offer empathetic support, potentially improving the reporting experience for vulnerable individuals.

Nonverbal communication is a cornerstone of effective human-robot interaction. In "Nonverbal Behavior of Service Robots in Social Interactions – A Survey on Recent Studies", Janika Leoste, Kristel Marmor, and Mati Heidmets investigate the nonverbal behaviour of service robots in human-robot interactions (HRI) [15]. It reviews 39 studies conducted between 2006 and 2023, highlighting how gestures, facial expressions, eye gaze, and body language shape the quality of communication with service robots. The paper emphasizes that nonverbal cues are critical for improving robots' social efficacy, trustworthiness, and adaptability across various settings, from healthcare to education. By cataloging the types of robots used, the nonverbal cues studied, and key empirical findings, the authors show the importance of enhancing robots' nonverbal communication skills to foster smoother, more intuitive interactions. This research points to the growing role of socially capable robots in everyday environments and the ongoing need to refine their nonverbal communication capabilities for more effective integration into human life.

As the above paper summaries illustrate, this special issue brings together a diverse array of papers investigating HRC foundations, centring on the importance of human-focused design principles across varied domains. The contributions span topics such as cognitive and physical ergonomics in collaborative environments, emphasising the need to balance physical safety with mental well-being. Industrial applications are explored through studies on cobot integration, highlighting holistic safety principles that address overlooked psychological and ethical considerations. The issue also examines innovative approaches like using sculptural insights to enhance robot expressiveness, improving the intuitiveness and empathy of social interactions. The papers include research on deploying social robots as supportive platforms in sensitive contexts, such as law enforcement, to assist vulnerable individuals non-judgmentally. Studies on the critical role of nonverbal communication for service robots demonstrate how enhancing gestures, facial cues, and body language can elevate social efficacy. In creative fields, AR in architectural processes showcases how HRC can facilitate more adaptable and efficient design workflows. Altogether, this special issue offers a comprehensive exploration of design-led and human-centred HRC, illustrating the potential for collaborative robotics to advance human safety, inclusivity, and creativity across healthcare, industry, and beyond.

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