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Contents

Human–Computer Integration

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ABSTRACT

Human-Computer Integration (HInt) is an emerging new paradigm in the human-computer interaction (HCI) field. Its goal is to integrate the human body and the computational machine. This monograph presents two key dimensions of Human-Computer Integration (bodily agency and bodily ownership) and proposes a set of challenges that we believe need to be resolved in order to bring the paradigm forward. Ultimately, our work aims to facilitate a more structured investigation into human body and computational machine integration.

Keywords: Human-computer integration; embodiment; augmented human; cyborg; fusion

1

Introduction

There is increasing interest in human-computer interaction via the human-computer integration, or "HInt", paradigm (Mueller *et al.*, 2020b). This paradigm is characterized by a move beyond the traditional source and sink relationship between human and computational machine and towards their fusion (Mueller *et al.*, 2020b). In this monograph, we consider this paradigm, focusing on a future in which the boundary between the human body and computational machine is blurred (Lopes *et al.*, 2015a), and we also identify the key challenges associated with this future. We specifically consider the challenge of discerning which of the user or the computational machine is in control of the fused body, and we note that this ability to fuse and share control might offer new opportunities, including unique user experiences, but it also brings new pitfalls and shortcomings (Mueller *et al.*, 2020b).

In this context, we believe it is important to articulate the challenges associated with these developments to help inform, improve and guide future design. In articulating these HInt challenges, we also contend that the HCI field has a responsibility to develop devices that are safe, ethical, and make positive social contributions.

Because HInt is not an isolated area of research, we can draw upon discussions from existing, related perspectives, including cybernetics (Ashby, 1961; Licklider, 1960), augmentation (Engelbart, 1962; Mann, 2001; Raisamo *et al.*, 2019; Rheingold, 2013), cyborgs (Clark, 2001) and wearables (Starner, 2001). However, while these prior works provide a grounding basis for HInt, and some of their associated challenges also apply to HInt, we focus on articulating the HInt challenges that are of particular relevance to HCI because we expect that the HCI field will engage with many HInt related developments in one form or another in the near future.

Prior work has investigated how integration happens at a societal level, whereby computational machines and people coordinate efforts towards a common goal (Mueller *et al.*, 2020b). In contrast with this societal emphasis (albeit, without dismissing it), we focus on integration that occurs primarily at the individual level, whereby computational machines provide "information directly to human senses rather than through symbolic representations and understanding the user's implicit, precognitive needs through bio-sensing" (Mueller *et al.*, 2020b). In this way, the concern of integration moves beyond the question "*How do we design technology that allows for better interactions with computers*?" to consider the question "*How do we design technology that integrates with the user's body*?" (Mueller *et al.*, 2020b).

This monograph makes three contributions: First, we apply two key dimensions from psychology – bodily agency and bodily ownership – to enhance our understanding of HInt systems (based on Mueller *et al.*, 2021). Second, we use these two dimensions to provide new perspectives on user integration experiences and to develop an integration systems design space. Third, we use the design space and its two dimensions to articulate HInt's key challenges (based on Mueller *et al.*, 2020b), and we group these challenges into four areas: design, society, identity, and technology.

In making these contributions, our aim is to help researchers and designers identify opportunities to contribute to the emerging HInt paradigm. Similarly, we hope that educators can profit from our work because our structured articulation of challenges can help teachers prepare materials for HInt classes, and HCI academics currently not

working in the field might find our work to be a useful introduction to recent HInt developments. Our work might also help academics who want to evaluate systems and wish to consider the HInt paradigm's wider implications. We hope that our articulation of HInt challenges also assists interaction designers to solve practical integration development problems and to avoid even bigger ones. Developers might use our work to guide them when identifying the capabilities required for engineering future systems, and developing training. We also hope that our work could help students understand the kinds of knowledge and capabilities required in an integration future, so that they can make better career choices. Lastly, we hope to support policy makers by providing them with a better understanding of the HInt paradigm and how it will influence the HCI field (and vice versa) and also with a set of key terms to use when discussing challenges across particular technology domains.

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