Enabling Digital Fabrication Approaches for the Design and Prototyping of Robotic Artifacts

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Abstract

Within the context of Human-Computer Interaction (HCI), Research through Design provides a reflective approach to generating new knowledge and insights through the creation of artefacts. This creation process supports stronger connections between design iterations and iterative problem solving as part of a methodology to enhancing interaction design within HCI. Robotics has become an increasing area of interest within the field of HCI as more work explores Human-Robot Interaction (HRI). However, the majority of current robotic studies employ off the shelve robots that are difficult to customise for bespoke applications and use cases. In the context of Human-Robot Interaction, I encourage the development of new digital fabrication approaches and workflows that can further support the creation of bespoke and customizable robotic artefacts. Specifically, I believe that by employing a cross-disciplinary approach that lies at the intersection between Human-Computer Interaction, Design, and Engineering we can further advance the insights for HRI. Essentially, I emphasis the potential opportunities for developing digital fabrication approaches, rather than one-off prototypes, for robotics which can supporting "learning through making".

CCS Concepts: • **Human-centered computing → HRI**.

Keywords: Design; Prototyping; Robotic Artifacts

1 Introduction

As a HCI researcher, I specialise in the design and development of emerging technologies such as shape-changing interfaces and wearables. My research adopts Research through Design to combine a mix of fabrication approaches for prototyping, together with co-design to encourages users and experts from different domains, to develop content and applications for the next generation of interactive systems (e.g. shape-changing displays) [3, 4]. Digital fabrication can enrich the design and development of new technologies through rapid and low-cost prototyping of artefacts [1]. In the context of robotics, RtD should take into consideration a multi-disciplinary approach that combines Computer Science, Design, and Engineering (see Figure 1).

Digital fabrication for iterative prototyping can also uncover insights for developing interaction techniques. Fabrication research [3] on designing meaningful user interaction can be extended for exploring new avenues in human-machine collaboration and how successfully these new robotic technologies can be adopted by users [2]. Iterative prototyping for Interaction Design also explores human factors such as; how one might preserve privacy, encourage trust in human-robot communication, and the implications of using a robot to stand in for the physical presence of a human. By allowing users to directly interact with and generate their own content/applications with such systems we can create more purposeful user experiences. Specifically, by engaging users and domain experts in the initial design processes.

In my work to date, I have employed Research through Design methodologies to develop digital fabrication approaches (see Figure 2) that support and direct the development of future actuated shape-changing interfaces [4]. For this workshop, I would like to contribute my insights and experience applying RtD with various users in co-design studies and sessions for developing shape-changing interfaces and data physicalizations [4–8].

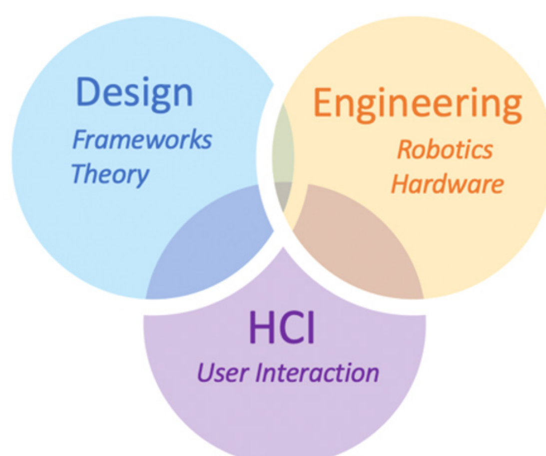

Figure 1. RtD for HRI should take into account a cross disciplinary approach that lies at the intersection between Human-Computer Interaction, Design, and Engineering.

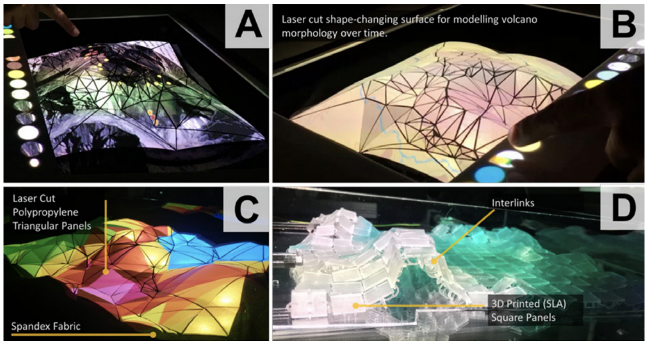

Figure 2. Semi-Solid laser cut surface [4] for modeling a shape-changing volcano morphology (A-B). Breakdown of laser cut semisolid surface structure (C). A 3D printed surface [5] used to show oceanography wave simulations (D-C).

2 Fabrication Approaches for RtD

Zimmerman et al. [10] propose the use of iterative problem solving as part of their model for enhancing interaction design within the HCI community. Essentially, their methodological model focuses on the iterative design and development of artefacts and prototypes to solve problems defined by the research community through anthropological insights gained during user-focused explorations. However, there are still a limited number of toolkits and fabrication approaches to enable iterative prototyping that facilitate the creation of customisable robotic artefacts for bespoke applications and use-cases. Based on my work on designing and developing shape-changing interfaces [3], I provide an overview of how the main themes of RtD can be applied in the context of human-robot interaction.

Process: It is important to establish fabrication processes and workflows for designing and developing robotic artefacts that are well documented and easily reproducible at low-cost. This should also include a clear rationale for the selection of the specific methods employed (e.g. laser cutting [4] or 3D printing [5]), actuation technquies (e.g. SMA [7]), and particular frameworks that are followed for design [8].

Invention: Each fabrication approach proposed should also come with additional details for the technical opportunities it can provide to the research community, providing them with guidance on what to build and how to build it effectively (e.g. provide application examples [9]).

Relevance: As well as ensuring that the fabrication workflow is documented in such a way that peers can reproduce the results (e.g. step by step instructions for reproducibility), researchers should also consider the preferred state the design attempts to achieve (e.g. the future vision of the actuated robotic artefacts) and provide support for why the community should consider this state to be the preferred. E.g. the preferred state could be moving away from mechanical actuator solutions to pneumatic actuation.

Extensibility: Extensibility is defined as the ability to build on the resulting outcomes of the design research: either employing the process in a future design process or understanding and leveraging the knowledge created by the resulting artefacts. Digital fabrication supports iterative prototypes and thus provides a progressive approach for developing prototypes and interaction design paradigms to go with those artefacts. Each iteration of the artefacts builds from the last through optimization.

3 Applying RtD Methodology for HRI

As mentioned above, this position paper proposes a cross-disciplinary methodology that should begin with design explorations and subsequently proposes a fabrication approach for helping address HRI research questions through making. Based on Zimmerman et al.'s [10] RtD methodology model, four key aspects can be adopted for HRI:

1. RtD encourages HCI to engage with "wicked" problems that cannot be easily addressed through traditional science and engineering methods. It is important to support creative design explorations for interaction in HRI to gain a better understanding of what kinds of problems and user challenges can emerge early on.
2. RtD ensures that technological opportunities are highlighted to both engineers and new insights are also uncovered from a design and anthropological perspective to motivate new research. RtD should aims to inform and engage both technical and design researchers through a cross-disciplinary approach (see Figure 1).
3. RtD for HRI should aim to support the creation of use-able systems rather than just prototype demos. Through the wider adoption of the fabrication approaches new research can provide novel opportunities for transferring knowledge from HRI research to other areas (e.g. digital health).
4. By utilising more generalized and accessible fabrication tools (e.g. 3D printers and laser cutters), new RtD projects can make it easier for HRI researchers and designers to create their own robotic artefact and prototypes. RtD also allows interaction designers to make research contributions that take advantage of the real skills designers possess by re-framing the problems through a process of making the right thing.

4 Discussion Points for Workshop

During this workshop I will be discussing the following:

1. Potential for employing digital fabrication approaches for designing and prototyping robotic artefacts.
2. The barriers to embracing RtD from an engineering perspective - e.g. lack of technical evaluations.
3. Differentiation of RtD in HCI and RtD in HRI.
4. Limitations and future directions for employing digital fabrication as part of a RtD methodology for HRI.

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