Designing For Human-Centered Automation: A Co-Design Study with Fabrication Professionals

Nur Yildirim
Carnegie Mellon University
Human-Computer Interaction
Institute, Pittsburgh, PA, USA
yildirim@cmu.edu

Workshop proceedings *Automation Experience across Domains*
In conjunction with CHI'20, April 26th, 2020, Honolulu, HI, USA
Website: http://everyday-automation.tech-experience.at

Introduction

Intelligent systems increasingly collaborate with people, automating a variety of work tasks and tasks of daily living. One constant challenge when designing for human-centered semi-automated systems is to negotiate the balance between human agency and machine autonomy. In this position paper, I share a co-design study that investigated the current and desired experiences of professionals in micro- and small-scale manufacturing settings.

Through this exploratory research, I aim to highlight (1) opportunities and pitfalls for semi-automated intelligent systems in the context of digital fabrication and (2) the role of design research in exploring the boundaries between machine autonomy and human agency. I identify and discuss the dimensions for designing human-centered automation that enhances professionals' felt experience of work without threatening their autonomy. By sharing these insights, I hope to start a discussion about the complexities of situating machine intelligence and automation within specific contexts.

Case Study

My ongoing research investigates how to enhance the user experience of fabrication systems through machine autonomy and intelligence. Digital fabrication tools (DFTs, e.g., 3D printers, laser cutters, CNC routers) have trans-

formed micro- and small-scale manufacturing and impacted the practices of professional craftspeople. These semi-automated tools give users superhuman abilities by making the fabrication process faster, more precise and more repeatable. However, with the arrival of DFTs, there has been some concern in the HCI community about a loss of agency, craft skill, creativity, and pleasure in making [2, 6].

The presented case study is an exploration of the current needs and future desires of fabrication professionals (e.g., custom manufacturers, fabrication specialists, shop stewards) with an eye for opportunities and pitfalls for automation. Professionals in small-scale production is an interesting group to explore the intersection of creative practice, control, and machine intelligence as they have a high-level of agency over their work (unlike other users in manufacturing, e.g., factory workers [5]). The goal of this work was to surface insights on how these tools might become more intelligent and capable to automate mundane work in ways that do not negatively impact the human experience.

"From a business standpoint, the less I have to do personally the more money I make. On my own personal projects, ***I'd still rather just push a button and have the part come out.****" (P19)*

Co-Design Workshops

To investigate possible futures for machine autonomy and its impact on user agency and control, I conducted a co-design study with 23 fabrication professionals. I asked, *"What if DFTs gained more intelligence to the point that they can be active collaborators in the fabrication process? How would DFTs with increased intelligence and automation impact users' felt experience of work?"* As a constructive activity, the co-design workshops enabled the participants to actively participate in envisioning the preferred futures instead of only focusing on breakdowns in current fabrication systems.

The co-design activities included *"tell"* and *"make"* [1], where participants told stories about their current experiences and brainstormed future interactions with DFTs. Throughout the sessions, I explored the boundaries between machine autonomy and user agency by using probes such as *"If your tool was intelligent enough to do anything, which part would you keep to yourself in the process of making?"* These discussions were essential in discovering which aspects of a task feel mundane and which aspects are critical to people's perception of agency. The workshop outcomes revealed several dimensions through which automation and machine intelligence can enhance professionals' felt experience of work without threatening their autonomy.

Desire for Increased Automation and Intelligence

Fabrication professionals expressed a desire for more automation and intelligence in the process of digital fabrication. Their concern for a loss of agency was unexpectedly less, given the literature and previous HCI studies. Almost all participants wanted fabrication systems to automate tasks such as machine setup, material registration, calibration, and maintenance. When asked to envision future DFTs, they described self-aware fabrication systems that can sense and act upon their performance and the workspace. They wanted intelligent DFTs that have awareness of users' high-level goals and that can self-adapt its plans based on results to achieve these goals.

Boundaries Between Autonomy and Agency

Professional users' concern for control and agency often centered on the inability to customize DFTs. They stressed that they *"should be able to tweak and take manual control over the settings"* if they didn't like the auto-generated ones. Some participants voiced concerns around paternalistic automation that impose limitations on users to provide *"ease of use"*. They described a spectrum of automation where a variety of tasks are automated for error prevention and efficiency, yet they can remain in control when needed.

"[System could say] 'Do you realize that at this level you're getting this quality, do you need that quality? You can have this or that.' (P11)

"[I should to be able to say] This is what I consider a good cut, because I use this laser totally different from everyone else." (P23)

Negotiation of Time-Quality-Cost Trade-offs
Professional users' desires, as well as their discussion around future intelligent DFTs, revealed a lack of support for making trade-offs between time, cost, and quality in current systems. Participants shared that they struggled while making these trade-off decisions, which are emergent in the situation. They wanted DFTs to have awareness over the quality of the outcomes (e.g., surface roughness, dimensional accuracy) and the controls to achieve those outcomes so that systems could help users to arrive at a set of trade-offs.

Intelligent Shop Assistant Rather Than Collaborator
Fabrication professionals desired DFTs that can leverage their machine capabilities to give users superhuman abilities. They wanted systems to log and recall settings, time, material used, and the outcome as an aid in documentation and self-reflection. They perceived future DFTs as intelligent shop assistants that actively learn how their users like to work, curate settings, and personalize their operations towards their users' tastes.

Prompts for Workshop Discussion

Through the above case study, I draw attention to the challenges and complexities of situating machine intelligence in contexts where creative practice and automation overlap. Previous HCI studies indicate that the level of desired automation may vary between different groups of users, even within the same domain or context [4, 3]. The insights from this case study can serve as a point of reference for other HCI researchers to identify and account for shared and conflicting desires of different user groups and stakeholders. The following reflections aim to start a discussion:

1. What are the dimensions of human-centered automation?
The findings of this fieldwork revealed productivity-oriented dimensions (e.g., error prevention, efficiency, self-maintenance, safety) as well as experience-oriented dimensions (e.g., personalization, decision support, skill development, resource curation) for automation technologies. What other dimensions might exist for human-centered automation? How might we, the HCI research community, build frameworks for automation that go beyond the paradigm of productivity? How might these frameworks generalize across domains and how might they situate into specific contexts and user groups?

2. How might intelligent semi-automated systems negotiate the quality of work?
Decision support for making time-quality-cost trade-offs was an emergent need that illustrated how we might design for an interplay of users and intelligent systems. How does an automated system gain knowledge about its own capabilities and the quality it is producing in order to negotiate such trade-offs? How do the abstract notion of quality and the subjective human judgment connect to the measured performance of a system?

3. How to develop a design process for blending human agency and machine autonomy?
Can we build on existing design research and interaction design methods to develop a design process for human-centered automation? How can we explore, design, prototype and evaluate automation experiences before investing in building these systems?

REFERENCES

[1] Eva Brandt, Thomas Binder, and Elizabeth B-N Sanders. 2012. Tools and techniques: ways to engage telling, making and enacting. In *Routledge*

international handbook of participatory design. Routledge, 165–201.

[2] Amy Cheatle and Steven J. Jackson. 2015. Digital Entanglements: Craft, Computation and Collaboration in Fine Art Furniture Production. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15)*. ACM, New York, NY, USA, 958–968. DOI: http://dx.doi.org/10.1145/2675133.2675291

[3] Peter Fröhlich, Matthias Baldauf, Thomas Meneweger, Ingrid Erickson, Manfred Tscheligi, Thomas Gable, Boris de Ruyter, and Fabio Paternò. 2019. Everyday Automation Experience: Non-Expert Users Encountering Ubiquitous Automated Systems. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, Article Paper W25, 8 pages. DOI: http://dx.doi.org/10.1145/3290607.3299013

[4] Verena Fuchsberger, Martin Murer, Manfred Tscheligi, Silvia Lindtner, Shaowen Bardzell, Jeffrey Bardzell, Andreas Reiter, and Pernille Bjorn. 2016. Fabrication & HCI: Hobbyist Making, Industrial Production, and Beyond. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*. ACM, New York, NY, USA, 3550–3557. DOI: http://dx.doi.org/10.1145/2851581.2856491

[5] Daniela Wurhofer, Thomas Meneweger, Verena Fuchsberger, and Manfred Tscheligi. 2018. Reflections on Operators' and Maintenance Engineers' Experiences of Smart Factories. In *Proceedings of the 2018 ACM Conference on Supporting Groupwork (GROUP '18)*. ACM, New York, NY, USA, 284–296. DOI:http://dx.doi.org/10.1145/3148330.3148349

[6] Amit Zoran, Roy Shilkrot, Suranga Nanyakkara, and Joseph Paradiso. 2014. The Hybrid Artisans: A Case Study in Smart Tools. *ACM Trans. Comput.-Hum. Interact.* 21, 3, Article 15 (June 2014), 29 pages. DOI: http://dx.doi.org/10.1145/2617570