Revolutionizing Assistive Device Creation via Advanced Distributed Fabrication: An Interdisciplinary Project

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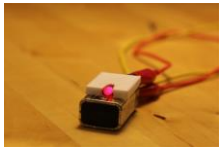
Abstract
In this workshop paper we briefly describe an ambitious new project seeking to create significant advances in the tools and processes surrounding new fabrication technologies. Our goal is to enable their use by distributed groups of ordinary people to do significant things. As a testbed for this project we will use the creation and delivery of assistive technology as a concrete application domain. Within this domain we seek to make a sea-change in the way many assistive devices are customized, made, delivered and updated in order to make them more effective and widely available. To achieve the goals of this project we believe significant advances will be needed in at least three broad areas: tools for describing and modifying the design of physical objects, strategies for coordination of work by groups with a wide range of skills, and domain specific understanding of how assistive devices are used (and what factors may lead to their abandonment).

Author Keywords
Fabrication; Assistive Technology; Tools; Group Work

Introduction
Advances such as graphical interfaces, desktop publishing and spreadsheets allowed computation to enhance the way many people work. The ongoing

Figure 1: Relevant Past Work on Tools and Technologies

a. New Fabrication Technologies [8,4,7]



b. Printing on and With Real World Objects [1]

c. Abstraction of Parameterizable Objects From Examples [9,10]

revolution in additive manufacturing could offer similar widespread impact – changing the way in which many things are made and who can make them, by moving from mass manufacturing to manufacture by the masses. The recent precipitous drop in the price of entry level hardware has brought 3D printing within many people's reach. However, advances in hardware have not been accompanied by the advances in the tools and processes necessary to let ordinary people make real use of 3D printing. People cannot 3D print in the same way that many people can use e.g., use a spreadsheet to make a custom application.

The project described here seeks to change that. It will consider both the tools used to design and built things and the processes need to bring together effective distributed teams across a wide range of expertise. It will do this using a concrete grounding in a challenging real world domain which is particularly well matched to the properties of new manufacturing technologies – assistive devices. One in four working Americans will face disability for some part of their working life. 71% of people in the US 80 and older are disabled. In today's society, the impairments underlying these disabilities have the power to take people out of the workforce, and diminish their quality of life. What people need is often simple – a better way to hold a knitting needle, roll out dough, or open a jar. Yet finding individually customized solutions to each of these problems is almost impossible – creating a device customized to each person hasn't (previously) been feasible at any large scale.

But that's not the way it needs to be. 3D printing offers the promise of easily and inexpensively making customized assistive devices. We just need to the tools and processes to let ordinary people do it. Making assistive technology should be as easy as ordering takeout or visiting a Wikipedia page (for the person who needs the technology), or (for a volunteer maker) perhaps using a spreadsheet.

Project

We propose a set of innovations needed to make this promise a reality: computationally enhanced tools to make physical device construction accessible for ordinary users and new concepts for expertise amplification through what we will call *virtual service teams*, which combine a range of human and automated capabilities. Our work aims to substantially change the trajectory of advanced manufacturing to include everyday people with everyday skills. Both of these also have the potential for substantial impact outside of our specific domain, and we fully expect those secondary benefits to be part of the success of this effort. Just as spreadsheets were designed for business accounting but are currently *the* most widely used personal programming platform, our 3D modeling advances aim to bring physical computing to the masses. Our work on problems such as expertise amplification within communities and service models for assistive technology delivery will have similarly broad applicability.

Figure 2: Past and Future Work With On-Line Communities

a. Studies of Social Transparency in Open Source Communities [2]

b. Techniques for Recruiting, Retaining, Motivating and Organizing the Work of On-line Communities [5,6]

c. Training Teachers and Veterans

However we also need to understand our domain well. As with many endeavors, what we will provide needs to fit into and modify an existing service economy. Think of the impact that takeout (an activity which requires coordination of many different skills) had on the restaurant industry. Our project aims to accelerate *custom* assistive device construction, which is currently limited and expensive. In the current process a clinician makes an assessment and prescribes a solution, with all the implied overhead of access to healthcare, cost, travel, and time lags. Instead we will amplify the impact of a few assistive technology experts with the fabrication skills of others through the use of new on-line distributed collaboration tools based on current work in crowd sourcing. This will fundamentally shift the way assistive technology is produced to make it both scalable and inexpensive. This is the only way we can effectively reach the full set of people who can benefit from it.

To tackle these challenges we have assembled an initial interdisciplinary team including researchers in HCI, advanced manufacturing and modeling, online communities and crowdsourcing and assistive technology. We have partnered with the rapidly expanding e-NABLE community, an online group of volunteers making custom prosthetic hands [3], which will be a real-world test bed in which we can deploy our experimental platform. Relevant past work by a few members of our initial team are highlighted in Figures 1 and 2.

Our proposed research activities are illustrated broadly in Figure 3. They include:

1) Development of a new class of design tools which

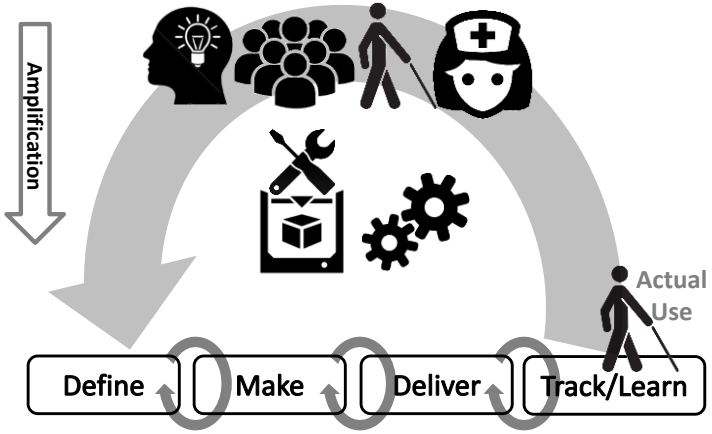


Figure 3: Overview of the proposed work, which is divided into three complementary activities (top to bottom): New processes for distributed work (virtual service teams), tools and automation, and assistive technology advances, all of which will be tested with our real world testbed of volunteer workers delivering assistive technology, the e-*NABLE community*.

work from end-user accessible forms of input such as photographs, 3D captures (e.g., reconstructed from a series of photographs or a video), sketches, and simple measurements. These tools will use mixed initiative techniques for human guidance of algorithms which relate user design inputs to a large corpus of examples and part libraries in order to create models both with parameterized, consistent and correct geometric properties, but also relationships between that geometry and the underlying semantics of the object being modelled.

2) Creation of a new kinds of support for distributed, multi-faceted teamwork for service design through the creation of Virtual Service Teams. Our work will automate the organization of hybridized teams through dynamically generated schemas which support shared context across interactions and workers. This will advance the science behind evidence-based design of online production communities.

3) Advancement of the model of service delivery for assistive devices. The inclusion of advanced manufacturing and advanced new tools will change the very meaning of this assistance from a static, one-time production by experts to a dynamic, ongoing, client-driven iterative process. We will motivate & support broader inclusion of professional skills and knowledge in Virtual Service Teams. We will introduce mechanisms for ongoing iteration and follow up which produce a more detailed understanding of assistive technology use abandonment in comparison to more traditional assistive technology provision models.

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