Personal Fabrication with Active Materials applied to Soft Robotics Strategies in Human-Computer Interaction Design

Ollie Hanton
University of Bristol
Bristol, UK
oliver@dulwich.co.uk

ABSTRACT

The personal fabrication of displays via additive manufacturing within HCI holds the potential for interactive devices that cam be seamlessly integrated into our surroundings. In our work we have built on this potential to create diverse form-factors for displays [3], investigate optimal active materials to bring into the sphere of personal fabrication [2] and look at fabrication methods for layering displays [4]. Through creation of new ways for non-specialists to fabricate displays we envision the progression in combining additive manufacturing of active materials with programmable matter and integrating interactive displays into a wider range of interactive systems. We propose that developments in expanding interaction with computers have the potential to both: 1) enrich work on creating interactive soft robotic structures through fabrication methods, material investigation and designing for interaction; and 2) broaden the scope of display properties and material depth in personally fabricated displays.

KEYWORDS

Fabrication; display fabrication; soft-robotics; actuated materials; Interaction design

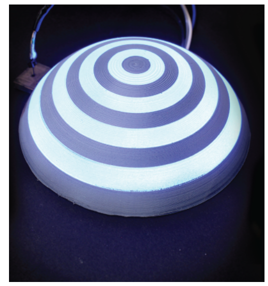

Figure 1: A 4-segment display produced using the ProtoSpray method, designed in CAD with active layers sprayed on.

1 INTRODUCTION

Interactive display types are available as flat typically regularly shaped components. These rigid form-factors limit the potential of our interactions. It is expensive to manufacture small quantities of physical interactive displays and often limiting to simulated integrated interactive surfaces through alternative measures (e.g. VR, AR, projected displays). Personal fabrication of displays presents a solution to this problem with the ability for non-specialists to fabricate interactive objects using methods and tools both from additive manufacturing (3D printing) and more craft-based practises (e.g. airbrushes [4]. hydroprinting [1]). However there are a range of limitations in the form-factors, resolution, device properties, fabrication methods and integration into systems that stem from the fabrication approach.

In our work we have introduced new ways to fabricate interactive displays alongside new form-factors and material investigations to expand the potential of this area. In "ProtoSpray" we develop a process that allows digital design of the shape of an object that contains interactive display elements using non-specialist additive manufacturing methods. This has both expanded the form-factors that can be achieved through personal display fabrication but also the levels of specialism needed for realising complex designs. In "FabricatINK" we explore and enable the use of E ink within personal display fabrication both investigating the material and developing ways to create bespoke irregularly shaped interactive display pieces outside of enclosed pixellated regularly shaped devices. Lastly our work in "Sprayable User Interfaces", we look at creating shapes programmatically and the potential user interactions with these.

These works contribute towards expanding form-factor, ease of implementation of fabrication process and breadth of interaction experiences. However many of the processes and demonstrations within these works need significant progress to build on them with key directions in potential deformability, further form-factors, exploration of interaction scenarios and interaction design combinations. We see integration with practises from soft robotics as feeding into these expansions. In return personal display fabrication has the potential to provide fabrication processes, active materials information and exploration and integrated interactive systems design to the area of actuated materials and soft robotics.

2 PROTOSPRAY

ProtoSpray is a fabrication method that combines 3D printing and spray coating to create touch-sensitive displays of arbitrary shape. Our approach makes novel use of 3D printed conductive channels to create base electrodes and shape displays. A channelled 3D printed object is then combined with spraying active, electroluminescent, materials to produce illumination. This demonstration involves multiple different devices, created through the ProtoSpray process, showing its free-form applicability to irregular shapes such as a mobius strip and spherical surfaces. Our work provides a platform to empower makers with displays as a fabrication material.

The ProtoSpray process involves 3D printing an object made of two materials (conductive and insulating) and then layering the components of an EL display using spray coating onto the object. The conductive material is printed in channels through the insulating material that then define the shape of the display cells when the active materials are coated on the object's surface. In doing this, the methods developed in ProtoSpray build on the

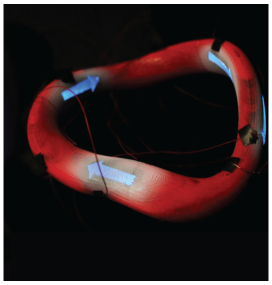

Figure 2: An irregularly shaped set of displays consisting of 7 segments as arrows on a 3D printed mobius strip created using ProtoSpray. Each arrow lights up in turn indicating a path along the strips only side.

more widely implemented use of 3D printing conductive plastic for custom shaped capacitive touch sensors by integrating input and output of interactive object design into a single fabrication process.

ProtoSpray eliminates masking by 3D printing base electrodes (channels) of conductive PLA, housed within the substrate object and printed simultaneously in a desired shape. By doing so we benefit from the printer resolution to reach similar or better precision than existing masking techniques, without requiring additional masking or sanding of the 3D printed shape. Masking by hand is a time intensive and skill dependent process. Manual masking is not straightforwards or easily replicable for objects which are strongly curved. It is also limited in scope with regards to being automated as a process and suffers from issues with scalability.

We demonstrate this process through a range of evaluative tests and interactive objects (shown in Figures 1 and 2).

3 FABRICATINK

We submit this workshop application paper alongside the publication at CHI2022 of our full proceedings paper "FabricatINK: Personal Fabrication of Bespoke Displays Using Electronic Ink from Upcycled E Readers".

FabricatINK presents an exploration of E ink for the purpose of integrating this impactful material into the personal fabrication of irregularly shaped displays. This paper analyses related work and technical patents in order to compare E ink to other materials used in display fabrication such as electrochromic and electroluminescent. We then performed a number of experiments to categorise E ink's suitability for deposition, deformation and use in an unenclosed manner.

In this paper we obtained E ink through hacking and upcycling damaged E readers to gain access to an otherwise unavailable material. Through this we discuss both the democratisation of materials and information and the potential empowerment of makers through materials for the creation of interactive objects.

4 SPRAYABLE USER INTERFACES

Sprayable User Interfaces explores the use of spraying as a fabrication technique for making large-scale interactive surfaces. These interactive surfaces contain input elements, such as touch sensors, sliders, and proximity sensors, as well as output elements, such as electroluminescent displays.

5 ALIGNMENT BETWEEN PROGRAMMABLE MATERIALS AND SOFT ROBOTICS AND PERSONAL DISPLAY FABRICATION

To build on the contributions we see between personal fabrication of active materials and programmable materials and soft robotics, we briefly expand our vision of crossover between these areas.

Fabrication methodology: Personal fabrication specifically involving active materials is an expanding area that still relies on a range of different fabrication processes to enable users to create interactive devices such as 3D printing, spraying, hydroprinting, screenprinting, painting and inkjet printing. Although this range of methods can be a hinderance, many different methods offer different benefits to both fabrication of active materials and others. This both requires further work to develop these methods to become usable, replicable and with desired outputs but the range of processes can also provide options to programmable materials and other potential required form factors.

Material investigation: The cross over in material information both through related work and patent information as well as investigations and evaluations appears to be a key to be addressed within both fields and where the potential for exchange of expertise and information would be strong. Similarly the integration of active materials into substrates, surfaces and textures that appears within personal fabrication could hold the potential for immersive interaction within soft robotics.

Designing for interaction: The interaction with soft robotics and personal display fabrication shape are shaped by interaction design. This area has significant scope for development within personal display fabrication and with work closer to deformable or programmable shape types [5], has increasing overlap with soft robotics.

Integration with commercial processes: As extensions to our work on personal display fabrication we are currently looking at integrating EL material into existing manufacturing production lines and the challenges that arise with that. Both integration of processes into industry but also work on development with industrial partners appears to challenge they way that HCI is traditionally researched and we are keen to explore this concept further.

6 INTEGRATING PERSONAL FABRICATION OF DISPLAYS INTO SOFT ROBOTICS PRACTISES

Beyond these four crossovers of interest we highlight themes for what our work on display fabrication can specifically bring to soft robotics design. Our key works of FabricatINK and ProtoSpray center around expanding the material properties and by extension the form factors and display properties of fabricated displays. However, these interactive displays are static and at best bendable. We see a key next step for future research between this work and soft robotics to involve either fully or partially seamlessly integrated displays into actuated systems drawing on the additive manufacturing tennets of the display fabrication work for material simplicity to increase potential form-factor and integration. We suggest a range of research directions to bring these two areas together centering on fabrication:

- Material investigations within display fabrication for a greater range of deformable and flexible sensing and output custom to actuated material usage (for instance building on our dual use of 3D printed conductive PLA for electroluminescent addressing as well as touch sensing).
- Development of fabrication techniques that can be easily integrated into other fabrication set ups (for instance an emphasis on spraying active materials due to it's additive nature and not getting substrates in contact with other materials that a process like hydrodipping might)
- Exploration of design for integrating soft-robotics and malleable sensing and output fabrication. We see potential to extend the design space of both areas by tapping into both the actuated form factors and irregularly shaped I/O of the two areas together and developing combined fabrication techniques to benefit HCI researchers.
- Addressing of questions that both sub-fields are trying to answer in tandem, such as how to improve fabrication methods and make them more accessible, cheaper, faster and with higher fidelity.

7 BIOGRAPHY

Ollie: is a PhD student working on display fabrication, focusing on creating displays using spraying. He is working on personal fabrication of displays from an additive manufacturing approach.

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