Ubiquitous Fabrication: can we all be makers?

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Abstract
Personal Fabrication has been big in research in the past decade and now starts to enter the actual homes of users. The technology and devices used for this purpose, however, seem to be highly connected to the early adopters (makers). This has been great in the past, but may not suffice in the future. Looking at a similar trend in the past, the introduction of computing technology, we have seen a wild growth in devices of different forms and shapes serving different purposes. We propose a similar trend for personal fabrication and sketch a future in which various devices, interaction techniques and fabrication purposes co-exist.

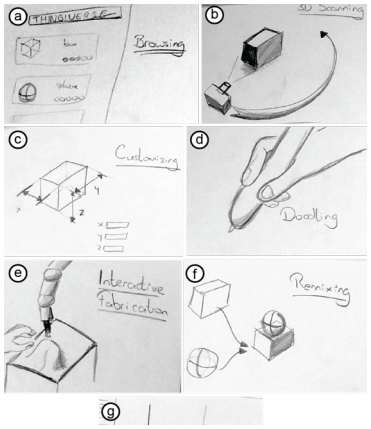
Author Keywords
Ubiquitous fabrication, future scenarios, personal fabrication

Author biography
Thijs Roumen is a second year PhD student at the Hasso Plattner Institute in Potsdam, Germany. His research is focused on 3D printing by makers and non-expert users. Last UIST he presented a paper called "Mobile Fabrication" [] in this scope, and is currently working on projects to make it easier for non-engineers to fabricate more interesting objects than the currently common decorative models.

Thijs holds a BSc in Industrial Design from Eindhoven University of Technology (TU/e) and a MSc in IT Product Design from the university of Southern Denmark (SDU). After that he has been research assistant at the National University of Singapore (NUS) before starting this PhD.

Introduction

Digital Fabrication is moving from just industry towards entering the consumer market in the form of Personal Fabrication. The key (non-expert) adopters of this technology currently are so called "makers", these users love the technology and typically are as fascinated by the process of fabricating as by the objects they fabricate with them. A consequence of that is that current 3D printers and other personal fabrication devices typically connect strongly to those users in their look and feel. Recent research put strong emphasis on making it easier for users to model [3,5], allowing them to make more advanced 3D prints with less domain knowledge [8] and solving other barriers to current day 3D printing like speed [4] and expressive exploration of form [2]. What is considered less so is in what way these machines will become part of the life of users e.g. what the machines will be like in a real "ubifab" scenario and how they will be controlled.



In Personal Computing the step towards ubiquitous computing has pretty much happened. We see a wild variety of computing devices around us that are interconnected and together form access points to the Internet and our personal data. These devices come in different shape and with different functionality depending on the type of context they are used for and how users can/will interact with them. An overview of this will be provided later in this submission. The key insight is that the way the user interacts with the devices determines their size/form and consequentially their context of use.

We believe the same will hold true for future fabrication devices. While we currently live with fabrication devices that compare to what MS-DOS computers were when computing took off, we think this is about to change. The hardware is getting smaller, faster and the type of users is slowly shifting towards more casual users. At this point in time users still mostly fabricate geeky stuff or cute customized objects, in the future this may look quite different. This is a good moment in time to understand that future and attempt to better understand how this is going to evolve.

In this submission, we take an outlook into such a future by using the analogy with ubiquitous computing

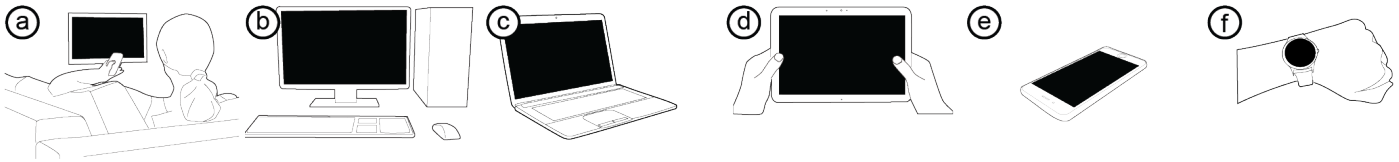


Figure 2: ubicomp devices ordered by display size

the form of Ubicomp hardware is based on interaction techniques

We have reached a state in which computing devices are no longer limited in their performance even if we make the devices the size of a mobile phone. These devices have access to terabytes of data through cloud storage and Internet and can process at speeds which suffice for most of our information processing purposes. We could thus essentially have one device that does all our information retrieval and processing tasks for us. However, we have a bigger variety of devices around us than ever before. The key difference between these devices is in how we use them, e.g. it seems to be that the user interaction is what determines form factor and context of use. (Figure 2)

What would this mean for fabrication?

Fab devices may ultimately be a product of their user interaction in similar ways. The output stays the same while the user input varies and determines the device's form factor. Figure 1 shows an overview of proposed interaction techniques. Here an overview from easiest (and thus accessible for most users) to the hardest to perform interaction

Browsing style interaction can be performed by anyone, you go through a series of models, pick the one you want and fabricate it directly. A typical UI for this would exist in Augmented Reality [1] in which one sees the result in context directly

Scan+print is a task to repair or replace objects in the house. You have an object which is broken, the scan compares it to the original model of the object and it would generate a solution to patch the broken object. This is in line with ideas in "patching physical objects" [6]

Customizing is the typical form of interacting with 3D models, mainly supported by the increased amount of parametric models. The user has a series of parameters. This can be set with simple slider type input.

Doodling is a type of interaction that requires a bit of skill and more so, it requires good instructions and guiding mechanisms for the user. Doodling is particularly useful in mobile contexts, since the user effectively *is* the machine here [2]. In a mobile context, it is key that the user can fabricate directly *on* the environment. We explored this notion in the project Mobile Fabrication [7]. Alternatively doodling could also be used as a more explorative form of fabrication by design and fashion experts.

Interactive Fabrication is a style of interaction which has the advantages of expressiveness and allows the user to create new contents relatively freely. It can be compared to the way many people use sketching, users have direct control over the object which is to be modelled but don't specify every small detail.

The highest level of complexity in creating 3D models by normal users in the future, we expect to be *remixing*. With access to large repositories of models, users can remix and fabricate objects as complex as machines. This building on the shoulders of giants will help users generate large amounts of interesting models based on their specific needs. When it comes to shape there is a corpus of research out there which deals with remixing interactions, building machines based on existing machines would be a step that could enable a large group of users to solve bigger mechanical problems together.

Modelling from scratch is the most elaborate form of 3D file creation possible. This will continue to happen, but gradually shift more towards super experts. Most objects can be made by remixing or customizing existing models, but in some cases one would model from scratch. This type of interaction takes a large amount of expertise either owned by professional engineers or advanced makers.

Future work

The goal is to understand the complete space for ubifab, this will require a deeper understanding of some of the proposed interaction styles and their consequences for a ubifab future. More work will be done to understand the user scenarios/contexts better and evaluate the assumptions on which these scenarios have been built. Finally, this raises questions about the ecological footprint of digital fabrication, follow up explorations need to be done into recycling and material choices.

Conclusion

We explore the idea of ubifab. The key idea is that there is a parallel between the way ubiquitous computing was introduced in the past. We believe this may hold partially true for fabrication as well and use it as an inspiration to explore what possible future scenarios co-exist. We think there are going to be devices for different purposes and with different interaction styles in use by future consumers of digital fabrication and each will have their own right of existence.

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