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THE PROTOTYPE IS THE PRODUCT: EXPLORING PERSONAL FABRICATION THROUGH A PRODUCT DESIGN PROJECT

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ABSTRACT
As the technology of rapid prototyping becomes less expensive and more compact, it's not hard to imagine a future where there is a desktop manufacturing machine in each home. This vision of a personal product printer has been proposed by Prof. Neil Gershenfeld of MIT as "personal fabrication." If consumers can "print out" products, then what are the implications for product design? How will that change the way product designers approach design? How does it change the possibilities for what a product can be? These are the questions that this project investigates through exploration, invention, and discovery, with the creative insights and experimental projects of design students.

Keywords: personal fabrication, desktop manufacturing, creativity, prototyping, design

1 INTRODUCTION
This paper describes a design project given to third year industrial design students. The focus is on additive rapid prototyping technologies as a method of manufacturing products. The students learned about various prototyping processes and their advantages and disadvantages. They imagined the future of personal fabrication and then conceptualized on product applications best utilizing that process.

2 LEARNING GOALS
2.1 To imagine a future scenario where there is a desktop manufacturing machine in each home
It's evident that desktop-manufacturing machines will be in the price range of many home consumers in just a few years. Rapid prototyping machines had cost over $100,000 US each, and now the latest generation is available under $10,000 US and within five years will be under $2000 US [2]. The vision of a personal product printer was promoted by Prof. Neil Gershenfeld of MIT as "personal fabrication." Students are challenged to extrapolate into the future and think of the implications of this scenario. How does it change the way products are designed, manufactured and delivered to consumers?

2.2 To learn about rapid prototyping technologies
Students investigate and experience various rapid prototyping technologies as they will be required to create and use rapid prototypes as professional designers. The current

professional product development process uses rapid prototypes extensively as a way to test and simulate products.

2.3 To practice and increase fluency in three-dimensional computer modeling

In order to create the design that they imagine, students must model the design in 3D computer modeling software such as Alias, Rhinoceros, or Solidworks. They would be required to practice and improve their computer modeling techniques and make valid solid models ready for production. This is a real-world skill that is required in the design profession. Students also learn from the process of manufacturing their computer model, connecting their imagined virtual design with the reality of a solid object.

3 MOTIVATED LEARNING ENVIRONMENT

Two dominant conditions of this project provided motivation for the student to learn the intended goals. One is the unique personalization of the product to be designed. Each student had a strong connection to the product that they were designing because it was personally valuable to them, and they knew that it would be made manifest into a material object. Secondly, the design project involved an interesting new concept that hasn't been explored thoroughly, so there is little prior art and even less pre-conceived notions about what is possible.

4 THE PROJECT RESEARCH PHASE

Students were asked a series of open-ended questions that required them to imagine the future of personal desktop manufacturing.

4.1 List of questions:

- What are the advantages and disadvantages to using rapid prototyping as a manufacturing process?
- What if each design could fit a person individually?
- If a product design can be extremely complex with no additional cost, what applications can you imagine?
- What if product design could be re-mixed, like music files are today?
- What does "direct from designer to user" mean to you?
- What are the implications of user designed products?

4.2 The response

The following are a few insights from this discussion into the exciting potential of personal desktop manufacturing:

4.2.1 The Advantages:

4.2.1.1 On demand Manufacturing

The common method of product development is to mass manufacture a product in great quantities and then attempt to sell each one. Now one can design a product, then promote and sell it, then manufacture as orders come in. Since there are no tooling-costs to absorb and each product can be quickly made one at a time, one only then needs to make just enough to satisfy demand. This means less waste, less overstock, and less overproduction.

4.2.1.2 Mass Customization

Each design could be made unique for each individual. A design could be modified through variables given by the customer; much like a tailor makes clothes to fit the body shape. Personal fabrication would allow for the variation of shape and proportion of every element of a product. One could justify the higher cost because of its inimitable quality and personalization.

4.2.1.3 Extreme complexity

Additive prototyping techniques allow for geometry that is not possible with injection molding or other mass production methods. Undercuts, internal features, varying wall thickness, zero draft, and other complex geometries are not a problem for rapid prototyping machines [4].

4.2.1.4 Serving the ignored markets

Many market segments are ignored, they are usually too small and don't have enough profit potential to get the attention of corporations. Whether they are people with disabilities, micro-niche groups or in those in developing countries, their needs are exceptional and specific to their culture and situation. Designers could work with them to design and fabricate products that serve these ignored micro-groups [1].

4.2.2 The Disadvantages

4.2.2.1 Cost

Part cost for personal fabrication is much higher than a mass-produced part, so the value of the product must be justified. This is not a process for everyday commodity objects. However, the lack of tooling costs, assembly, inventory management, packaging and shipping costs will offset this high part cost to some degree. Also, part cost will decrease with time as the technology advances.

4.2.2.2 Material limitations

The materials available for rapid prototyping are severely limited in diversity, surface quality and structural properties. For example SLA parts are brittle and tend to warp over time and FDM parts are limited to ABS or poly carbonate thermoplastics of a single colour. The surface texture of these parts is rough compared to injection-moulded parts, which limits its application potential [4].

4.2.2.3 Abuse

People could use desktop manufacturing to make weapons or other harmful products. As with any tool, it could be used for malevolent purposes. This capability, combined with the ease of Internet file transfer could mean the simple creation and proliferation of destructive devices.

4.2.2.4 Intellectual property protection

A product design could be easily copied just as any data file can be copied today. This will require that the 3D data files are copy-protected, or only allowed to be fabricated a limited number of times. It may devalue the work of the designer, and create a black-market of pirated designed objects. Coordination with software developers and programmers will be necessary.

4.2.3 *The Potential*

4.2.3.1 Re-mixed product Design

Just as musicians can upload tracks of their music files for the public to download and re-mix, the same could happen for product design. For example, a user could purchase a software program from Motorola and create one's own mobile phone design. They could choose shape, configuration, button layout, size, graphics and color and then print out their unique creation.

4.2.3.2 Open-source product Design

Much like open-source software, personal fabrication would make open-source product design possible. A design could be available for download as a parametric solid model file. This file could then be modified and revised by product designers as they desire, adjusting functionality, changing shapes, or structure. Then, these revisions could be shared with all for the evolution of the design.

4.2.3.3 Directly from Designer to the User

Potentially this process allows the industrial designer to directly serve the end-user. An entrepreneurial designer could design a product, promote it directly to a micro niche market, and manufacture it as orders come in. The designer could even offer multiple designs for sale, without additional tooling investment costs.

4.2.3.4 User Designed: Who Needs product Designers?

Users could define their own need, design it, create it through computer modelling and then fabricate it themselves. This is user-defined, user-designed, and user-fabricated design [2].

5 SAMPLE PROJECTS

After this research and exploration, the students were asked to conceptualize applications that best utilize this technology. The following sample projects show the diversity of ideas that came from the students.

5.1 Tyler Swain's Pendant Lamp

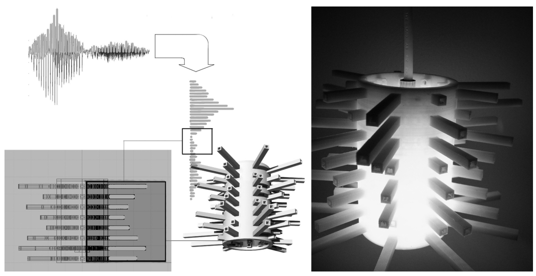

Figure 2. Transforming a sound wave pattern into a lamp form.

Tyler's concept begins with sound, either a voice or music sound wave as given by the customer. It could be a spoken word, a message or a preferred musical sound. That sound wave is digitised into a pattern, which is then reinterpreted to the varying lengths of the rods protruding from the lamp. The rods lengths are adjusted with CAD modelling software and then exported as an STL file. This file is then sliced and produced using an additive rapid prototyping process, in this case FDM.

5.2 CJ Fredrickson's Audio Speakers

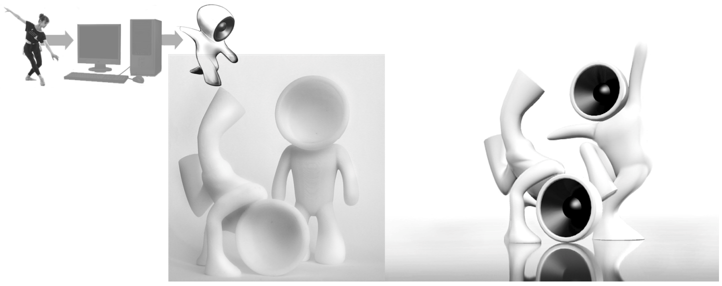

Figure 3. Personal body pose becomes form for audio speakers

CJ's audio speakers begin with a bodily pose that the customer captures through a three dimensional scan of themselves. Computer software then translates that pose to the flexible digital figure. It then adjusts the scale to fit the speaker diameter chosen and exports the model as an STL file. Desktop manufacturing creates the figures in plastic, the speaker cone and wiring are installed and the speaker is ready to play.

5.3 Sarah Owens Relief Photograph Display

Figure 4. The process of translating a digital image into a physical relief display

Sarah's display begins with a digital photograph provided by the customer. This photograph is transformed into a topographical relief surface. The brightest portions of the photo are the thinnest section and the darkest areas are the thickest sections. This 3D data is converted into surfaces and fabricated using an FDM machine. When light is transmitted through the semi-translucent display the photograph appears as areas of dark and light.

6 FUTURE REVISIONS TO THE PROJECT

Two major revisions will be made to this project after having conducted it for the first time. One is to reduce the product volume envelope and part volume limitation to reduce FDM machine time and material use. Another was the addition of a product category constraint, such as lighting. This would narrow the constraints further and make it easier for the students to focus. The difficulty is in judging the degree of difficulty and achieving a balance between struggle and achievement.

7 CONCLUSIONS

Personal fabrication empowers the product designer by providing the opportunity to by-pass the traditional and expensive product development infrastructure. It also empowers the amateur to invent and design their own products and by-pass product designers entirely. The role of the product designers may then be to help create software that enables the public to do their own product design.

To imagine the power of a manufacturing facility contained within a small affordable device is an exciting prospect for product design. It changes the very nature of product development as it is done today. Rather than working on single products designed to fit the majority of the population, designers will be creating products that will be modified to suit each individual. Designers will not be creating fixed forms, but rather forms that can be shifted and transformed. This will require the collaboration between industrial designers, software programmers, and engineers to make this shape shifting possible and intuitive.

References

[1] Gershenfeld, N. *FAB: The Coming Revolution on Your Desktop—From Personal Computers to Personal Fabrication.* (Basic Books, New York, 2005).

[2] Hansell, Saul (2007, May 7). Beam It Down From the Web, Scotty: 3D Printers Could Be in Homes Much Sooner Than You Think. *The New York Times*, pp. C1, C8.

[3] Khemsurov, Monica (2006) Private First Class: Four designers use rapid-prototyping technology to invent products inspired by intimacy. *I. D.* November.

[4] Noorrani, R. *Rapid Prototyping: Principals and Applications.* (New Jersey: John Wiley & Sons, Inc. 2006).

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