Low-Fidelity Fabrication: Speeding up Design Iteration of 3D Objects

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Abstract
Low-fidelity fabrication systems speed up rapid prototyping by printing intermediate versions of a prototype as fast, low-fidelity previews. Only the final version is fabricated as a full high-fidelity 3D print. This allows designers to iterate more quickly—achieving a better design in less time. Depending on what is currently being tested, low-fidelity fabrication is implemented in different ways: (1) *faBrickator* allows for a modular approach by substituting sub-volumes of the 3D model with building blocks. (2) *WirePrint* allows for quickly testing the shape of an object, such as the ergonomic fit, by printing wireframe structures. (3) *Platener* preserves the technical function by substituting 3D print with laser-cut plates of the same size and thickness.

At our CHI'15 interactivity booth, we give a combined live demo of all three low-fidelity fabrication systems—putting special focus on our new low-fidelity fabrication system *Platener* (paper at CHI'15).

Author Keywords
rapid prototyping; design iteration; prototyping; 3D printing; laser-cutting; personal fabrication.

ACM Classification Keywords
H.5.2

Introduction

The recent development in rapid prototyping tools, such as 3D printers, allows users to prototype one-off objects and to iterate over designs. Even though considered a *rapid* prototyping tool, 3D printers are so slow that a reasonably sized object requires printing overnight. This slows designers down to a single iteration per day. A typical iteration process therefore easily adds up to a week—even though the actual design work may not have taken longer than a few hours. This turns the 3D printer into the bottleneck of the workflow.

Low-fidelity Fabrication

With low-fidelity fabrication [2], we propose to speed up design iteration by printing intermediate versions of a prototype as fast, low-fidelity previews. Only the final version is fabricated as a full 3D print (see Figure 1).

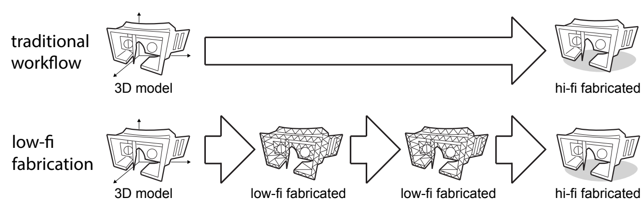

Figure 1. Low-fidelity fabrication: fast low-fi previews for intermediate versions, full 3D print only at the end.

Low-fidelity fabrication can be implemented in different ways depending on what is currently being tested. In the next section, we present our three low-fidelity fabrication systems *faBrickator* (CHI'14), *WirePrint* (UIST'14), and *Platener* (CHI'15) that all address a different use case.

Low-fab #1 faBrickator: faBrickator [3] saves 3D printing time by automatically substituting sub-volumes with standard building blocks. After faBrickator converted a 3D model to Lego, users can mark parts of the 3D model as "high-resolution" to indicate that these should be 3D printed. faBrickator generates instructions that show users how to assemble Lego bricks and 3D printed parts. If users keep iterating on the prototype, faBrickator offers even greater benefit as it allows reprinting only the elements that changed.

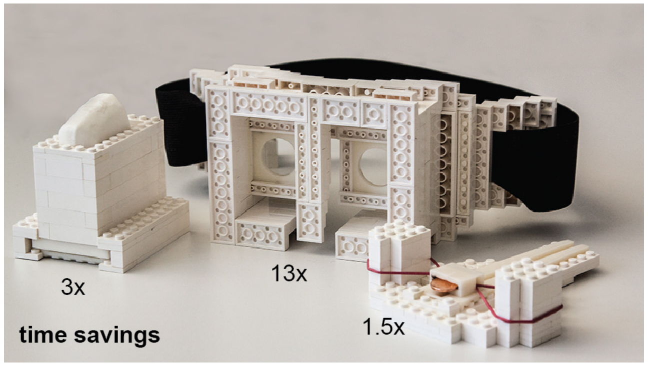

Figure 2. *faBrickator* subsitutes sub-volumes of a 3D print with building blocks.

Low-fab #2 WirePrint: *WirePrint* [2] achieves its speed-up by replacing the surfaces of a 3D print with a wireframe mesh. Since wireframe previews are to scale and represent the overall shape of the 3D object, they allow users to quickly verify key aspects of their 3D design, such as the ergonomic fit. To maximize the speed-up, *WirePrint* instructs 3D printers to extrude filament not layer-by-layer, but directly in 3D-space, allowing them to create the edges of the wireframe model directly one stroke at a time.

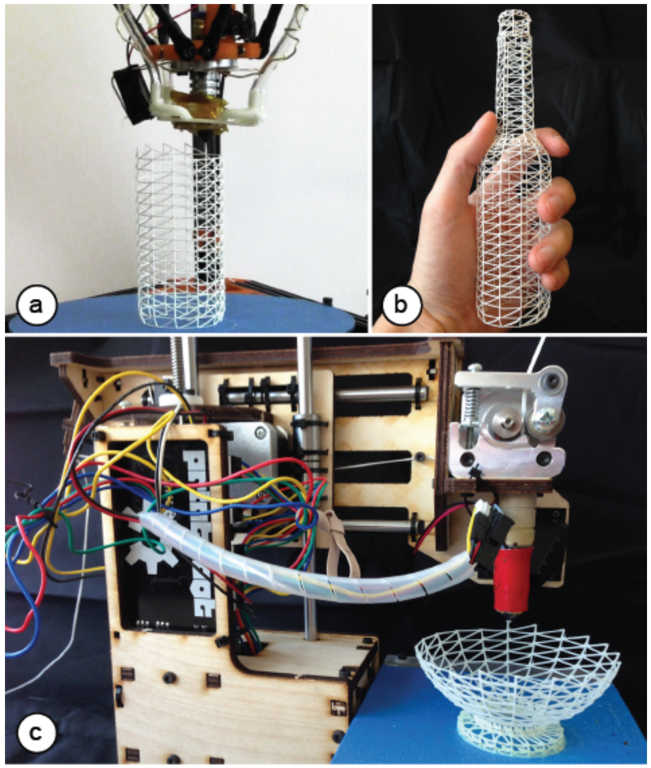

Figure 3. *WirePrint* preserves the overall shape of objects by replacing surfaces of a 3D model with a wireframe. This allows users to, e.g. test the ergonomic fit of this bottle quickly.

This allows *WirePrint* to achieve speed-ups of up to a factor of 10 compared to traditional layer-based printing. *WirePrint* runs on standard FDM 3D printers, such as the *PrintrBot* or the *Kossel mini.* Users only need to install the *WirePrint* software, making *WirePrint* applicable to many 3D printers already in use today.

Low-fab #3 Platener: *Platener* [1] achieves its speed-up by extracting straight and curved plates from the 3D model and substituting them with laser cut parts of the same size and thickness. Only the regions that are of relevance to the current design iteration are executed as full-detail 3D prints.

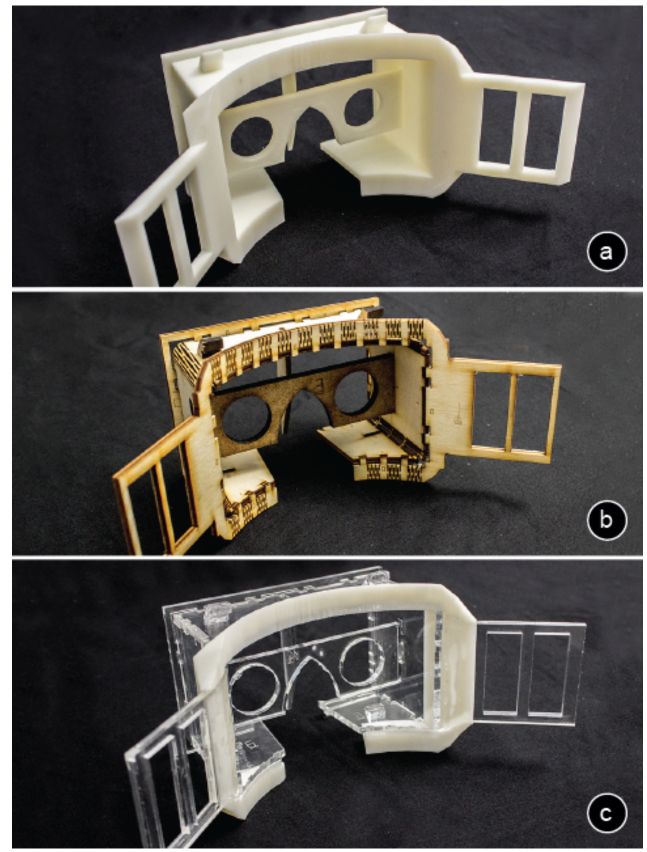

Figure 4. *Platener* substitutes 3D print with laser cut plates allowing users to test an object's technical function quickly.

Platener connects the parts it has created by automatically inserting joints. To help fast assembly it engraves instructions. Platener allows users to customize substitution results by (1) specifying fidelity-speed tradeoffs, (2) choosing whether or not to convert curved surfaces to plates bent using heat, and (3) specifying the conversion of individual plates and joints interactively.

Platener is designed to best preserve the fidelity of *technical* objects, such as casings and mechanical tools, all of which contain a large percentage of straight/rectilinear elements. Compared to other low-fidelity fabrication systems, such as *faBrickator* and *WirePrint,* Platener better preserves the stability and functionality of such objects: the resulting assemblies have fewer parts and the parts have the same size, thickness, and approximate weight as in the 3D model.

We validated *Platener* at the example of 2.250 3D models downloaded from a 3D model site (*Thingiverse*). Platener achieves a speed-up of 10 or more for 39.5% of all objects.

Conclusions

The three *low-fab* systems presented in this paper speed up fabrication by a factor of 3-10 on average. This allows designers to have more iterations in a day, leading to a better design in less time.

Different design iterations focus on different key aspects, such as testing the technical function of an object first and then optimizing the shape for the best ergonomic fit. Different *low-fab* systems thus support different conversions of the original 3D model (e.g. *Platener* preserves the technical function of an object using plates of the same thickness, and *WirePrint* preserves the shape of an object by using a wireframe mesh).

Since different *low-fab* systems have different ways of converting the 3D model, each low-fab technique is best suited for a certain class of objects (e.g. *Platener* achieves its maximum speed-up for objects that have many rectilinear elements), while they are less suitable for others.

For future work we want to explore how to apply the *low-fab* concept to prototyping interactive and animated objects.

References

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