sPrintr: Towards In-Situ Personal Fabrication using a Mobile 3D Printer

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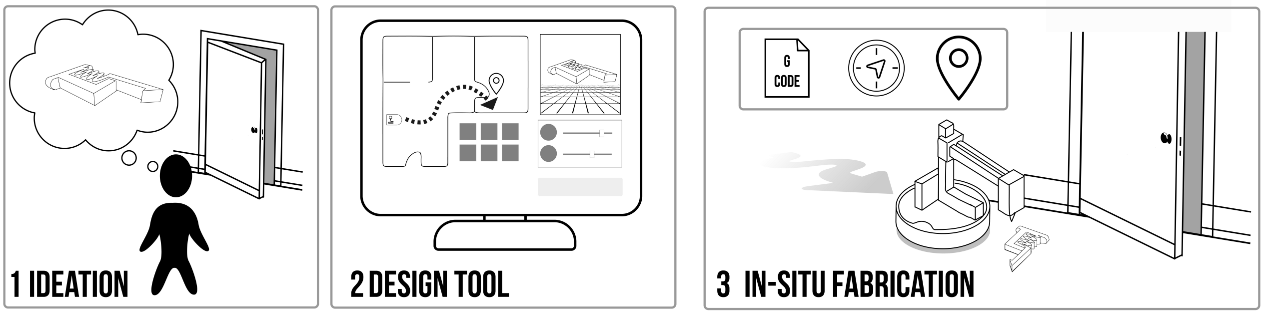

Figure 1: Proposed workflow to support in-situ personal fabrication —1) identifying specific locations to print in; 2) editing, arranging, and previewing objects at specific locations; 3) making 3D objects in-situ using a mobile 3D printer.

ABSTRACT

We present our early work on sPrintr, a pipeline consisting of a mobile 3D printer and graphical interface to enable in-situ fabrication with consumer-grade hardware and fabrication tools. We prototyped two initial components of that pipeline i) a mobile 3D printer and ii) a user interface that helps users arrange, preview, and plan prints in their environment using a floor plan layout. We identify challenges in the automation of mobile printing systems, on-the-go printing, and human-machine interfaces for in-situ design and fabrication.

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1 INTRODUCTION

Personal fabrication allows novices to create custom objects to augment their homes and personal spaces but the process falls into a pattern: generate or download 3D models, set up, verify, print, evaluate, and repeat as needed [Hudson et al. 2016]. Since most consumer 3D printers are desktop machines, this means removing the print, taking it to a location, and evaluating the object in place for scale, fit, and appearance. This process divorces the final object from the desired location and context of use, which can lead to more design iterations, errors, and suboptimal designs [Kim et al. 2017]. One way to address this problem is to have the fabrication machine itself go to the location and print the object in place, instead of having the user travel back and forth.

Mobile fabrication refers to machines that fabricate objects *in-situ* directly in the environment. Large-scale, industrial applications like architecture, and construction have led to a variety of mobile fabricators. Researchers used assembly-line robotic arms on moving platforms for collaborative printing [Zhang et al. 2018]; architects made teams of robots to build cement structures [Jin et al. 2018]; businesses are selling robotic products to help with on-site building information management (BIM) tasks like chalking floor plans [HP 2022]. Instead, we aim to make mobile fabrication personal, so that novices can use design tools to fabricate objects *in-situ* using consumer-grade technology [Gershenfeld 2007]. This would enable people to directly augment their environment for accessibility modifications, home construction projects, or decoration. For example, imagine a mobile 3D printer capable of creating a wheelchair-accessible ramp over a door entrance or adding tactile surface indicators before a staircase.

In this demo, we present sPrintr, a personal fabrication pipeline with i) a custom mobile 3D printer and ii) a design tool for in-situ design for personal fabrication. Figure 1 illustrates our vision for the integrated pipeline. Below, we present prior work on in-situ design and adaptive printing, describe our current prototype, challenges, future work, and close with our demo overview.

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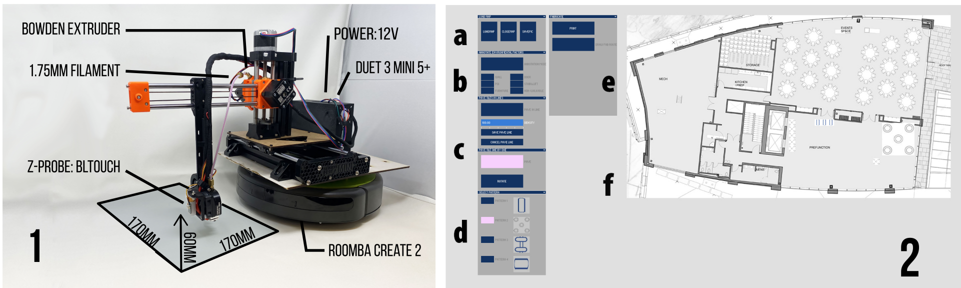

Figure 2: Our sPrintr includes 1) a cantilevered 3D printer on a moving base; and 2) a GUI with options to a) load floor plans, b) annotate points of interest, c) place objects individually or along a path, d) select from a model library, e) confirm layout, and f) place and preview the objects on a map.

2 BACKGROUND

Mobile and In-situ Personal Fabrication. We build on prior work in mobile fabrication and 3D printing for dynamic surfaces/objects. One approach has been to create portable 3D printers so that they are easier to transport between locations and faster to set up [OLO 2016; Peek and Moyer 2017; Roumen et al. 2016]. However, this limits the objects to an enclosed build volume with a dedicated print bed. Conversely, hand-held and wearable fabrication tools *e.g.* [3Doodler 2022; Agrawal et al. 2015; Gannon et al. 2016; Zoran and Paradiso 2013] let users "draw" their designs directly on various surfaces like skin or a phone screen but their hand-made nature means the objects are one-offs. Our approach allows us to print on multiple surfaces like handheld tools but would also have the repeatability and accuracy of traditional consumer-grade 3D printers.

Adaptive 3D Printing. In-situ design and fabrication can further previous research that mitigates the difficulties novice users face when remixing and adapting existing 3D designs for their homes [Alcock et al. 2016]. For example, *Reprise* allows users to specify adaptations to household objects [Chen et al. 2016] and *Medley* is a library of objects that can be embedded into 3D prints to change their mechanical properties [Chen et al. 2018]. Moreover, researchers have used 3D printing to support modifications to the environment for accessibility [Guo et al. 2016]. Our goal is to combine the adaptive approach of these design tools with the ability of mobile printing to produce objects directly in the environment.

3 SPRINTR PROTOTYPE

Toward our vision of in-situ personal mobile fabrication, we made a prototype mobile 3D printer and an accompanying design tool. With sPrintr, users determine where in a given location they want a printed object then use the design tool to arrange, preview, and finalize the object locations. Currently, we are manually controlling the printer to move and print designs in the environment but plan to integrate the two components in the future.

Mobile 3D Printer. We used an *iRobot Roomba Create 2* robot as the mobile base and a cantilevered 3D printer based on the *Prusa Mini*. Figure 1 shows the current prototype and contains additional printer specifications. The printer is controlled by a *DUET 3 Mini 5+* running *Reprap* firmware.

Design Tool. We are working on a GUI built using *Processing* where users can upload a floorplan, place desired 3D models from a library of objects, and place them in the context of their home. The tool allows them to place objects along a path or individually. Users can also view the path the printer will take to print the items, and preview the layout of the objects. In the future, we are working towards generating toolpaths for the robot to follow and wireless communication to the robot.

4 CHALLENGES AND FUTURE WORK

Autonomy. Autonomous navigation in uncontrolled environments is a longstanding research problem that we need to address in addition to the question of how to position and orient our printer for a successful print. Moreover, we need to sync the coordinate system of the design tool with the real-world environment the robot needs to navigate.

Printing On-the-Go. Mobile printers could far exceed the print volumes of existing 3D printers but the differential motor drive on the Roomba does not afford the same level of control as the stepper motors on most 3D printers. Additionally, G-code slicers do not support robot movement so the slicing and parsing of files would need to interface with the robot movement controls.

Human-machine interfaces and interaction. Personal fabrication called for new design tools that leveraged personal computing to interface with 3D printers [Baudisch et al. 2017]. Likewise, mobile fabrication can make use of the advent of mobile computing. This could push the design process to be more situated in the environment and interactive, turning the machines into collaborators.

The goal of sPrintr is to bring mobile fabrication systems into the realm of personal fabrication with consumer-grade hardware and design tools to make it easier for novices to augment their environments. We will improve the mechanical design of the mobile printer and make the system battery-powered. We will also work on the design tool that allows users to edit their 3D models out in the world and then have sPrintr go out and fabricate the objects in place. This would open new possibilities to adapt and modify environments to customized needs like accessibility and open up new research questions regarding personal in-situ design and fabrication.

5 DEMO REQUIREMENTS

We will demo sPrintr—both the mobile 3d printer and lightweight design tool. We will set up a demo to print a small object on the floor. We need a poster stand, access to power, and about a 2m x 1.5m floor area.

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