

# RoCuModel: An Iterative Tangible Modeling System

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## ABSTRACT

This paper presents *RoCuModel*, an iterative tangible modeling system that helps users build 3D models in a tangible way for personal fabrication. It consists mainly of a special tangible curve and an infrared camera. Users can create 3D objects by creating sketchy low-fidelity shapes with the hand. By rotating the curve along a fixed axis, users can visualize the volumetric model in a 3D space in real time. *RoCuModel* provides a new way for people to design and create a rotationally symmetric 3D model. This is our first step towards eliminating the gap between specialists and non-specialist users in personal fabrication.

## Author Keywords

Tangible interaction; 3D modeling; personal fabrication; user interface

## ACM Classification Keywords

H.5.2 [Information Interfaces & Presentation]: Interaction styles.

## General Terms

Design

## INTRODUCTION

With increased availability and affordability of 3D printers, we have now reached a point where it is possible for anyone to participate in the fabrication process of customized artifacts [2]. One challenge for a non-specialist is that the user needs to prepare a 3D model of the physical object. It requires the use of specialized digital modeling tools and an understanding of the physical feasibility of the object to be created. This hampers these users' ability to quickly explore their creative ideas through rapid prototyping.

This motivates us to investigate how an interactive system can be designed such that it can simplify the process of personal fabrication as well as facilitate the learning of physical object design and fabrication. In our daily life there are all kinds of rotationally symmetric objects, such as

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bottles, table legs, or a doll's arms. We focus on this kind of common and simple models firstly, to explore a new interactive system for modeling design and personal fabrication.

This paper presents *RoCuModel*, a new tangible modeling interface, which a flexible curve serves both as a tangible modeling proxy input and a volumetric 3D image output for previewing the model before fabrication. With *RoCuModel*, people can design a model by hand-shaping a tangible curve with an LED (light emitting diode) array that can be detected by an infrared (IR) camera. By rotating the curve along a fixed axis, the 3D model can be previewed in the 3D space instead of viewed as 2D projections of a 3D object on a computer screen (see Figure 1). Beginners can create the objects by sketching low fidelity with this device, which also helps people create things from sketch to object in real time. In this paper, we first review some relevant work in tangible modeling and interactive fabrication. We then explain our system design process and the prototype implementation. Detailed information about application will also be given.

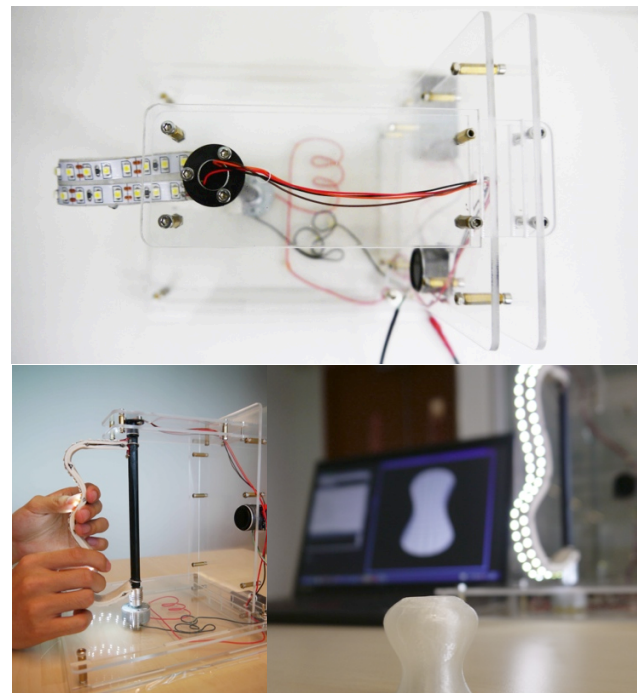


Figure 1. *RoCuModel*, an Iterative Tangible Modeling System

**RELATED WORK**

Many research projects have explored tangible modeling interfaces and interactive fabrication. We briefly review some of the prior work.

**Tangible Modeling Interfaces**

Tangible user interfaces (TUIs) take advantage of human’s abilities to grasp and manipulate physical objects and materials [5]. Many studies have demonstrated the usefulness of TUIs in modeling collaboration, learning, and design. There are two main ways to achieve tangible modeling: by directly instrumenting a modeling medium with embedded computation or by using an external sensor to capture the geometry [1]. Grossman et al. [3] described an interface for controlling a model of 3D curves by using a high degrees-of-freedom bendable rope-like input device. Sheng et al. [7] explored direct finger input via physical proxy to create and manipulate 3D geometric models. These two projects achieve tangible modeling in the two aforementioned different methods, respectively.

**Interactive Fabrication**

Whereas TUIs focus on the input methods, interactive fabrication considers the entire design process from input to output stages. Willis et al. [8] describe Spatial Sketch that uses physical movement to make a 3D sketch and builds it into physical objects by cutting planar materials. It brings physical input and output closer together to help designers better understand their creations [9]. However, while their system allows real-time input to digital fabrication, it does not provide any opportunity to modify object models after they’ve been created. Our work improves upon the prior work by adding a real-time preview process in interactive fabrication, which we term *iterative* fabrication.

**DESIGN**

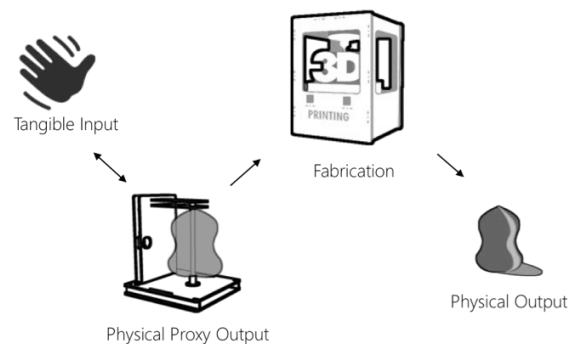
Our goal in building *RoCuModel* is to design a system that can simplify the process of personal fabrication and bridge the gap between specialists and non-specialist users. This section describes our design process.



**Figure 2. Rotational symmetry objects in our daily life**

Many objects in our daily environment are rotationally symmetric (see Figure 2). In digital modeling tools, such

objects are generated by rotating a curve shaped by the user through multiple control points. To the best of our knowledge, *RoCuModel* is the first system that proposes to let a user shape the curve with the hand, outside of the computer screen. This gives the user immediate, tangible feedback on the 3D model in two ways (see Figure 3). First, the user can feel and see the shaped 2D curve during manual manipulation. Second, the user can visualize the intended 3D object by rotating the curve around a fixed axis. This system gives users a more intuitive, immediate and hopefully more satisfying experience in designing 3D models.

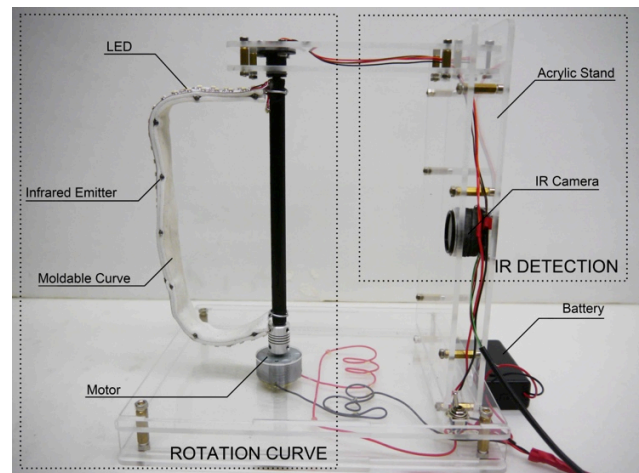


**Figure 3. Modeling system structure**

**PROTOTYPE IMPLEMENTATION**

**Hardware**

The prototype consists of two main components for curve rotation and IR detection (see Figure 4). The structures are built by clear PMMA (polymethyl methacrylate) using a laser cutter.



**Figure 4. Prototype Structure**

**Curve Rotation**

This part consists of a moldable curve, a rotational axis, and a spinning motor. The curve is mainly made of a moldable wire with a series of LEDs (for shape visualization by the user) mounted along the outside length and eight infrared emitters (for shape capture by the IR camera) along its

inside (see the left half of Figure 4). We used a rotational motor (Model 13H-12, Nidec, Japan) with a fixed speed of 500 rad/s. When the motor is off, the user can shape the curve by hand. When the motor is on, the afterimage of the LEDs allows the user to see the 3D model as a volumetric 3D object in the 3D space (see Figure 5). The users can therefore gain a more 3D-like, direct preview of the 3D object being created. Viewers can use their inherent physiological mechanisms for depth perception to gain a richer, more accurate understanding of the virtual 3D scene [4].

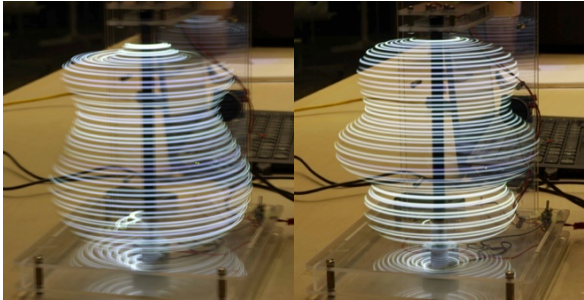


Figure 5. Volumetric 3D Models

**IR Detection**

Our system uses an IR camera to detect the positions of the eight IR emitters for subsequent modeling of the curve shape. The IR camera is made of a wide-angle web camera with an IR filter. The use of the wide-angle camera allows us to minimize the space taken up by the overall structure.

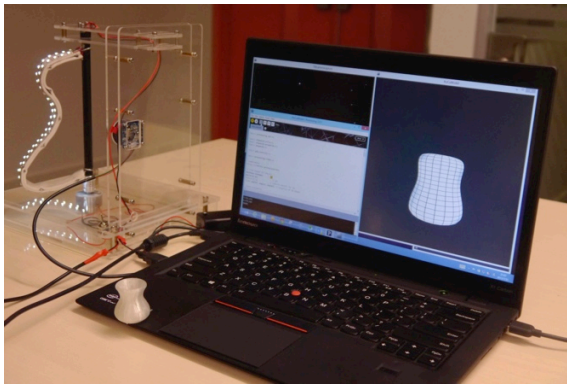


Figure 6. The curve shape is detected by IR camera and a 3D model is built in computer according to the curve.

**Software**

The software part is built in Processing. Our device needs image processing and 3D modeling abilities. Processing can satisfy both of them. After users finish shaping the curve, the location of the IR emitters can be easily identified by the video and image-processing libraries in every frame. According to the IR emitters' location information, we calculate two control points for each IR emitter point. Bezier Algorithm will generate a curve that passes through all the IR points. Then a 3D model can be built according to the curve in the computer (see Figure 6).

Later with ModelBuilder library [6], we will get Processing to export straight to STL format for 3D printing.

**Result**

Currently, there are eight infrared emitters inside the prototype curve. These eight points decides the model. We tried several different curve shapes (see figure 7).

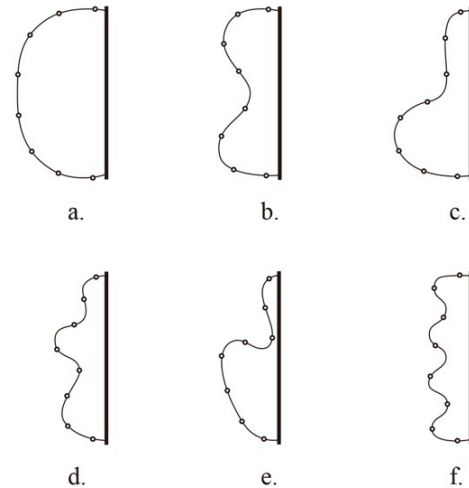


Figure 7. Curves like a, b, c, d and e, can be shaped. Curve like f cannot be shaped well in current prototype.

Some simple curves can be easily shaped and identified while other relatively complex curves like curve f in figure 7 can't be identified correctly. The tangible curve's material and the number of emitters inside limit its possible designs. However, this can help non-specialist users to creating sketchy low-fidelity shapes with the hand.

**DISCUSSION AND FUTURE WORK**

This paper explored a new interface for creating 3D models to help promote personal fabrication. There are some challenges we faced when building this kind of modeling system. How to bridge the gap between digital media and physical action control using an effective way for a wide range of people? How to let generic users understand the 3D model without special technical requirement? Although our solution, *RoCuModel*, provides a new way to create 3D models in some extent, there are still a lot of limitations and future works in our project.

**The accuracy of modeling**

As discussed above, the possible models are limited because of the tangible curve's material and the number of emitters inside. In order to improve the accuracy, more emitters should be attached on the modeling curve. We also consider adding one more curve on the prototype so that one can decide the exterior and the other one decides the interior. This work can contribute to design more complex model.

**If using a mobile phone camera instead**

We use an IR camera in the *RoCuModel* device as a detection part. If the *RoCuModel* adopts a mobile phone's

camera instead, it can be designed as a low-cost hardware accessory for tangible 3D modeling and reviewing. With the cellphone, it will be more convenient and portable to conduct the 3D modeling things. Imaging this scenario, people design and build a 3D model using a portable cellphone accessory and then printed by 3D printer directly. This can eliminate the gap between users population and design in personal fabrication.

#### **Modular modeling system**

The *RoCuModel* system can only create customized objects in rotationally symmetric form-factor. While, there are plenty of things composed of this kind of form-factor. If the model created by the *RoCuModel* is one part of an entire complex model, this limitation can be minimized. In the future work, people can create customized rotationally symmetric object with an extra joint modular part by this tangible curve and later all the separated parts can be assembled with each other.

#### **Future tangible input**

We also want to improve our system support not only asymmetric models. One solution we have discussed is to use a rectangle filled with led arrays to replace the tangible curve input. This rectangle can be programmed to display the different 2D curve as section when it is in rotation mode, so it can display a non-asymmetric model. Curve modeling is just one of the modeling methods in digital software. It can also be explored to achieve other modeling methods in a tangible way. More tangible input methods will be explored to use in our modeling interface.

#### **CONCLUSION**

With the *RoCuModel* prototype, users can interact with the tangible 2D curve to create a 3D model. At the same time, a real-time volumetric 3D model can be displayed in the rotation mode, which is totally different a visual experience compared to being displayed by GUI. *RoCuModel* provides a new way for people to design and make a 3D model. By combing the tangible modeling and interactive fabrication, we explored a new modeling system intended to simplify the process of personal fabrication as well as facilitate the user's learning on personal fabrication. We reported our current prototype implementation and discussed the limitations and future work in our system. It responds that *RoCuModel* can help generic users population to

understand how to build a 3D model in an easier way and enable them to be more confident to make objects.

#### **ACKNOWLEDGMENTS**

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