

CopyCAD: Remixing Physical Objects With Copy and Paste From the Real World

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ABSTRACT

This paper introduces a novel technique for integrating geometry from physical objects into computer aided design (CAD) software. We allow users to copy arbitrary real world object geometry into 2D CAD designs at scale through the use of a camera/projector system. This paper also introduces a system, CopyCAD, that uses this technique, and augments a Computer Controlled (CNC) milling machine. CopyCAD gathers input from physical objects, sketches and interactions directly on a milling machine, allowing novice users to copy parts of real world objects, modify them and then create a new physical part.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. Input devices and strategies.

General terms: Design, Human Factors

Keywords: TUI, fabrication, design tools, prototyping.

INTRODUCTION

Real world computer aided design is rarely done from scratch solely on the computer. Instead designers integrate real world sketches, found parts, as well as designs from other people. Likewise designs rarely stay only in digital form, moving quickly between digital and physical. Rapid prototyping machines have increased in speed and decreased in cost, ever tightening this loop. Yet the tools for integrating real world geometry remain extremely complicated (3d scanners) or simple and indirect (calipers and rulers).

At the same time these Rapid Prototyping and CAD tools are becoming more accessible. FAB labs and hacker spaces have brought these tools to the masses, and Sketch Up and Maker Bot are bringing them into their homes. These new users may have different needs than of traditional CAD designers. They may want to modify existing products they already own, make spare parts to repair them, or craft their own.

We propose interactions that will allow users to design by example, to show the computer what geometry they want to

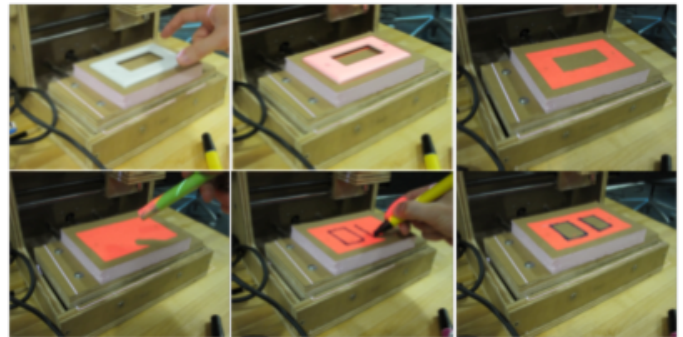


Figure 1: CopyCAD system interaction for modifying a lightswitch cover. Clockwise starting in top left: 1. Place object, 2. copy shape, 3. shape is projected, 4. delete interior shape, 5. draw new geometry, 6. copy new geometry.

borrow from the real world and where to put it in their current design. By shortening the loop, users can quickly base designs off of found real world objects, bring in other parts, and edit them. This type of digital "remixing" has generally existed for only temporal media such as video or audio; we seek to expand it to physical objects.

RELATED WORK

We build upon work from the area of augmented design tools. ModelCraft [5] correlates sketching on a physical model with actions and annotations in CAD software (in this case, SolidWorks). In a similar vein, Pictionary has allowed designers to collaborate and annotate across both physical and digital objects [1]. The Designasaur and the Furniture Factory both allow users to design physical objects through sketching, generating press-fit laser cut pieces for easy assembly [3]. A number of projects [4, 6] have also sought to augment CNC machines, however this is only for machining not for CAD design and is focused on industrial machines not for novice users.

INTERACTION

The CopyCAD system includes several modes of interaction for users to create and modify 2D designs. First, users can capture 2D geometry from a physical object by placing it on the machine. The curves will be extracted and projected in the same location where the physical object was. Users can

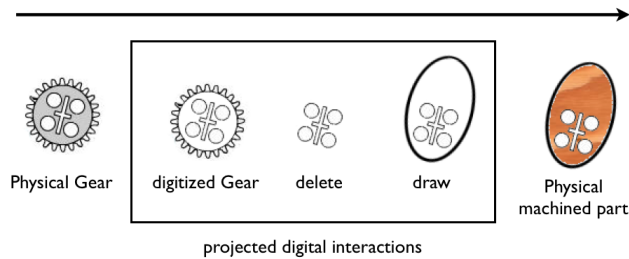


Figure 2: Creating a lego cam from a lego gear.

also sketch directly on the material using any pen and these inked curves will also be captured. Currently the users has to press a button to capture the new geometry.

After geometry has been created users can edit by using their fingers or a specially marked pen tracked by the system. Users can select contours and move them by touching and dragging or copy them by touching and holding. All of the contours may also be resized, either as a whole or as some subset of the whole. Users may select contours to delete by pointing with the back of a marked pen at their projected images on the machine bed.

Finally, CopyCAD provides users with projected feedback of physical dimensions. Users can then press a button on a keypad to start cutting their design on the machine.

USE CASES

A user can use CopyCAD to remix a design; that is, to model by augmenting an existing base object. For example, a user might have a light switch plate which no longer fits after the installation of a new, differently dimensioned light switch. Leaf earrings could be fashioned by copying a leaf and drawing a hole for the metal loop. Or a user could combine geometry from multiple sources.

CopyCAD can be employed for the purposes of crafting entirely original designs from scratch. In order to do this, the user may simply draw directly onto the surface of the material which he would like to cut. Users can also mock-up physical objects by sculpting them with clay, then using CopyCAD to capture their shapes for further manipulation and machined output.

IMPLIMENTATION

At the core of CopyCAD is a Mantis 3-axis milling machine [2]. The machine bed can cut a variety of materials, such as wood, paper, fabric, and foam. A webcam is mounted above the machine bed in order to capture the outlines of physical objects. Next to the webcam is a projector, which provides visual feedback to the user by projecting the outlines back onto the machine bed. A red laser with a line lens is used to detect touch selections.

The software was written using OpenCV to do simple image processing to capture the interior and exterior curves of an object or sketched lines. Currently the system implements simple background subtraction to find the curves.

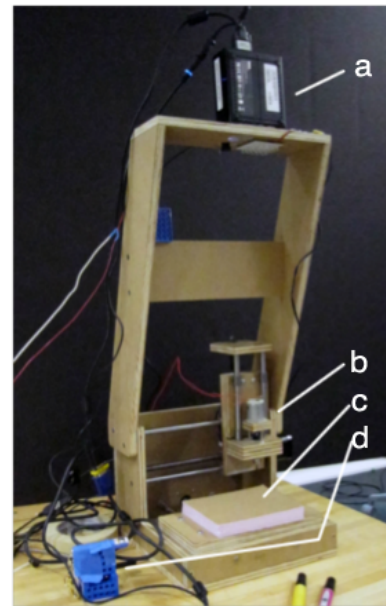


Figure 3: CopyCAD system setup: a. Camera and Projector, b. 3-axis milling machine, c. Work area, d. Laser with line lens for multitouch input.

CONCLUSION

We have shown an example of how novice users can easily copy real world geometry and modify their designs through sketching and a projected touch interface. Also by placing the interface directly on the rapid prototyping machine, we have further closed the loop for designing physical objects. By allowing for easy integration of existing physical objects, we believe users will be able to explore the possibilities of digitally remixing physical objects.

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