Laser Cutting Tips and Tricks

6.810 Engineering Interaction Technologies

Prof. Stefanie Mueller | MIT CSAIL | HCI Engineering Group
how does a laser cutter work?
distance of sheet to lens is important (focal length of lens)

focused! defocused : /

too little power for cutting
can we use a laser cutter to make these 3D reliefs?

<30 second brainstorming>
can we laser engrave 3D reliefs?

no, they are made with a different type of machine.
• two lasers from different sides aim at same spot.
• where they interfere, the power is high enough to break the glass and create a ‘dot’.
joints: creating 3D objects
finger joints::

Offene eckige Fingerzinken

Halbverdeckte, eckige Fingerzinken
will this fit and hold together?

<30 second brainstorming>
no, it will not fit.
it will be very loose.
material evaporates during cutting.
you need to make the joint larger than the gap
Box Designer

Give us dimensions and we’ll generate a PDF you can use to cut a notched box on a laser-cutter. Check out this example box design. People have used this website to design more than 150,000 boxes!

Use this box designer a lot? Consider chipping in some money to support our hosting and bug fixes!

Donate

email: rahul [at] connectionlab [dot] org
a Connection Lab project
twitter: @rahulbot
version 2.1.0

Add your picture to the flickr pool!

http://boxdesigner.connectionlab.org/
replace 3D print with laser cut 2D plates:

to speed up design iteration...
plate-joint graph
Platener: Low-Fidelity Fabrication of 3D Objects by Substituting 3D Print with Laser-Cut Plates

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ABSTRACT
This paper presents Platener, a system that allows quickly fabricating intermediate design iterations of 3D models, a process also known as low-fidelity fabrication. Platener 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. 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 functional objects, such as casings and mechanical tools, all of which contain a large percentage of straight/rectilinear elements. Compared to other low-fab 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 and thickness as in the 3D model.

To validate our system, we converted 2,250 3D models downloaded from a 3D model site (Thingiverse). Platener achieves a speed-up of 10x or more for 39.9% of all objects.

Author Keywords: rapid prototyping; 3D printing; building blocks; physical prototyping.
there are other problems when laser cutting this…
**focus** is on top of the workpiece

\[ z = 3\text{mm} \]

your gap will **not be straight**

it actually matters **in which direction** you assemble your joints!
would this be any better if you put $z = 1.5\text{mm}$?
well, a bit maybe… direction doesn’t matter anymore, but there’s no way to get the cut perfectly straight
lot’s of other connection joints....
lock in place::
slide to lock::
gravity or other force holds it
bending
bend acrylic:

to bend acrylic use a **heatgun**

or **strip heater**
living hinges::
living hinges::
other ways to make 3D
stacking::

connector

clamp
intersecting::

- Green paper art
- White paper rhinoceros
- Wooden light bulb sculpture
surface folding::
Autodesk 123D Make::
moving parts
gears & linkages::
tips & tricks:
line color...
laser cuts colors **in order from top to bottom:**
black first, then red, green, yellow
which one is better and why?

<30 second brainstorming>
what laser cutters exist?
industrial laser cutter
$20k - 50k
consumer laser cutters $3,000 (e.g., GlowForge)
hacker laser cutters < $1,000
water pump under the desk!
**MicroSlice** ca. $200
Arduino, super low-power laser (cuts paper and makes light engravings)
coding for laser cutters
LAOS board
(open source controller board)

Destructive Games: Creating Value by Destroying Valuable Physical Objects

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ABSTRACT
While personal fabrication tools, such as laser cutters and milling machines, are intended for construction, we are exploring their use for destruction. We present a series of games that result in valuable physical objects being destroyed—objects owned by the players. Interestingly, we found that we can design these games to be desirable to play, despite the loss of the object, by instead producing social value. As part of a user study, twelve students played a destructive game in which a laser cutter cut up their own money bills. Surprisingly, 8 out of 12 participants would play again. They shared their post-game stories with us.

Author Keywords: destruction; laser cutting; games; personal objects; interactive art.

ACM Classification Keywords: H.5.2 [Information interfaces and presentation]: User Interfaces.

INTRODUCTION
While the primary objective of engineers is to create, artists and researchers have occasionally reversed this main underlying principle and explored destruction. This approach of reversing a central question has a long tradition as it can help understand the original question.

In the virtual world, game designers have explored destruction as a tool for increasing excitement by adding irreversible consequences to otherwise generic and replicable experiences [7]. In the physical world, artists and researchers picked up on the topic, creating artifacts that either allow users to destroy physical objects [14], or that self-destroy themselves after a limited period of time [9] or usage [12].

Figure 1: Destructive games are games that result in valuable physical objects being damaged or destroyed. To play destructive Tug-of-War, each player places a money bill into the laser cutter, and then tries to direct the laser into the other player’s bill. Surprisingly, we found that 8 out of 12 players would play again.
gcode::

programming language for controlling industrial machines such as mills, lathes and cutters as well as 3D-printers

move

G1 X0 Y0 Z3 F500

draw on the workpiece with a laser pointer

[Mueller, Lopes, Baudisch UIST 2012]
polyline
Interactive Construction: Interactive Fabrication of Functional Mechanical Devices

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ABSTRACT
Personal fabrication tools, such as laser cutters and 3D printers allow users to create precise objects quickly. However, working through a CAD system removes users from the workpiece. Recent interactive fabrication tools reintroduce this directness, but at the expense of precision.

In this paper, we introduce constructable, an interactive drafting table that produces precise physical output in every step. Users interact by drafting directly on the workpiece using a hand-held laser pointer. The system tracks the pointer, beautifies its path, and implements its effect by cutting the workpiece using a fast high-powered laser cutter.

Constructable achieves precision through tool-specific constraints, user-defined sketch lines, and by using the laser cutter itself for all visual feedback, rather than using a screen or projection. We demonstrate how Constructable allows creating simple but functional devices, including a simple gearbox, that cannot be created with traditional interactive fabrication tools.

Author Keywords: interactive fabrication; laser cutting; rapid prototyping; sketching; construction; mechanics.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General Terms: Design; Human Factors.

INTRODUCTION
Rapid prototyping/personal fabrication tools, such as 3D printers and computer controlled milling machines help users create one-off prototypes rapidly.

Figure 1: (a) Constructable users interact by drafting directly on the workpiece with hand-held lasers.
(b) Here the user sketches a finger joint across two objects (c) The system responds by cutting the desired joint using the cutting laser. (d) Constructable allows creating precise & functional mechanical objects, such as this simple motorized vehicle.

(3) Precision: constructions aids, such as constraints allow users to precisely manufacture pieces that can perform mechanical functions.

On the flipside, the transition from traditional tools to personal fabrication tools means that all editing is now done on a computer screen, which removes users from the workpiece.
advanced tricks with defocused laser
focused laser lens
defocused laser
laser cutting:

our idea: bending

[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]
[Mueller, Kruck, Baudisch, LaserOrigami CHI 2013]
LaserOrigami: Laser-Cutting 3D Objects
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ABSTRACT
We present LaserOrigami, a rapid prototyping system that produces 3D objects using a laser cutter. LaserOrigami is substantially faster than traditional 3D fabrication techniques such as 3D printing and unlike traditional laser cutting the resulting 3D objects require no manual assembly. The key idea behind LaserOrigami is that it achieves three-dimensionality by folding and stretching the workpiece, rather than by placing joints, thereby eliminating the need for manual assembly. LaserOrigami achieves this by heating up selected regions of the workpiece until they become compliant and bend down under the force of gravity. LaserOrigami administers the heat by defocusing the laser, which distributes the laser's power across a larger surface. LaserOrigami implements cutting and bending in a single integrated process by automatically moving the cutting table up and down—when users take out the workpiece, it is already fully assembled. We present the three main design elements of LaserOrigami: the bend, the suspender, and the stretch, and demonstrate how to use them to fabricate a range of physical objects. Finally, we demonstrate an interactive fabrication version of LaserOrigami, a process in which user interaction and fabrication alternate step-by-step.

Author Keywords: rapid prototyping; laser cutting; interactive fabrication; 3D; physical prototyping.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces.

General Terms: Design; Human Factors.

Figure 1: LaserOrigami fabricates 3D structure by bending, rather than using joints, thereby eliminating the need for manual assembly. Here it fabricates a mobile phone screen cam by (a) cutting the contour lines on the (b) laser table.
LaserStacker
locally welding multiple sheets together

[Umapathi, Chen, Mueller, Seufert, Wall, Baudisch, UIST 2015]
LaserStacker creates 3D objects using a new cut/weld/heal process.

[Umapathi, Chen, Mueller, Seufert, Wall, Baudisch, UIST 2015]
LaserStacker: Fabricating 3D Objects by Laser Cutting and Welding

Udayan Umapathi, Hsiang-Ting Chen, Stefanie Mueller, Ludwig Wall, Anna Seufert, Patrick Baudisch
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ABSTRACT
Laser cutters are useful for rapid prototyping because they are fast. However, they only produce planar 2D geometry. One approach to creating non-planar objects is to cut the object in horizontal slices and to stack and glue them. This approach, however, requires manual effort for the assembly and time for the glue to set, defeating the purpose of using a fast fabrication tool.

We propose eliminating the assembly step with our system LaserStacker. The key idea is to use the laser cutter to not only cut but also to weld. Users place not one acrylic sheet, but a stack of acrylic sheets into their cutter. In a single process, LaserStacker cuts each individual layer to shape (through all layers above it), welds layers by melting material at their interface, and heals undesired cuts in higher layers. When users take out the object from the laser cutter, it is already assembled.

To allow users to model stacked objects efficiently, we built an extension to a commercial 3D editor (SketchUp) that provides tools for defining which parts should be connected and which remain loose. When users hit the export button, LaserStacker converts the 3D model into cutting, welding, and healing instructions for the laser cutter.

We show how LaserStacker not only allow making static objects, such as architectural models, but also objects with moving parts and simple mechanisms, such as scissors, a simple pinball machine, and a mechanical toy with gears.

Author Keywords: rapid prototyping; laser cutting.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User interfaces—Graphical user interfaces; D5.4 [Simulation and Model Checking]: Automation—Automation for processes; D5.5 [Simulation and Model Checking]: Software testing—Software testing methods; C.2.6 [Computer-aided Engineering]: Simulation—Computer aided design.
lens array: locally melting with defocused laser

[Mike Sinclair]
haptic features, e.g. a mini keyboard

[Mike Sinclair]
although only 2D, laser cutters are very versatile!
organization stuff
this friday

• Computer Vision skills lab (needed for pset3)
this friday

• please bring your multi-touch pad (grading pset1/2)
group project: TA assignment

- each team has a TA assigned

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### group project: ordering parts
- order your parts!

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group project: milestone #1
- copy your first milestone over to the milestone grading spreadsheet
feedback for previous assignments

• next week, so you know where you stand!
preview of next weeks

- 3D modeling + Firefly
- making 2D drawings
- making photos
- editing video
- making a website
end.