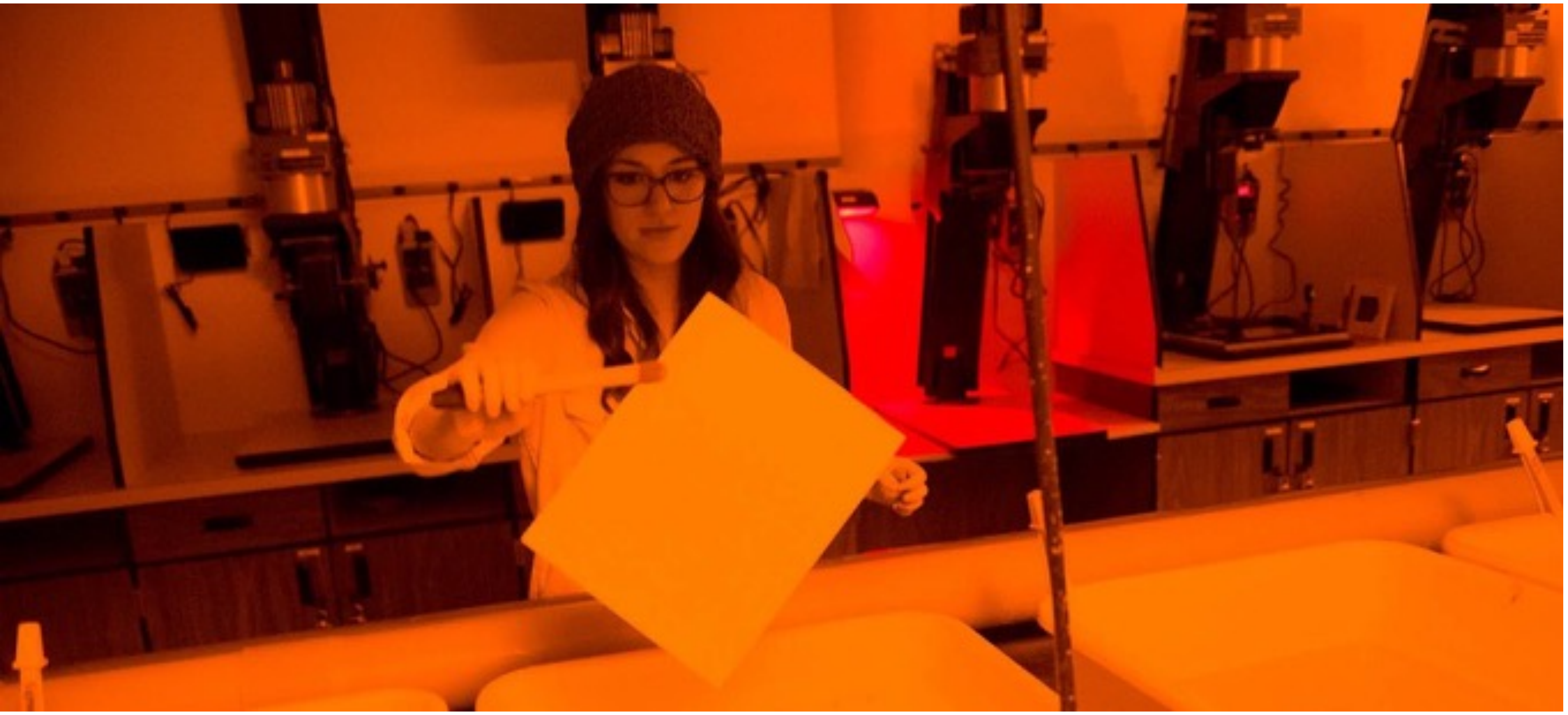
Creativity Support Tools

6.S063 Engineering Interaction Technologies

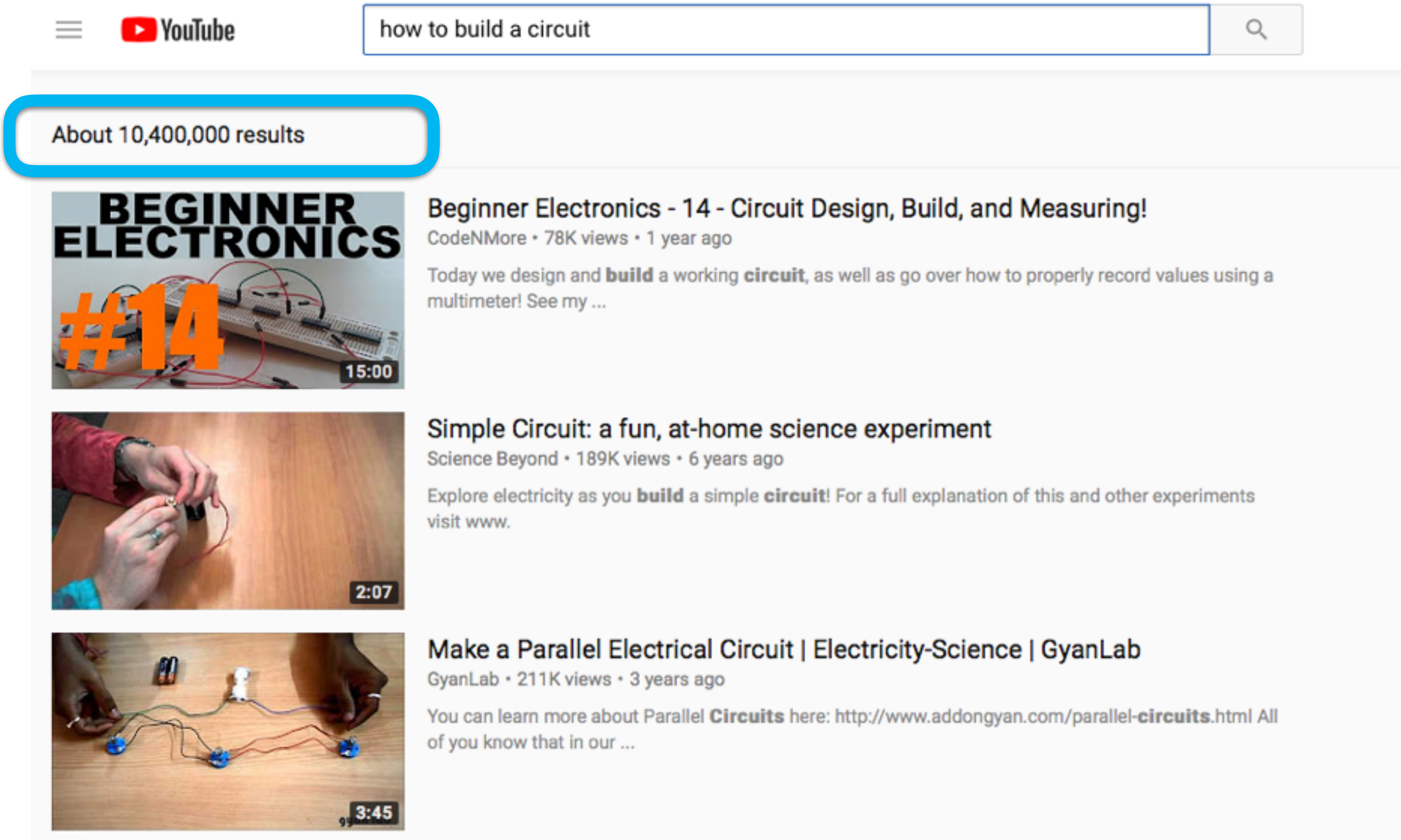
Prof. Stefanie Mueller | HCI Engineering Group

past of **text editing:** expert user + special machine



past of **photography:** expert user + special machines

past of **video editing:** expert users + special machines



today: **everyone** can contribute!

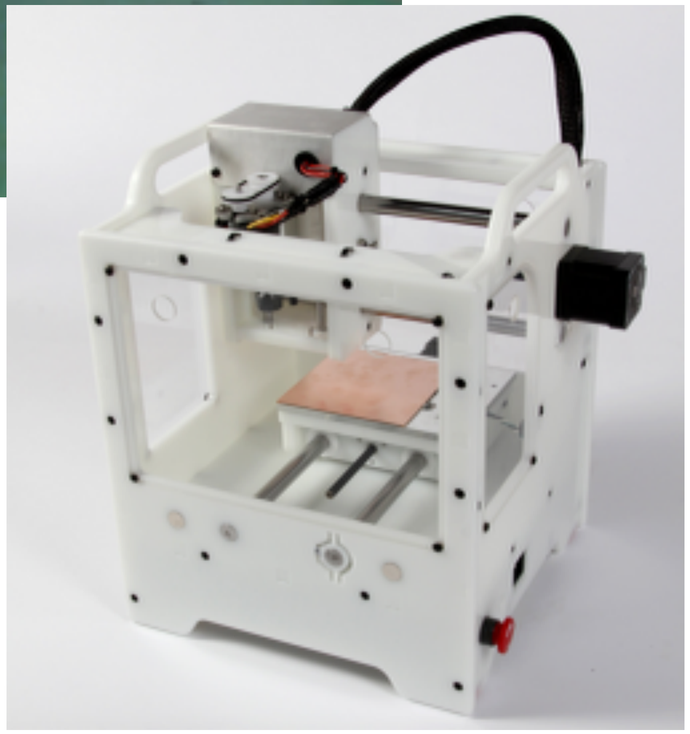
so what is the next medium
that will be accessible to everyone?

<30 sec brainstorming>

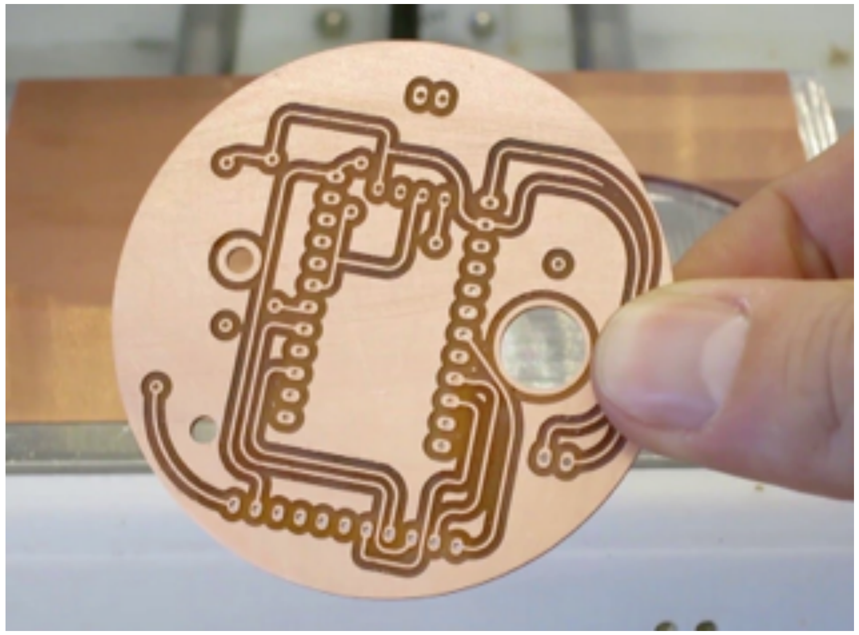
so what is the next medium
that will be accessible to everyone?

physical things
electronics & fabrication

past of **3D printing:** expert users + special machines



Othermill



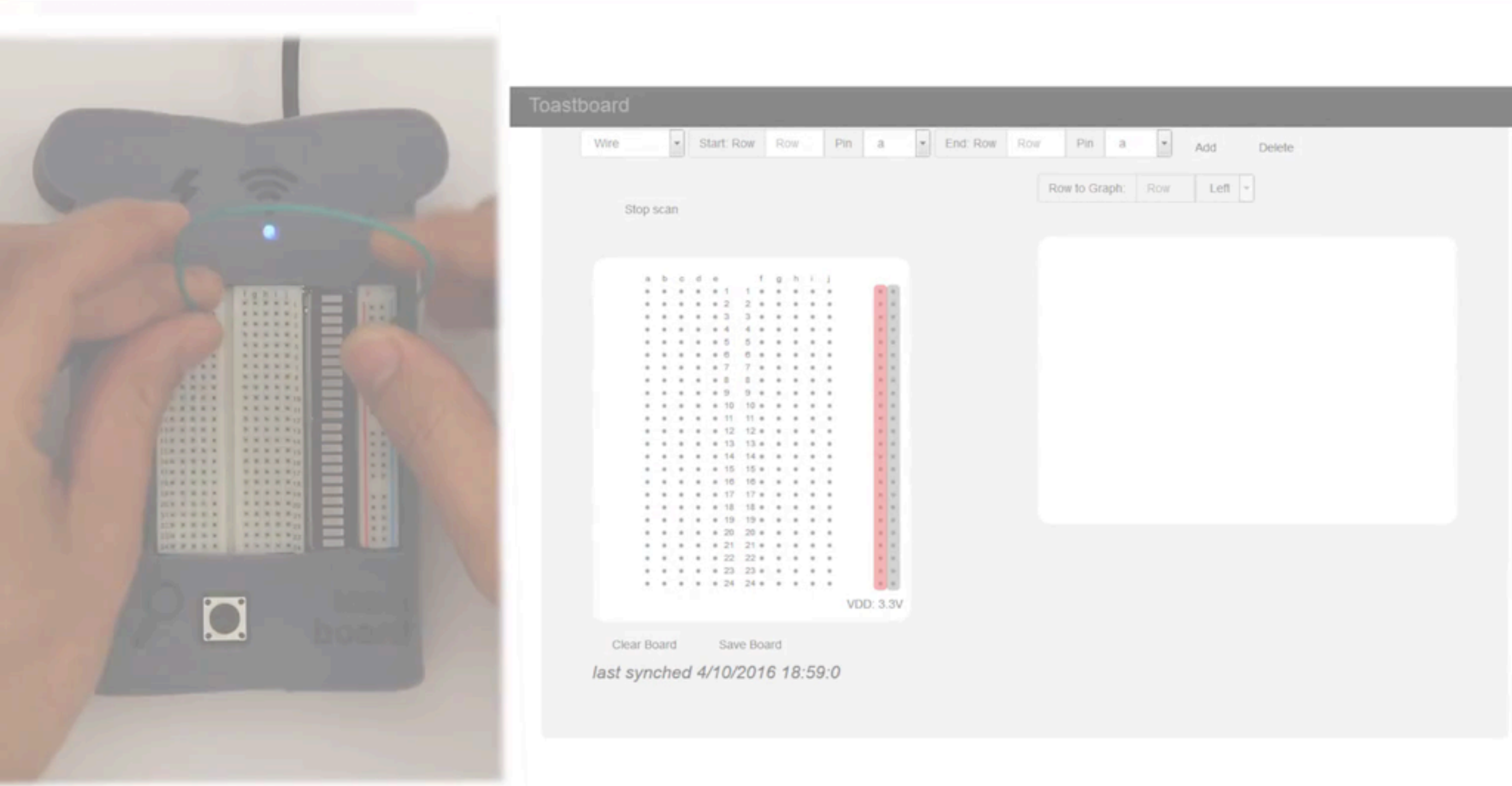
past of **PCB making:** expert users + special machines

the hardware is getting there…

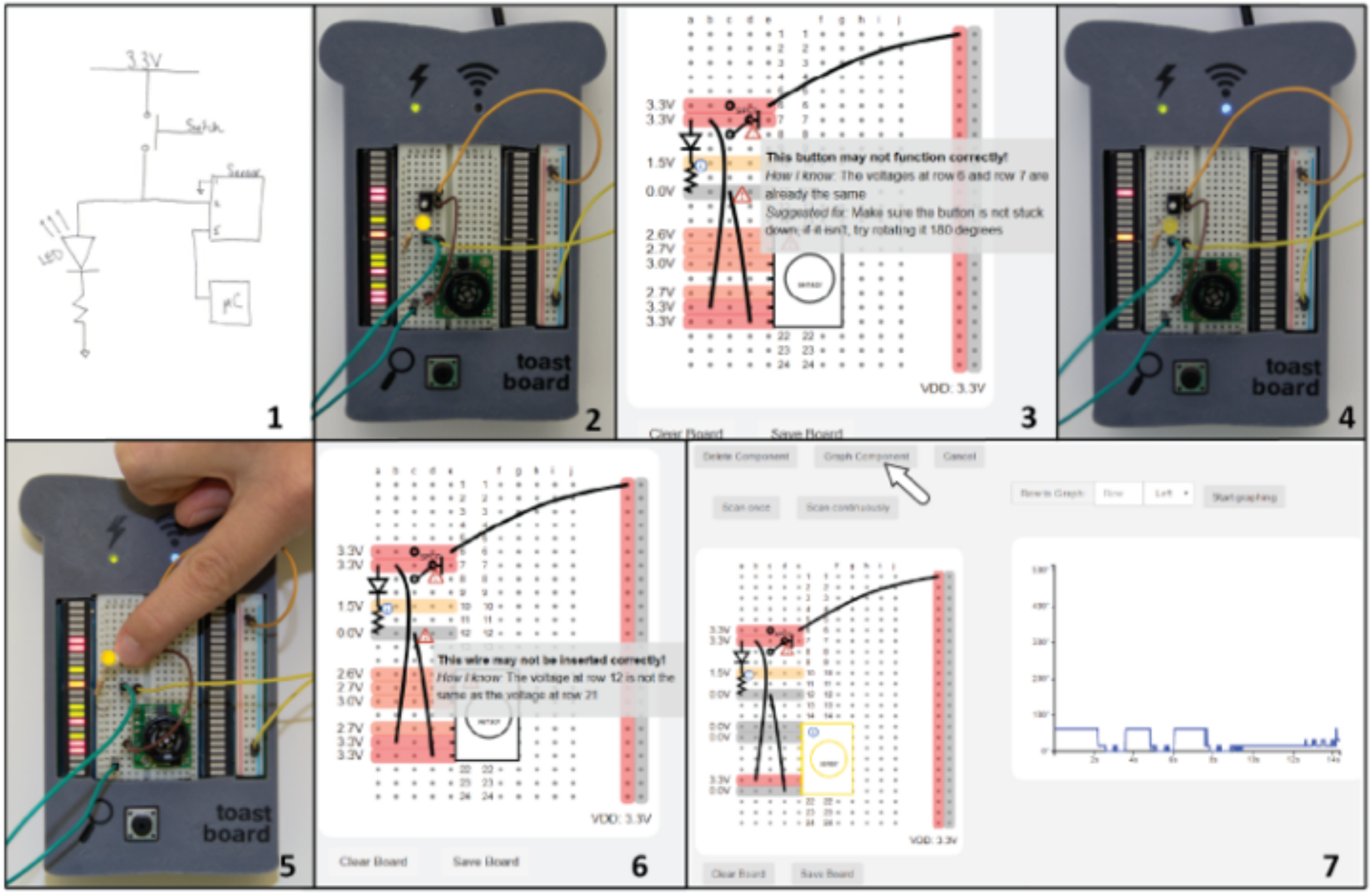
but it's still **hard to design**

electronics and physical objects.

making
electronics easier to use



2016 Toastboard: interactive feedback during prototyping



- every row is **scanned** (multiplexed)
  - connected to AD converter to measure voltage
- **voltage information displayed** via LED bar
- software interfaces with more **high-level reasoning**
  - user first has to indicate the type of component

The Toastboard: Ubiquitous Instrumentation and Automated Checking of Breadboarded Circuits

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ABSTRACT

The recent proliferation of easy to use electronic components and toolkits has introduced a large number of novices to designing and building electronic projects. Nevertheless, debugging circuits remains a difficult and time-consuming task. This paper presents a novel debugging tool for electronic design projects, the Toastboard, that aims to reduce debugging time by improving upon the standard paradigm of point-wise circuit measurements. Ubiquitous instrumentation allows for immediate visualization of an entire breadboard's state, meaning users can diagnose problems based on a wealth of data instead of having to form a single hypothesis and plan before taking a measurement. Basic connectivity information is displayed visually on the circuit itself and quantitative data is displayed on the accompanying web interface. Software-based testing functions further lower the expertise threshold for efficient debugging by diagnosing classes of circuit errors automatically. In an informal study, participants found the detailed, pervasive, and context-rich data from our tool helpful and potentially time-saving.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords

Physical computing; debugging interfaces; circuits

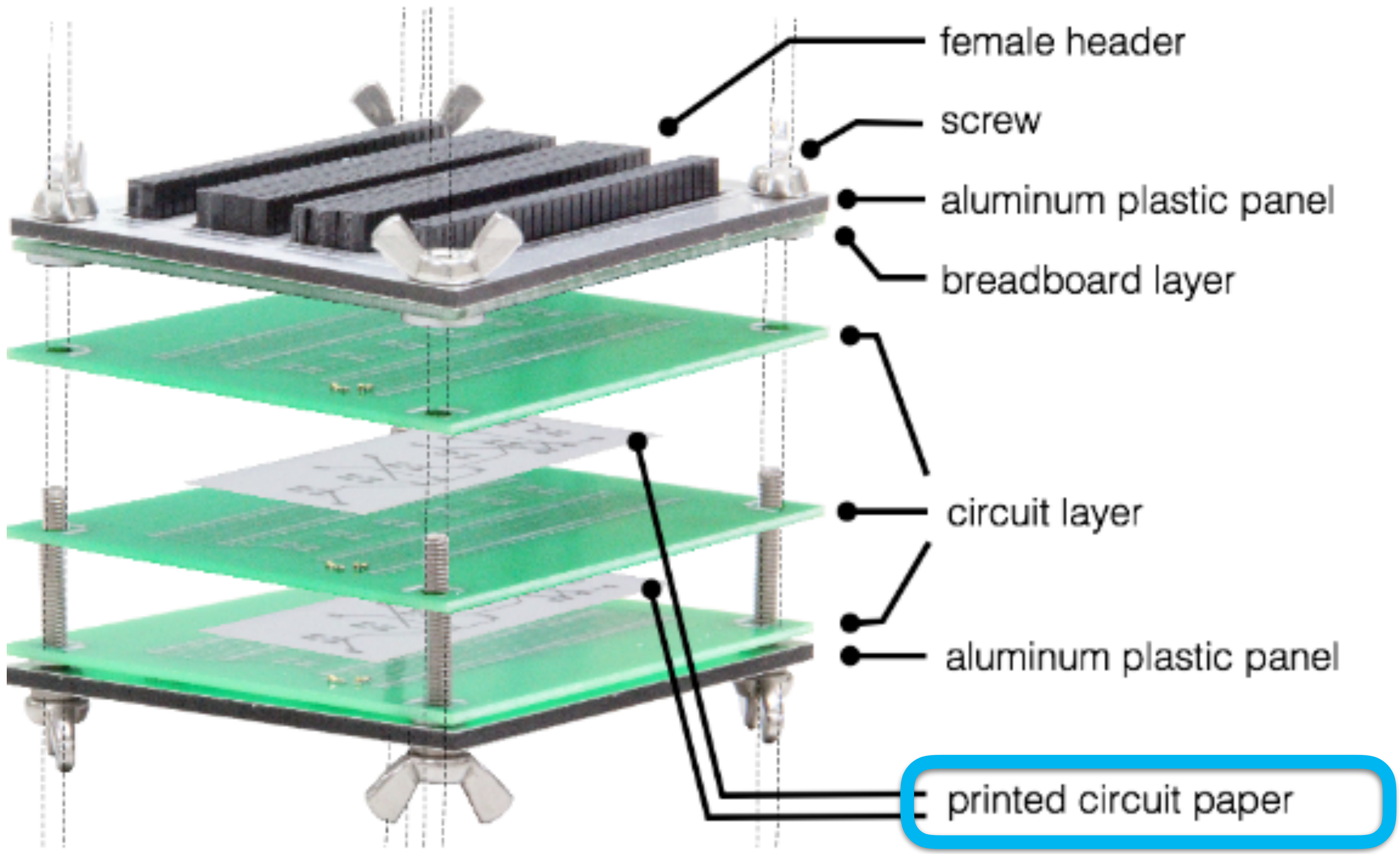
Figure 1. The Toastboard device and accompanying software. (1) LED bars indicate power, ground, or other voltage. (2) A push button triggers a scan. (3) Quantitative voltage data is displayed in the accompanying software. (4) Components are associated with testers that run on every scan. (5) The voltage at a selected row can be viewed over time as a graph.

frustrating, and time-consuming to debug. Errors can stem from a variety of sources all requiring different tools and techniques to diagnose. Users who have not yet built up debugging experience and intuition often find it difficult to efficiently locate and correct hardware bugs [7, 13, 18, 27].

The solderless plugboard, or breadboard, became available in the 1970s [24]. This passive device for making electrical connections is so prevalent that it is almost synonymous with the act of circuit prototyping. Despite their popularity, breadboarded circuits are prone to a host of common issues

2016 CircuitStack: hybrid of printable circuit and breadboard

- disconnects wires from components



e.g. find circuit online, print PCB layer, then plug components

CircuitStack: Supporting Rapid Prototyping and Evolution of Electronic Circuits

Chiuan Wang* **Hsuan-Ming Yeh*** **Bryan Wang*** **Te-Yen Wu*** **Hsin-Ruey Tsai***
Rong-Hao Liang* **Yi-Ping Hung†** **Mike Y. Chen†**
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†{hung, mikechen}@csie.ntu.edu.tw

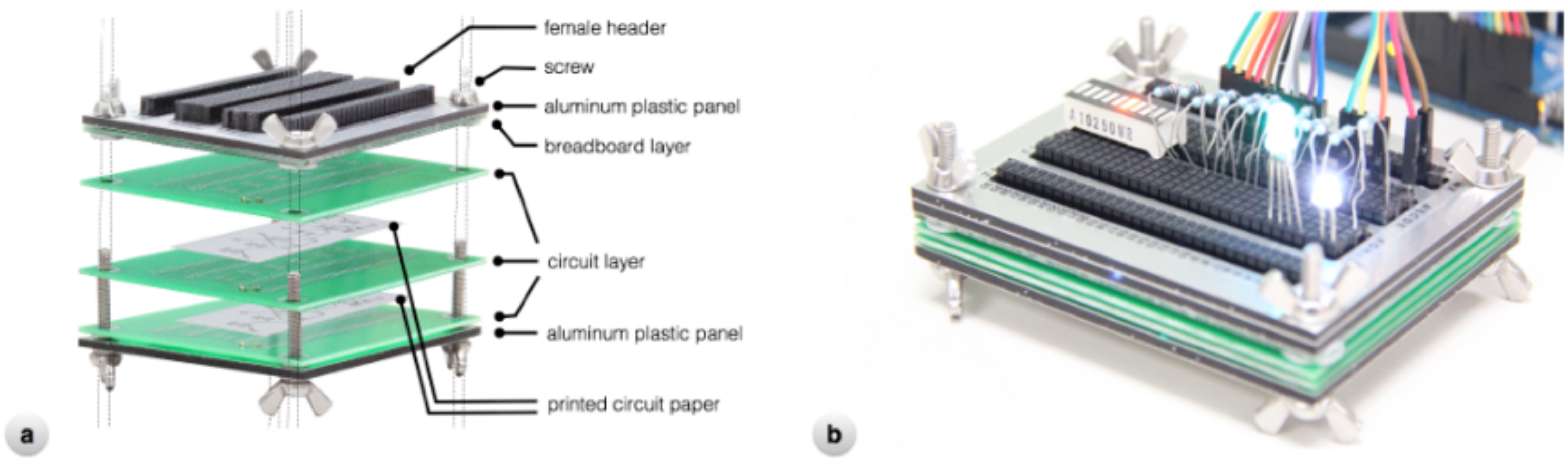
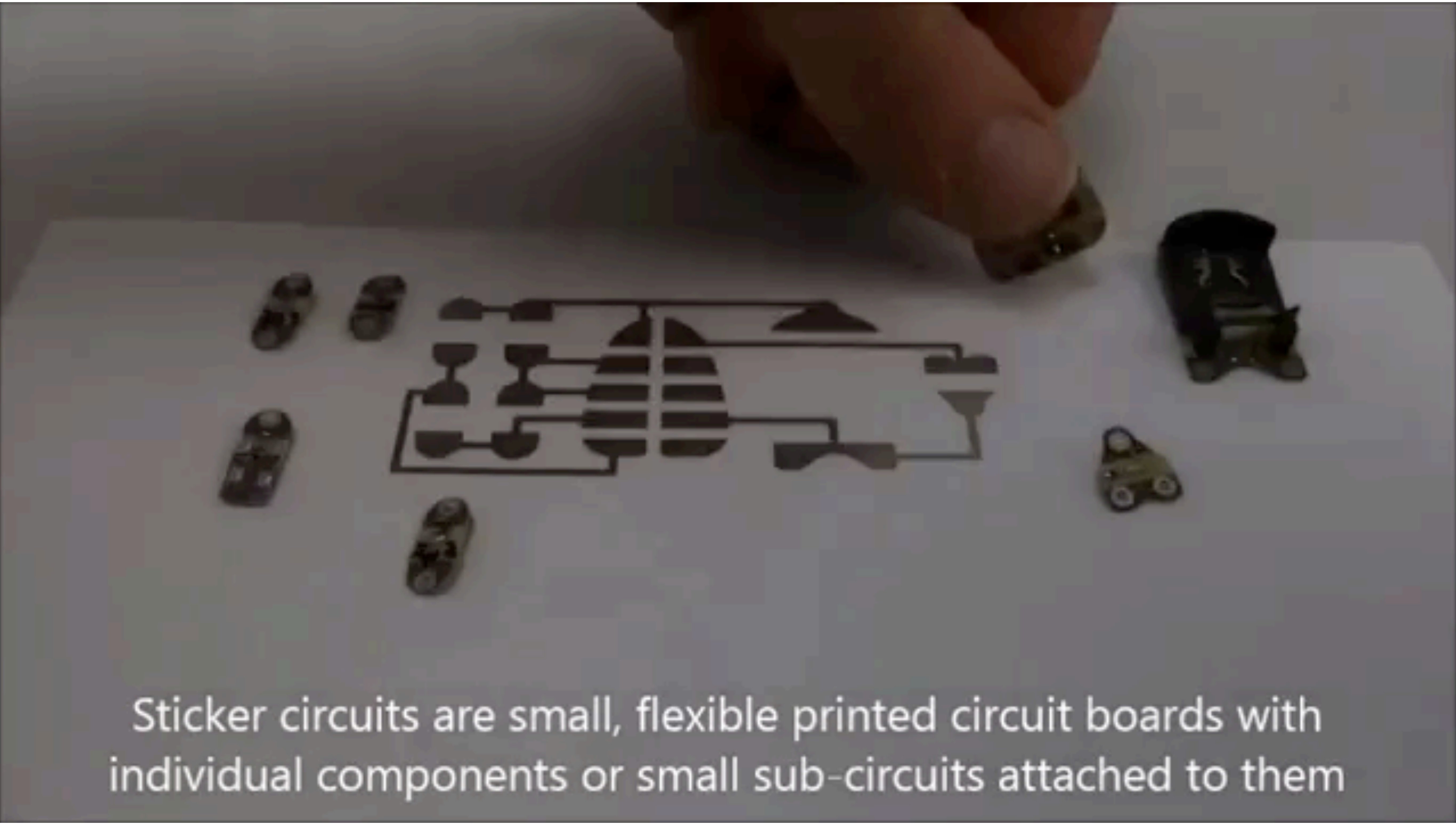


Figure 1. *CircuitStack* is a hybrid system of breadboard and printed circuits which compose of customized PCBs in a stacked structure. (a) Overview. (b) Assembled state with placed components.

ABSTRACT
For makers and developers, circuit prototyping is an integral part of building electronic projects. Currently, it is common to build circuits based on breadboard schematics that are available on various maker and DIY websites. Some breadboard schematics are used as is without modification, and some are modified and extended to fit specific needs. In such

ACM Classification Keywords
H.5.2. [Information Interfaces and Presentation]: Prototyping

INTRODUCTION
Circuit prototyping is an essential process in which makers and developers build, experiment on, and verify circuit designs for various types of electronic projects. Currently, cir-



2014 Circuit Stickers:

- no soldering, just stick it on

Circuit Stickers: Peel-and-Stick Construction of Interactive Electronic Prototypes

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ABSTRACT

We present a novel approach to the construction of electronic prototypes which can support a variety of interactive devices. Our technique, which we call *circuit stickers*, involves adhering physical interface elements such as LEDs, sounders, buttons and sensors onto a cheap and easy-to-make substrate which provides electrical connectivity. This assembly may include control electronics and a battery for standalone operation, or it can be interfaced to a microcontroller or PC. In this paper we illustrate different points in the design space and demonstrate the technical feasibility of our approach. We have found circuit stickers to be versatile and low-cost, supporting quick and easy construction of physically flexible interactive prototypes. Building extra copies of a device is straightforward. We believe this technology has potential for design exploration, research prototyping, education and for hobbyist projects.

Author Keywords

Conductive inkjet; silver ink; rapid prototyping; physical computing; solderless electronics; tangible interfaces.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

In recent years there has been an explosion in the availability and use of electronic prototyping platforms in a range of our scheme, the hardware building blocks for constructing a device are simple elements in the form of small printed circuit board (PCBs). These are connected together physically and electrically to form a working prototype by sticking them onto a cheap and easy-to-make substrate. A battery can be included for standalone operation, or the resulting assembly can be interfaced to a microcontroller or a PC.

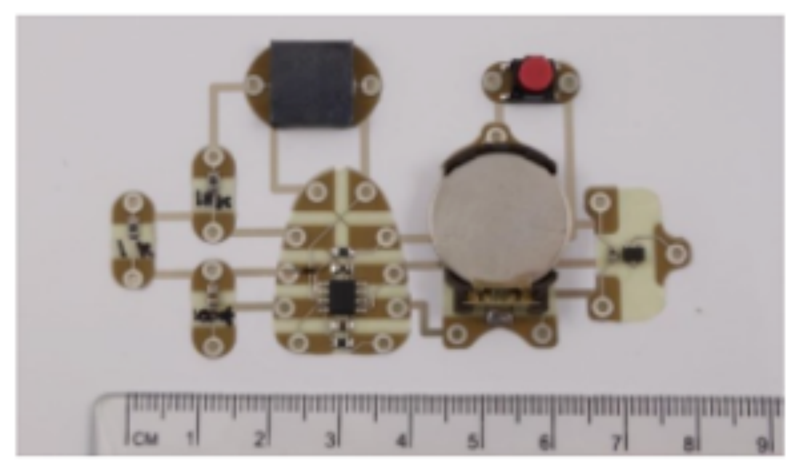
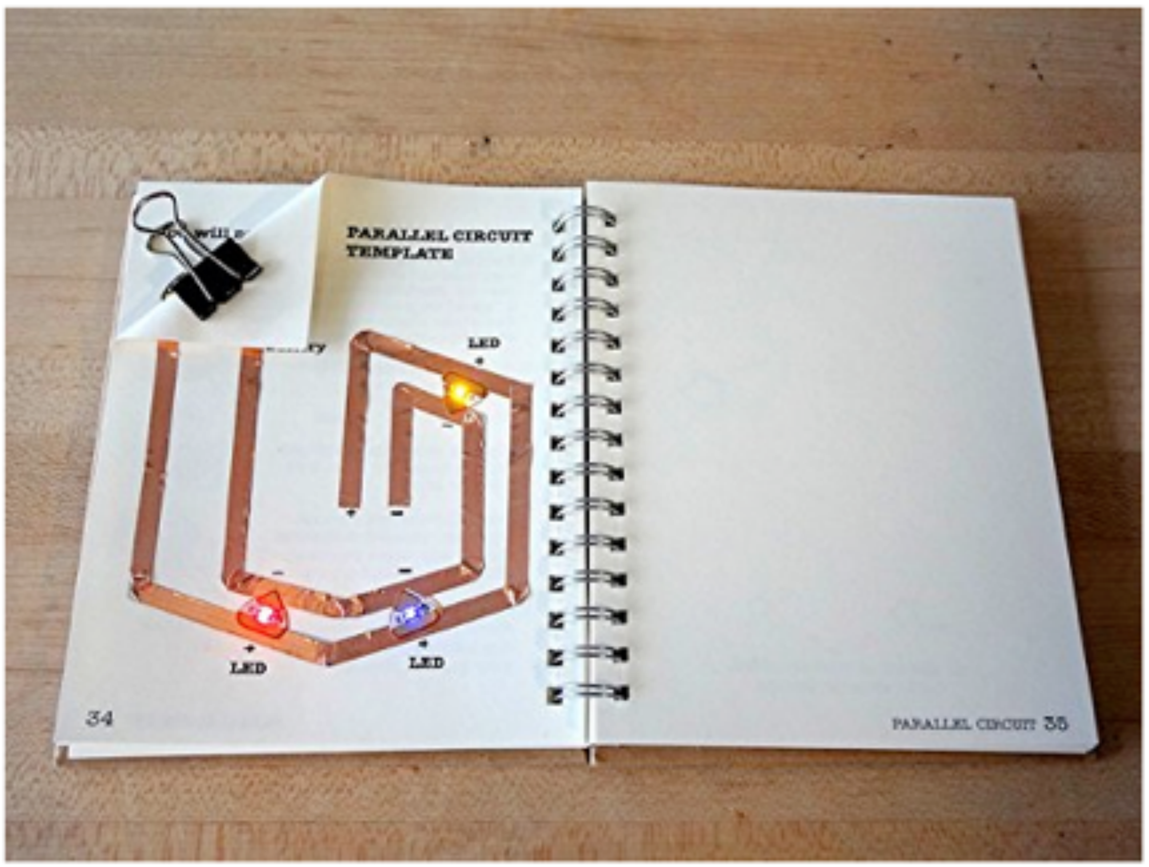


Figure 1: An example circuit sticker design. The stickers needed for a coin-cell powered musical toy are stuck to a sheet of paper which has been inkjet printed with silver conductors.

Whilst our technique is not a panacea, it provides a useful alternative to established approaches. We believe it is particularly well-suited to building reasonably compact and robust interactive devices. It is simple to use, versatile, easy to replicate and results in physically flexible prototypes.



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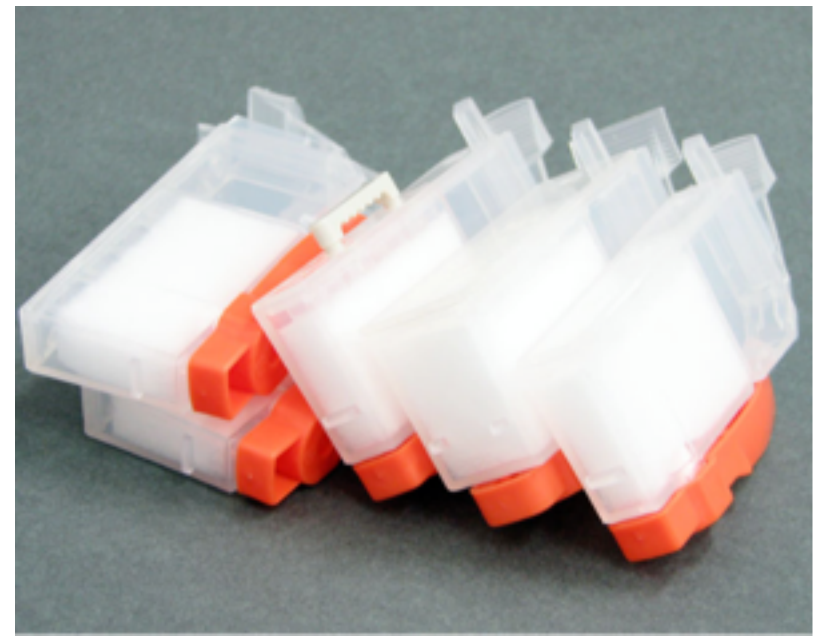
2014 Circuit Stickers: commercially available as Chibitronics silver ink

2D printer

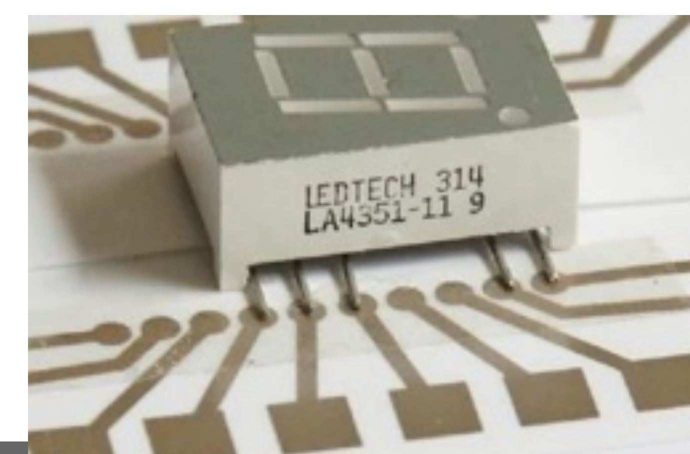
Epson Stylus C88

Price: $110.00

empty cartridges

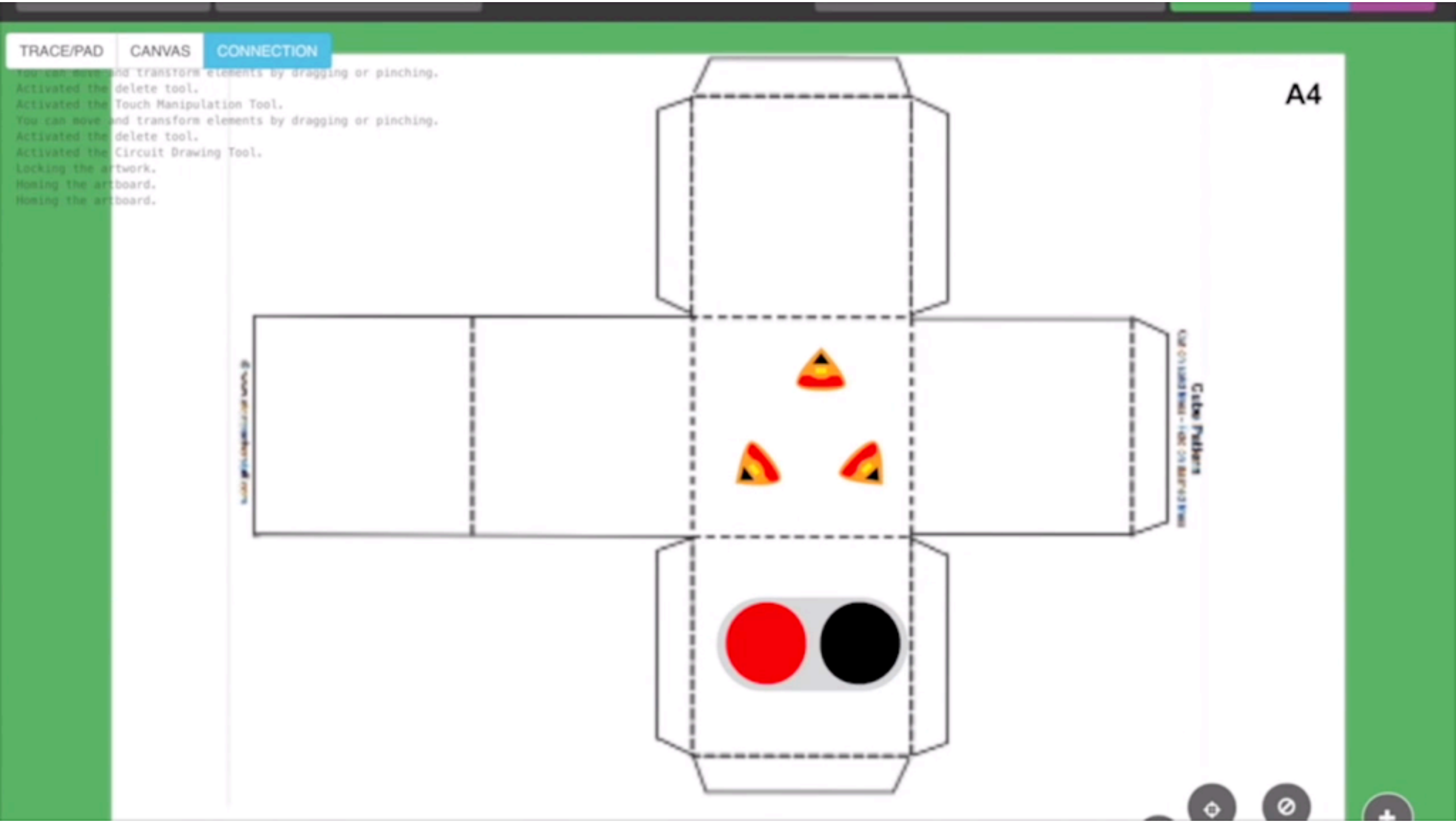


syringe

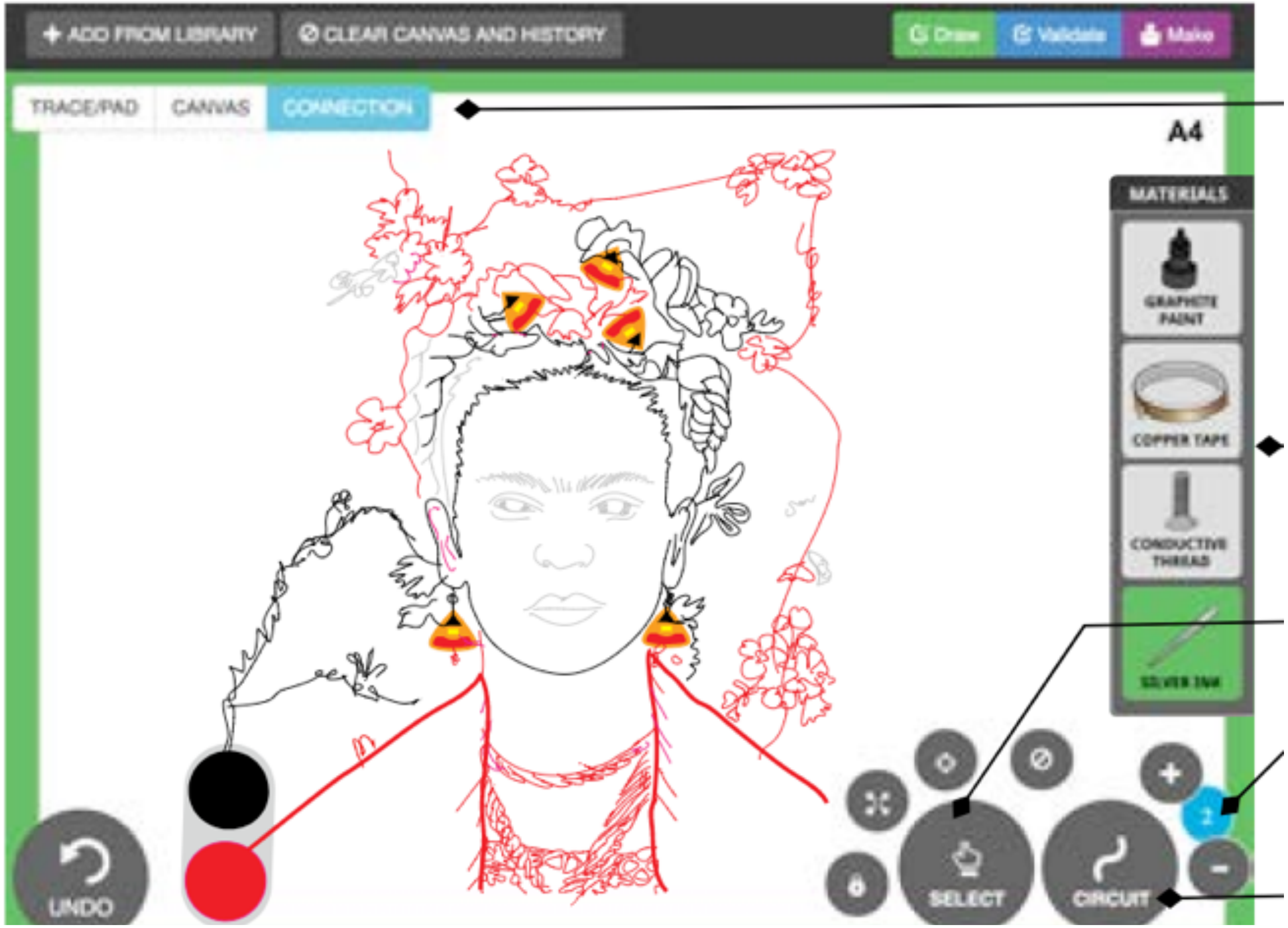


http://www.nano-di.com/conductive-inks

#1 conductive inkjet printing



2016 aesthetic electronics



- color code lines connected to V, G, or neutral (black, red, gray)
- graying out design traces while testing circuit traces
- battery check
- connection check
- resistance check
- fabrication check

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#2 silver pen

Aesthetic Electronics: Designing, Sketching, and Fabricating Circuits through Digital Exploration

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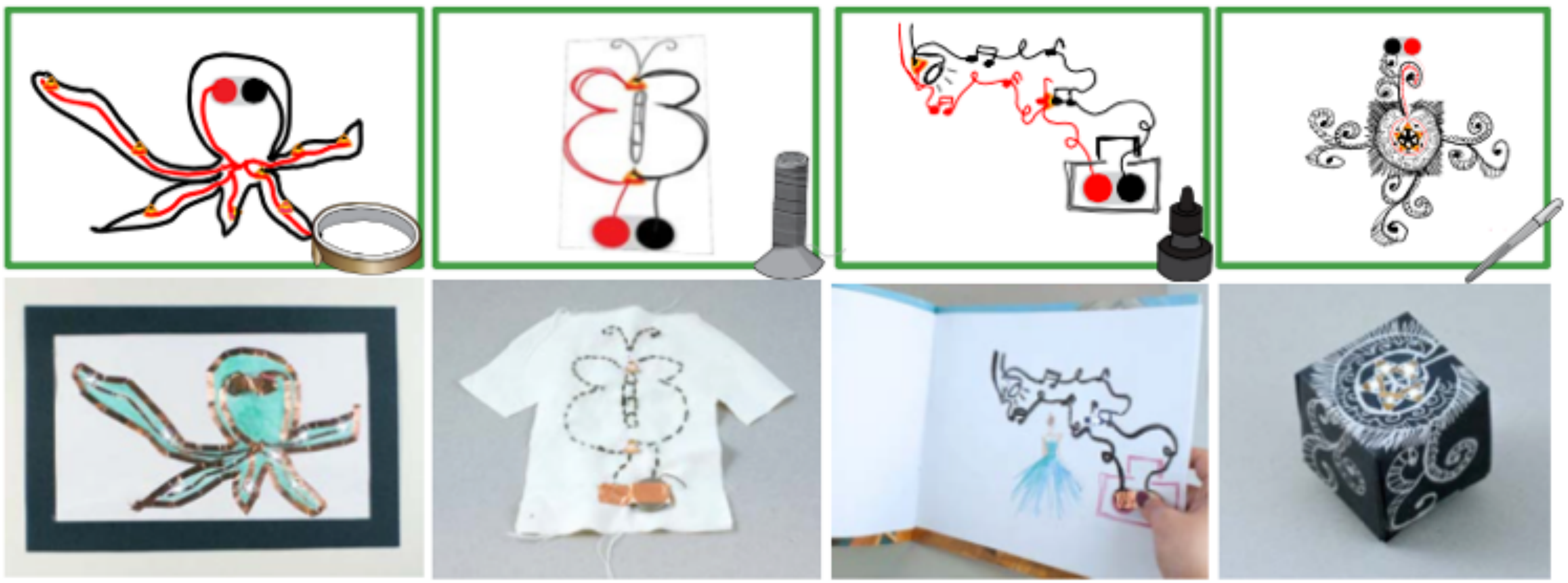


Figure 1. Sketched digital circuits (top), and fabricated circuits (bottom) created through various craft mediums: a) copper tape painting on paper, b) sewn conductive thread on fabric, c) painted graphite ink as interactive illustration, and d) decorative silver ink to ornament physical objects.

ABSTRACT

As interactive electronics become increasingly intimate and personal, the design of circuitry is correspondingly developing a more playful and creative aesthetic. Circuit sketching and design is a multidimensional activity which combines the arts, crafts, and engineering broadening participation of electronic creation to include makers of diverse backgrounds. In order to support this design ecology, we present Ellustrate, a digital design tool that enables the functional and aesthetic design of electronic circuits with multiple conductive and dielectric materials. Ellustrate guides users through the fabrication and debugging process, easing the task of practical circuit creation while supporting designers' aesthetic decisions throughout the circuit authoring workflow. In a formal

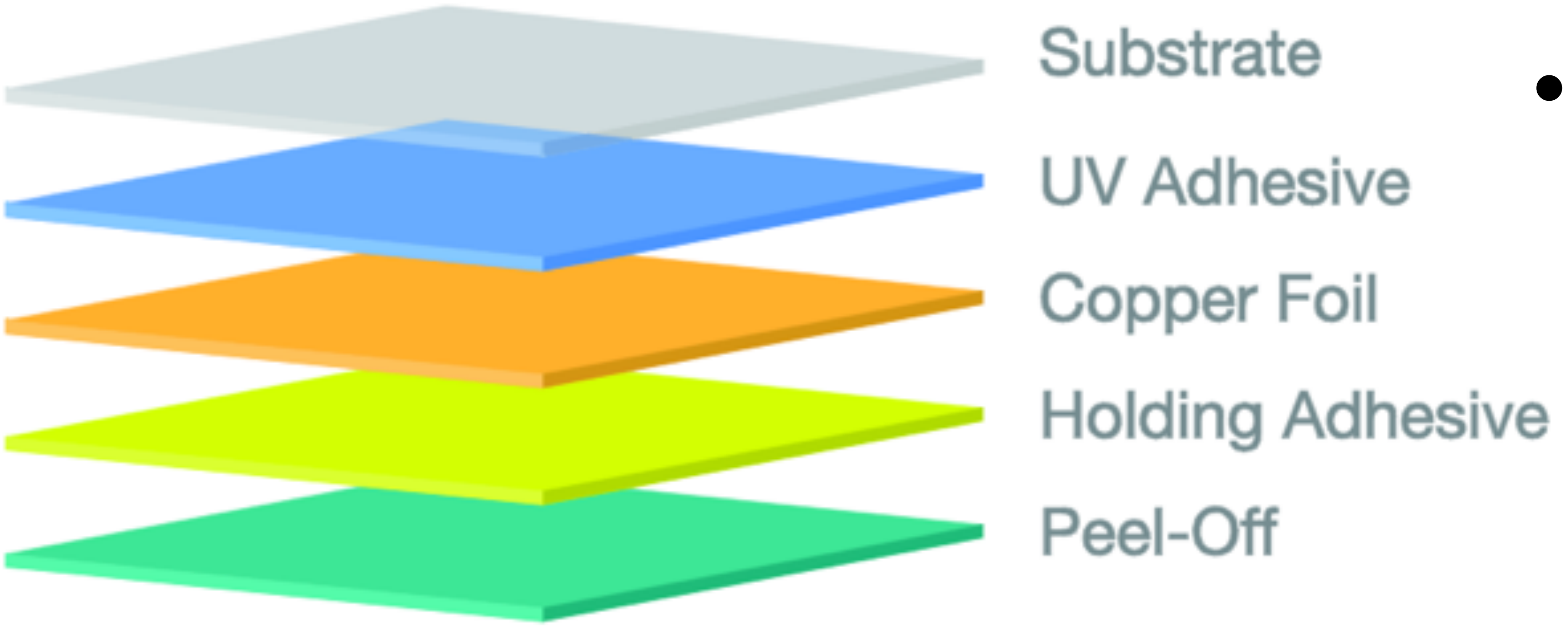
ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

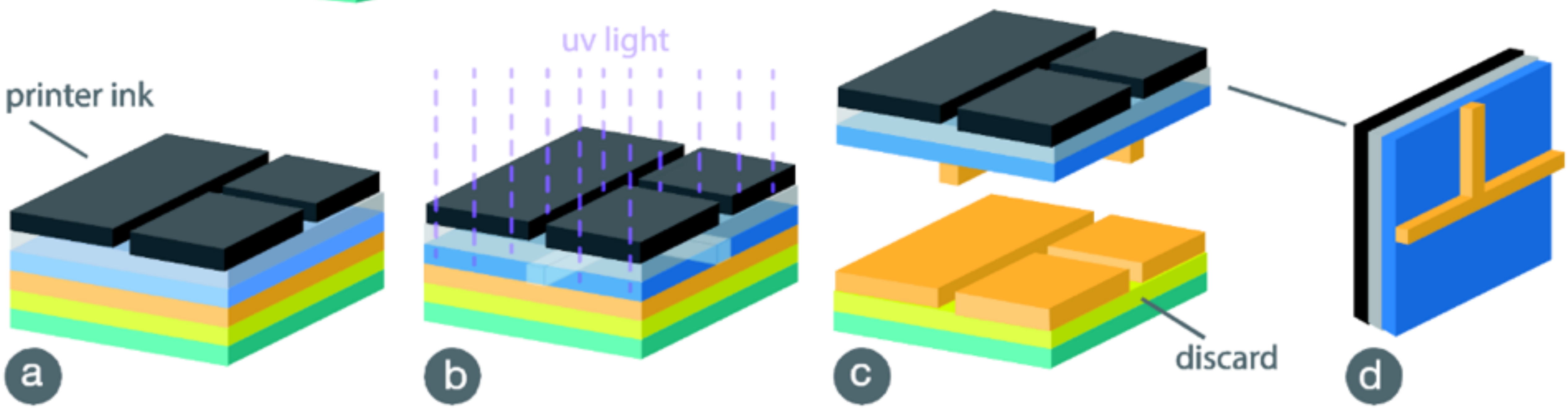
INTRODUCTION

The landscape of electronics is rapidly changing. Devices are becoming exponentially smaller, requiring electronic circuits to be printed directly on a device's housing and on ultra-thin wearables [19, 14]. As such, new designs must blend functional and aesthetic design variables. Echoing the Radical Atoms vision, such designs compel "new material design principles" that unify these design variables in order to"treat objects as homogeneous entities with the ability to change their properties" [12]

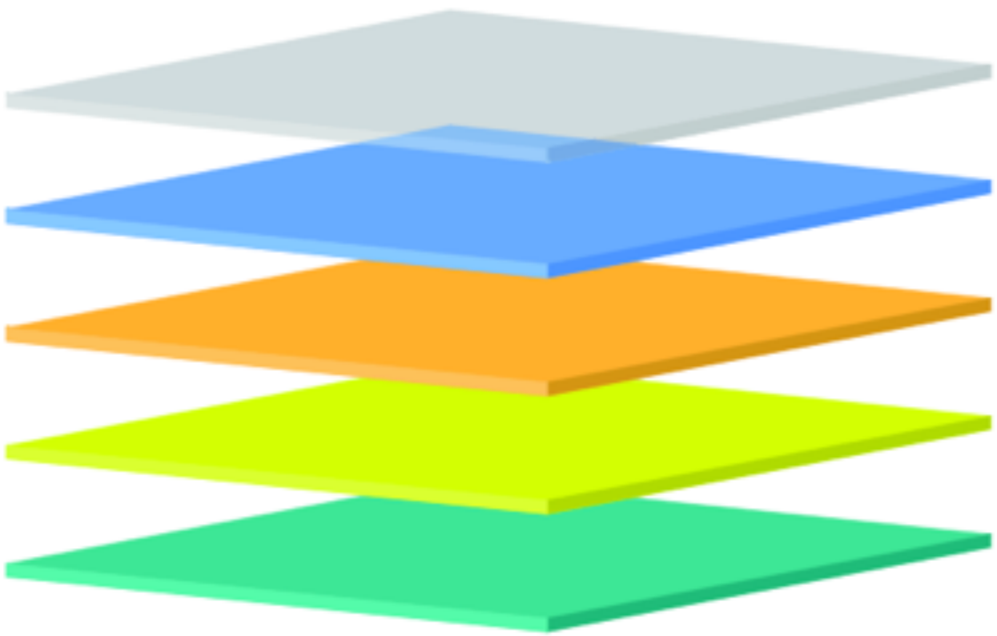
2015 Printem: no need for PCB etching, just use 2D printing!



- thin enough for 2D printing



- print negative of circuit with black ink on printem film
- expose film to UV light for 90 seconds (activates glue)
- where there's no black, light activates glue
- peel off layer: removes conductive ink in adhered areas



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Length: **100 ft**

#3 copper foil

Printem: Instant Printed Circuit Boards with Standard Office Printers & Inks

Varun Perumal C, Daniel Wigdor
Department of Computer Science
University of Toronto, Toronto, ON, Canada
{varun | daniel}@dgp.toronto.edu

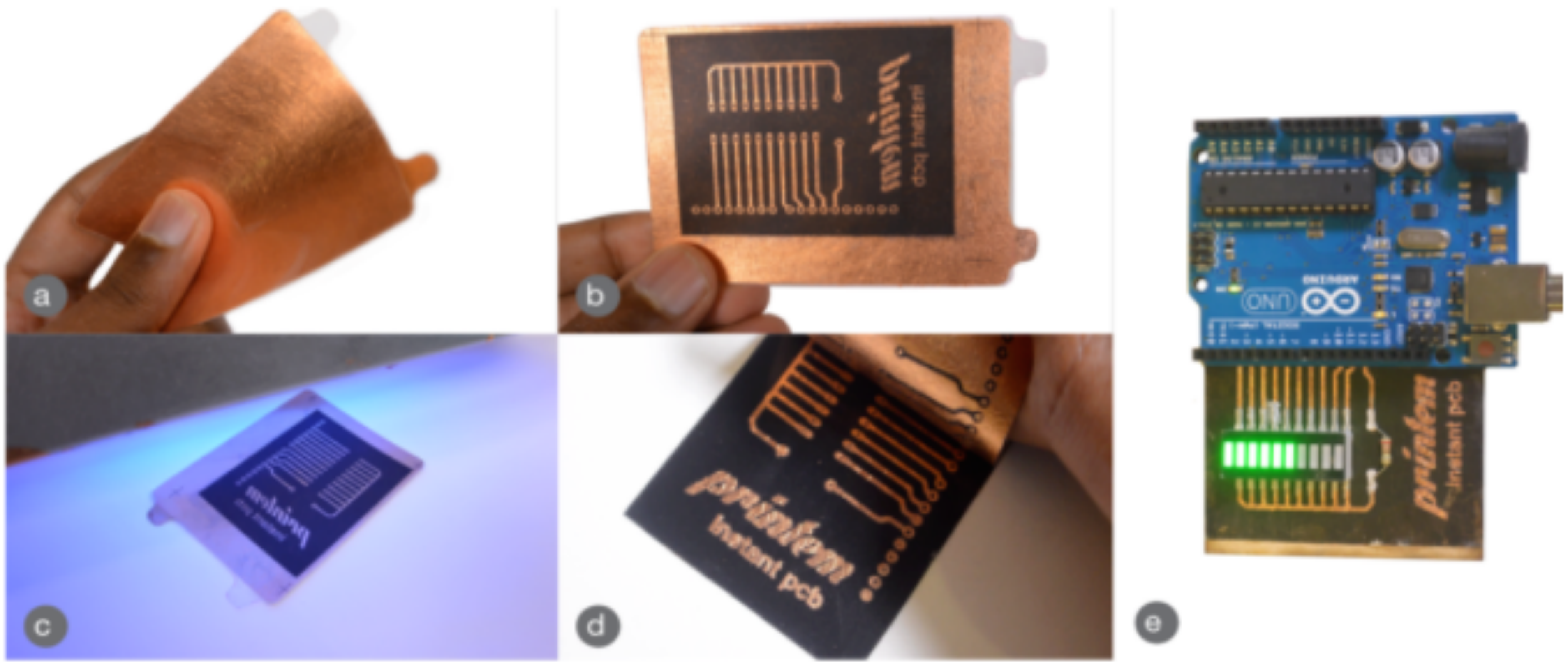


Figure 1. The use of Printem to instantly create a printed circuit board: (a) a blank Printem film; (b) a mask is printed; (c) the arrangement is exposed to UV or sunlight (d) top layer is removed, leaving behind a copper PCB; (e) components are added.

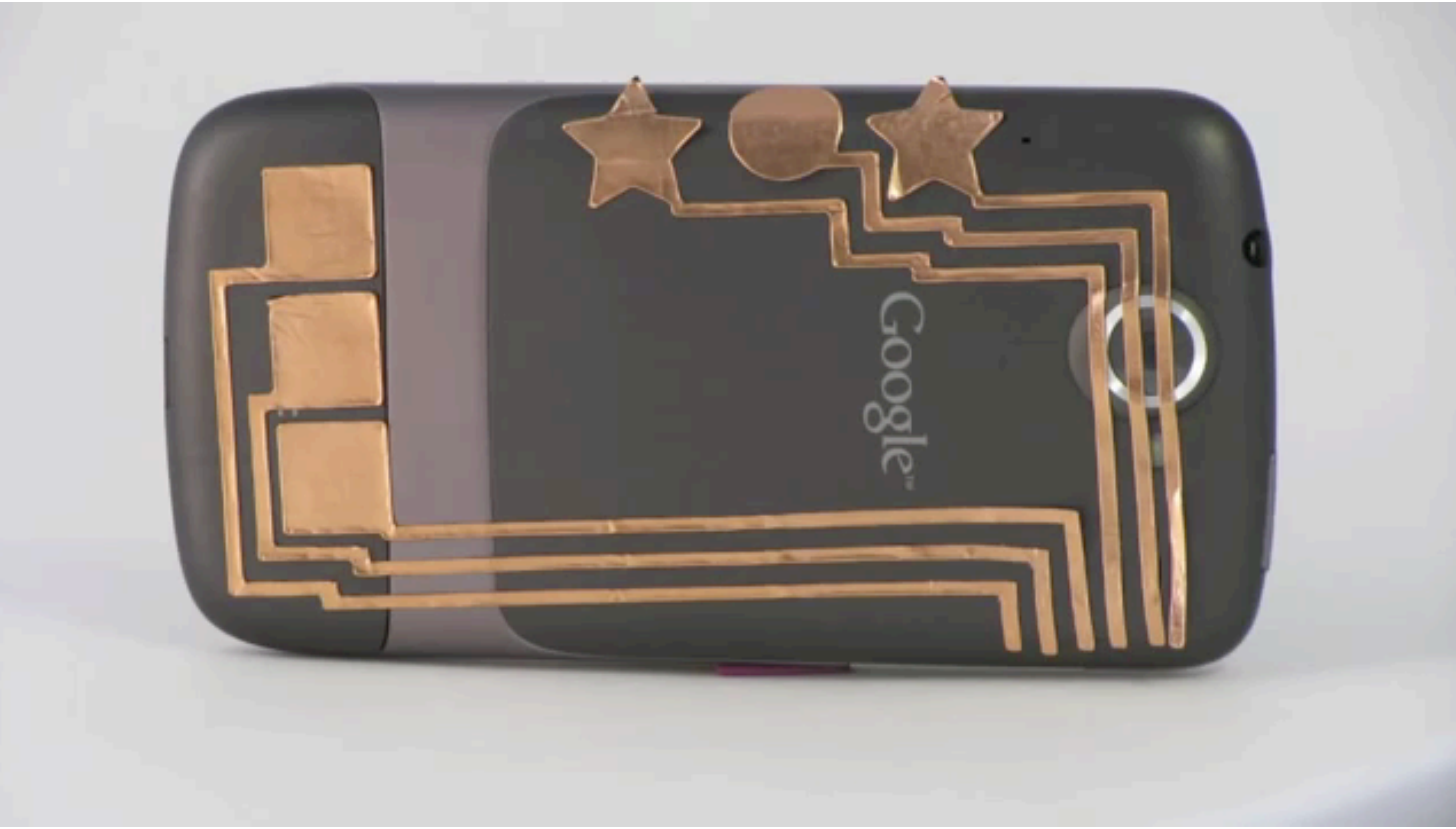
ABSTRACT

Printem film, a novel method for the fabrication of Printed Circuit Boards (PCBs) for small batch/prototyping use, is presented. Printem film enables a standard office inkjet or laser printer, using standard inks, to produce a PCB: the user prints a negative of the PCB onto the film, exposes it to UV or sunlight, and then tears-away the unneeded portion of the film, leaving-behind a copper PCB. PCBs produced with Printem film are as conductive as PCBs created using standard industrial methods. Herein, the composition of Printem film is described, and advantages of various materials discussed. Sample applications are also described, each of which demonstrates some unique advantage of

INTRODUCTION

Printed Circuit Boards (PCBs) form the structural and connective underpinnings of electronic assemblies. Nearly every electronic device contains one or more PCBs on which the functional components such as integrated circuits (ICs), resistors, connectors, etc. are placed. PCBs function to provide power to the various components, enable communication, and act as a mechanical support structure to allow the assembly to be fixed into enclosures.

Despite their prominence, building physical electronics prototypes is presently cumbersome. Industrial processes, such chemical etching, require significant equipment and hazardous materials. Prototyping methods such as silver inks



2012 Midas: help with **laying out wires**

Midas: Fabricating Custom Capacitive Touch Sensors to Prototype Interactive Objects

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University of California, Berkeley
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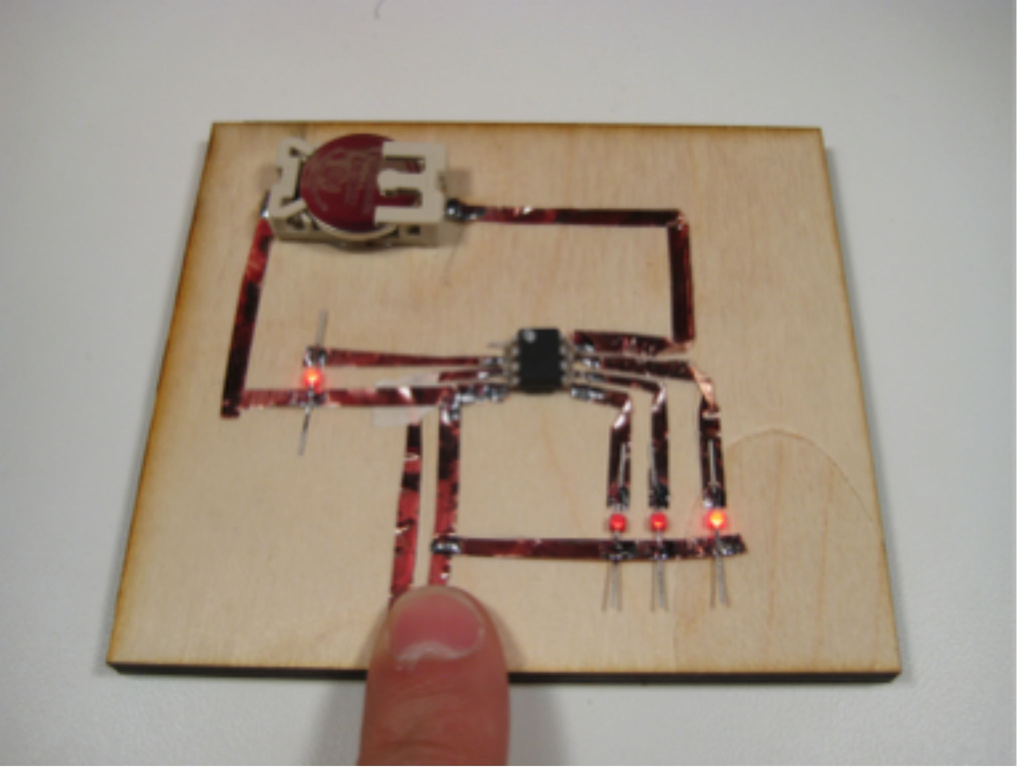
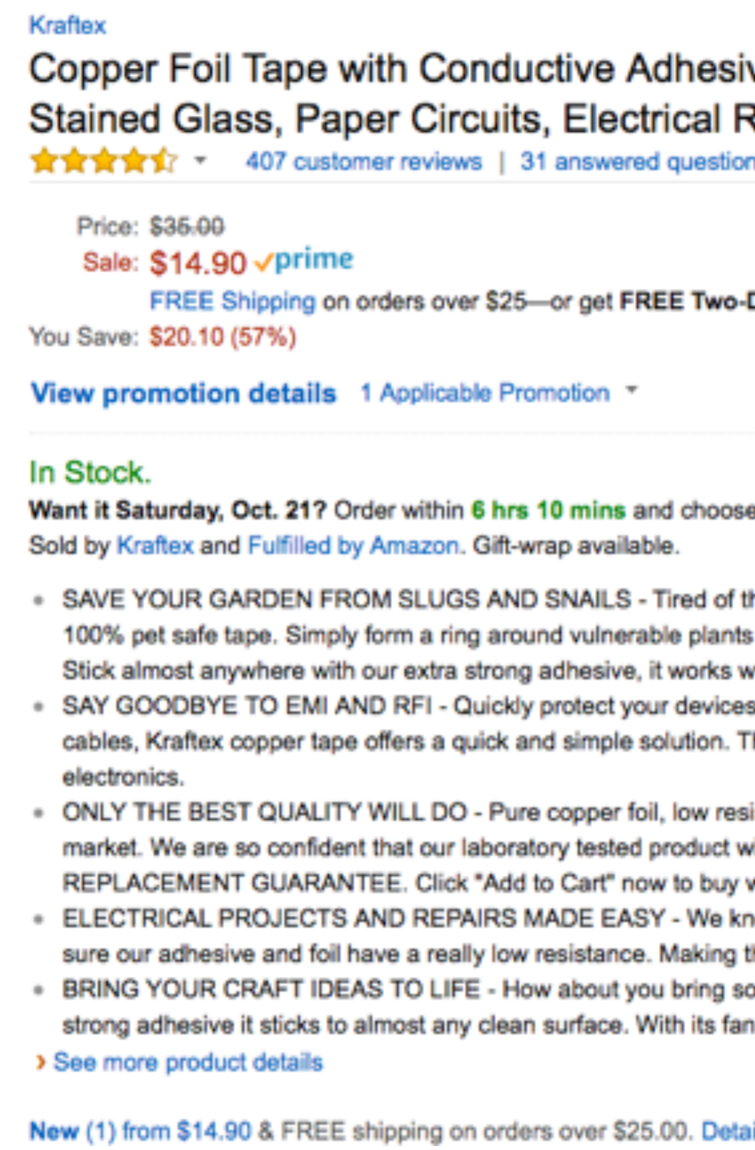
ABSTRACT

An increasing number of consumer products include user interfaces that rely on touch input. While digital fabrication techniques such as 3D printing make it easier to prototype the shape of custom devices, adding interactivity to such prototypes remains a challenge for many designers. We introduce Midas, a software and hardware toolkit to support the design, fabrication, and programming of flexible capacitive touch sensors for interactive objects. With Midas, designers first define the desired shape, layout, and type of touch sensitive areas, as well as routing obstacles, in a sensor editor. From this high-level specification, Midas automatically generates layout files with appropriate sensor pads and routed connections. These files are then used to fabricate sensors using digital fabrication processes, e.g., vinyl cutters and conductive ink printers. Using step-by-step assembly instructions generated by Midas, designers connect these sensors to the Midas microcontroller, which detects touch events. Once the prototype is assembled, designers can define interactivity for their sensors: Midas supports both record-and-replay actions for controlling existing local applications and WebSocket-based event output for controlling novel or remote applications. In a first-use study with three participants, users successfully prototyped media players. We also demonstrate how Midas can be used to create a number of touch-sensitive interfaces.

Figure 1: Midas enables users to define discrete and continuous touch sensors with custom shapes and layout. It generates fabrication files and assembly instructions. Designers can also define the interaction events of their prototype.

Digital fabrication processes like 3D printing and CNC machining make it easier to prototype the form of such products, enabling designers to go directly from a digital 3D model to a physical object. In addition, user interface prototyping tools have lowered the threshold to connect sensors to





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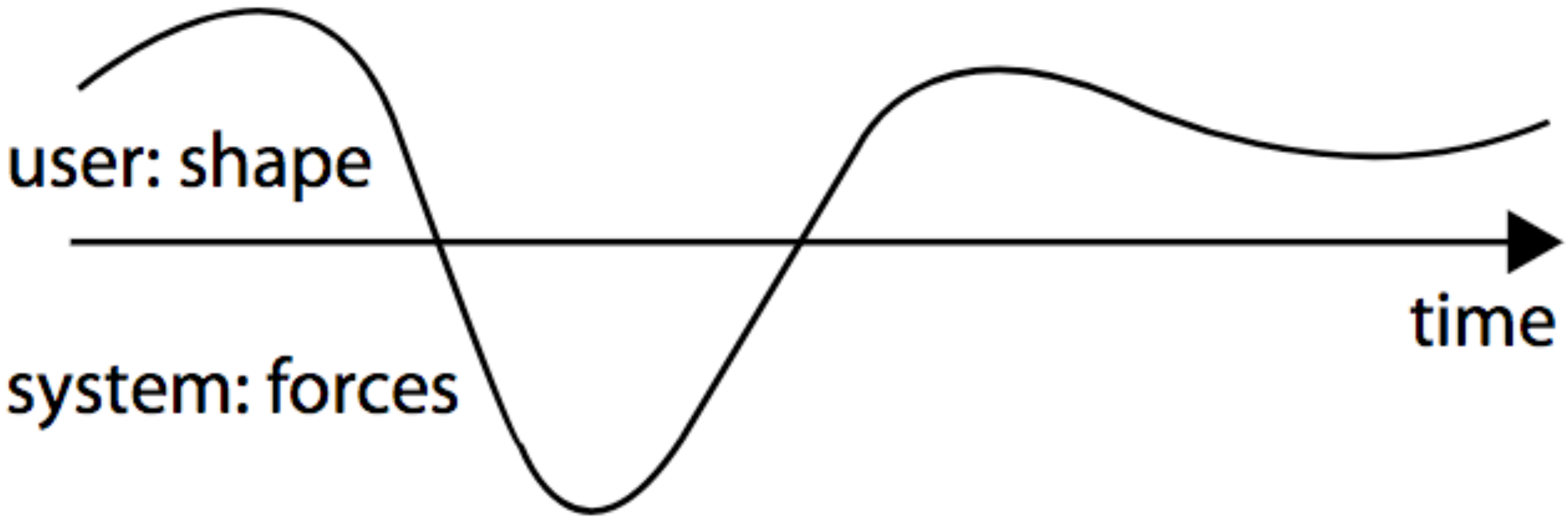
#4 copper tape

making
physical object design
easier

almost all 3D printed designs are just **decorative shapes :(**



- users are good at designing shape
- but are typically bad at designing for **forces** (invisible)
- understanding of forces is required for **functional objects**

2011 SketchChair - analysis of **balance (statics)**

SketchChair: An All-in-one Chair Design System for End Users

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ABSTRACT
SketchChair is an application that allows novice users to control the entire process of designing and building their own chairs. Chairs are designed using a simple 2D sketch-based interface and design validation tools, and are then fabricated from sheet materials, cut by a laser cutter or CNC milling machine. This paper presents the concepts and details of *SketchChair*, and both miniature and full-sized chairs are designed using the application. We conclude with results and insights from a workshop in which novice users designed their own model chairs.

Author Keywords
User-generated Design, Rapid Prototyping, User Interface, Sketch-based modeling, Fabrication, Customization.

ACM Classification Keywords
I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling; H.1.2 User/Machine Systems; J.6 Computer-aided engineering (computer aided design).

General Terms
Design, Experimentation.

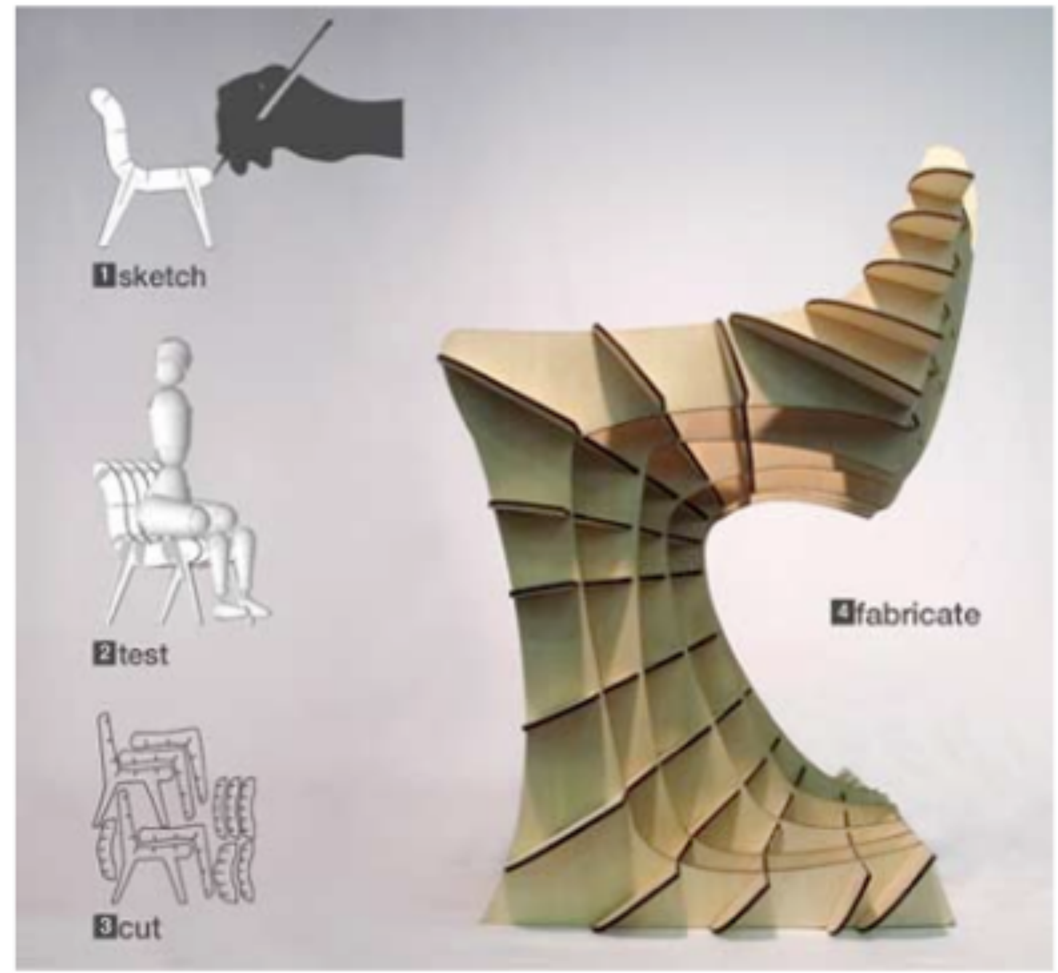


Figure 1. Process diagram for designing a chair using our system.

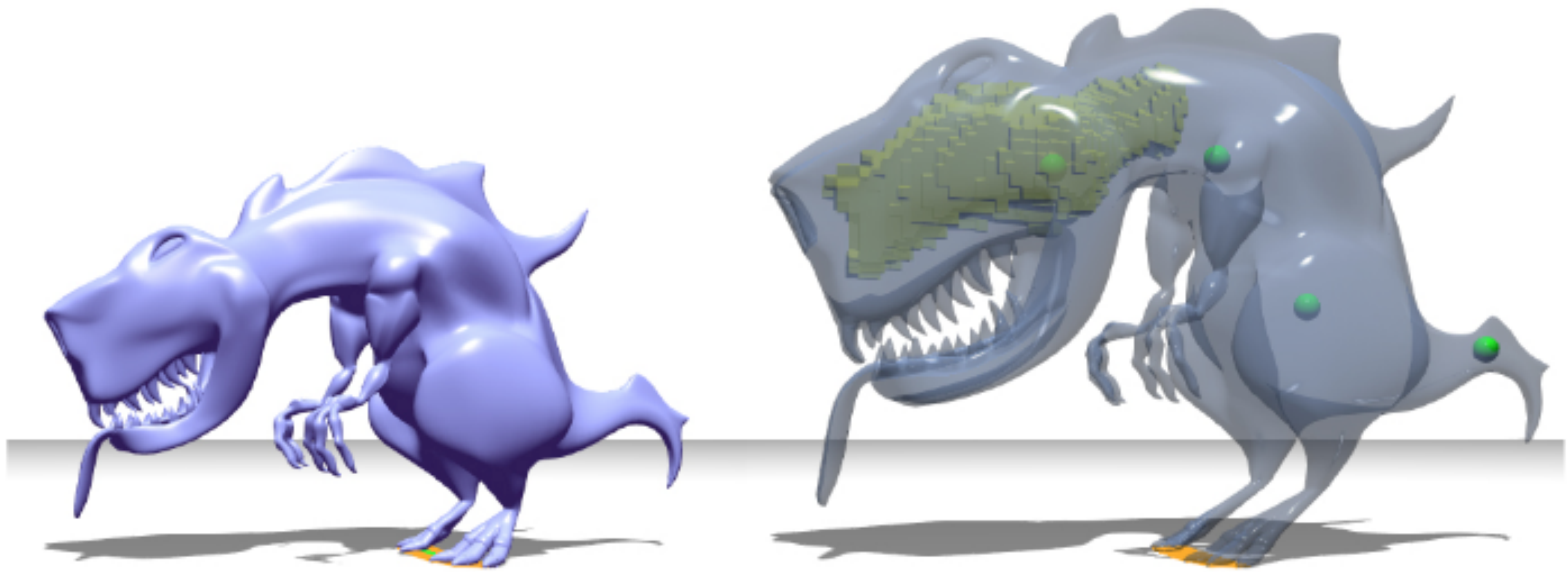
INTRODUCTION
Recently, there have been significant advances in digital manufacturing technologies. Tools, such as 3D printers, laser cutters, and computer-controlled milling machines, have become cheaper and more accessible to consumers. These

faced with complex programs intended for experts, such as SolidWorks [3] and AutoCAD [1]. Moreover, these tools are usually only part of the design process. Before a functional product can be developed, other steps may need to be performed outside the CAD system (e.g., sketching, prototyping, testing).

2013 Make it Stand - analysis of **balance (statics)**

any idea what they do to the model to make it stand?

<30 sec brainstorming>



any idea what they do to the model to make it stand?

- redistribute infill
- use two different print materials (one light, one heavy)
- deform object only if other two approaches are not enough

Make It Stand: Balancing Shapes for 3D Fabrication

Romain Prévost[1] Emily Whiting[1] Sylvain Lefebvre[2] Olga Sorkine-Hornung[1]

[1]ETH Zurich [2]INRIA

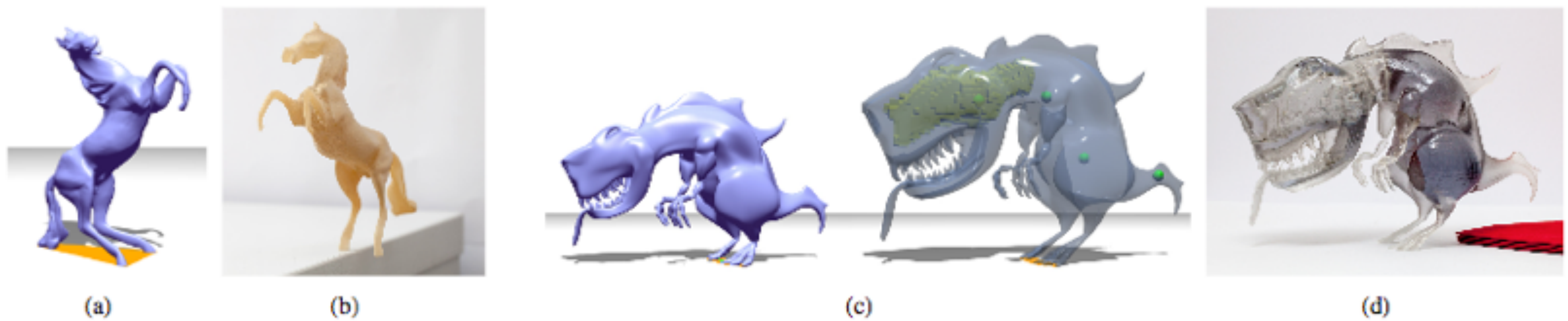


Figure 1: *Our algorithm iterates between carving and deformation to reach the final, balanced result. (a) The original horse model does not stand on its hind legs and requires using the tail as a third support. (b) Our approach deforms the horse to make it stand on a single hind leg. (c,d) The user scaled up the head of the T-Rex. Our optimizer succeeds in finding the delicate balance of a massive head and body on a tiny base of support. It deforms and carves the model (yellow region visible by transparency) to precisely position the center of mass.*

Abstract

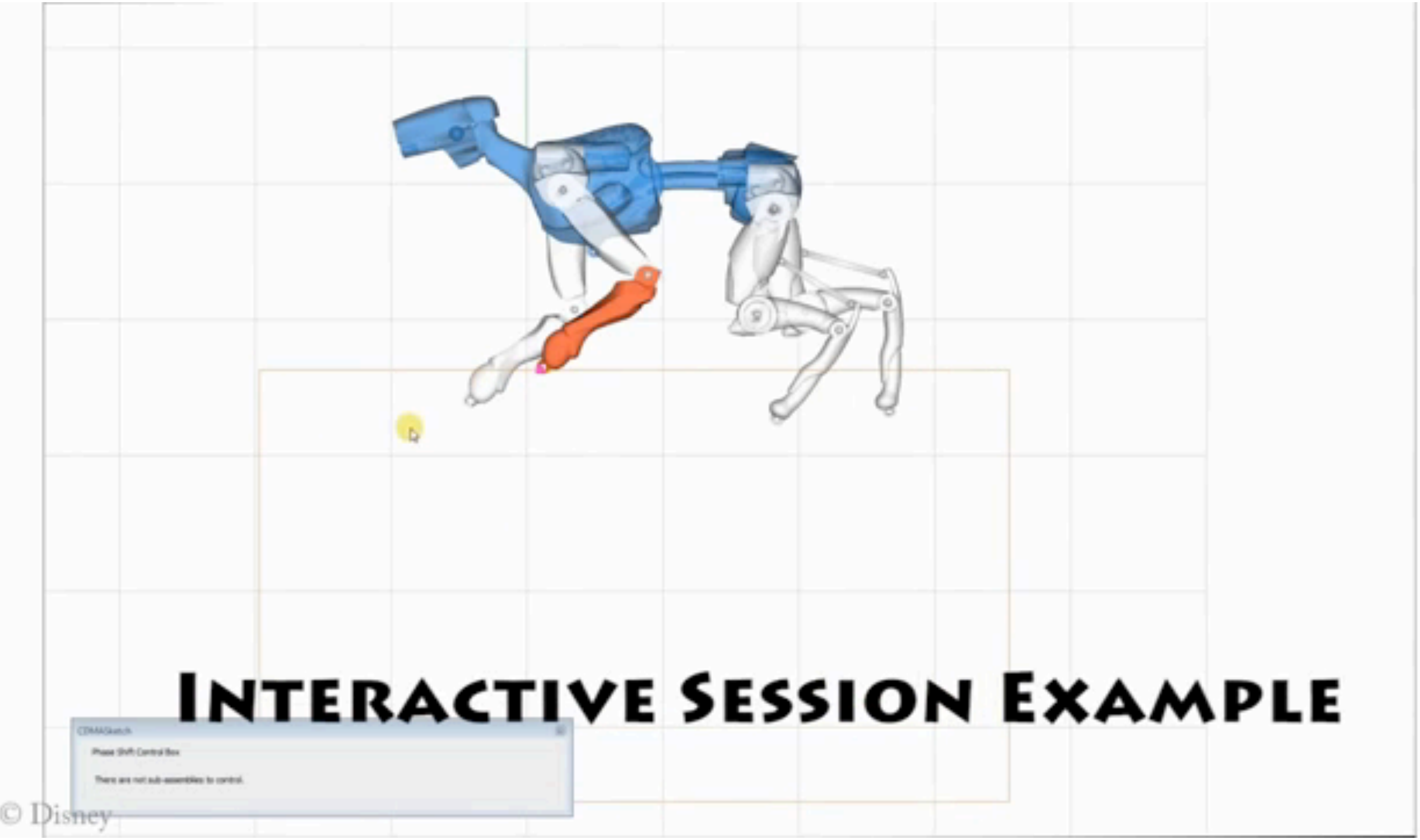
Imbalance suggests a feeling of dynamism and movement in static objects. It is therefore not surprising that many 3D models stand in impossibly balanced configurations. As long as the models remain in a computer this is of no consequence: the laws of physics do not apply. However, fabrication through 3D printing breaks the illusion: printed models topple instead of standing as initially intended. We propose to assist users in producing novel, properly balanced designs by interactively deforming an existing model. We formulate balance optimization as an energy minimization, improving stability by modifying the *volume* of the object, while preserving its surface details. This takes place during interactive editing: the user cooperates with our optimizer towards the end result. We demonstrate our method on a variety of models. With our technique, users can produce fabricated objects that stand in one or more surprising poses without requiring glue or heavy pedestals.

CR Categories: I.3.7 [Computer Graphics]: Computational Ge-

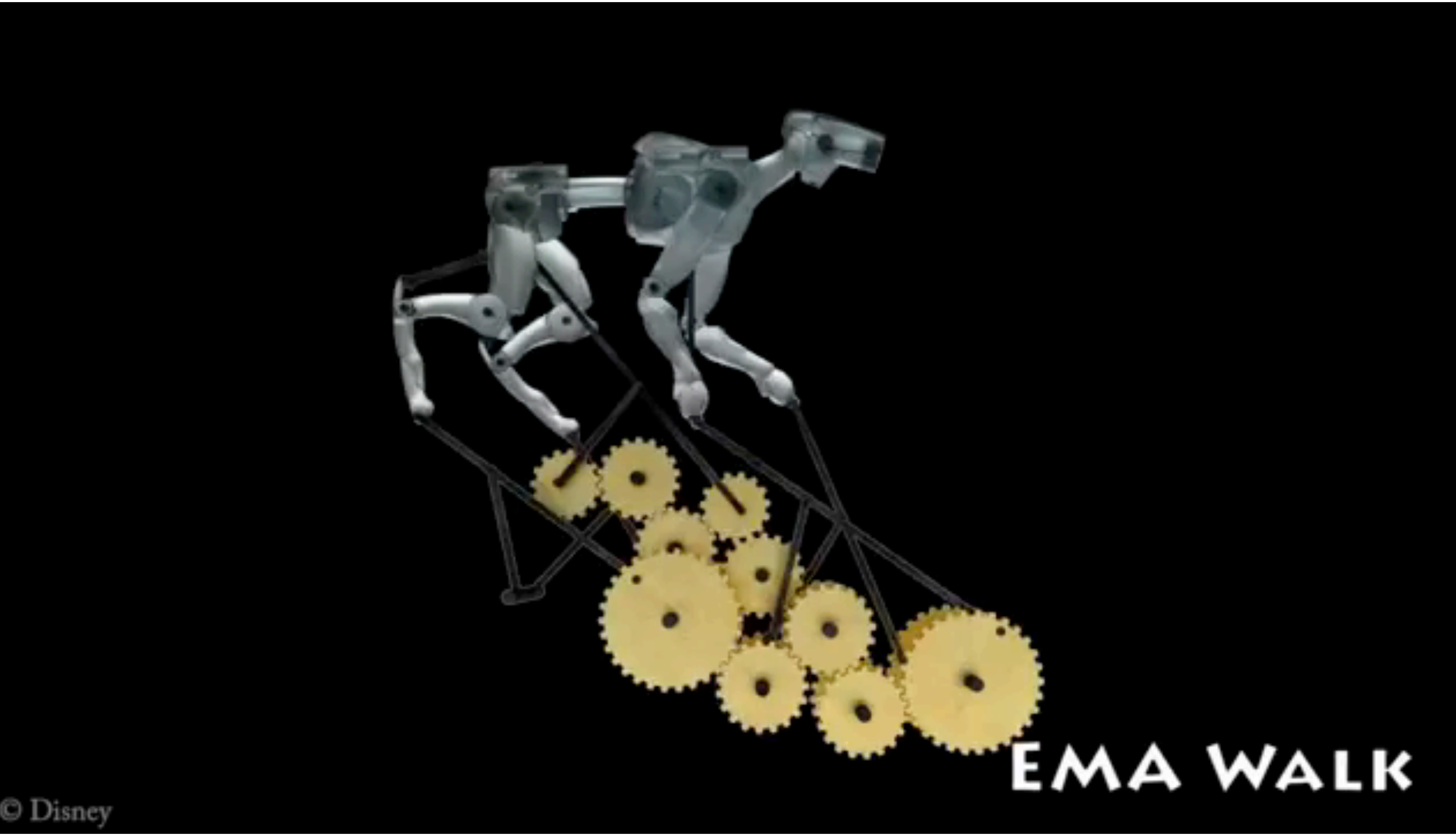
1 Introduction

Balance is a delicate compromise between shape, weight and pose. It is therefore difficult to visually assess whether a given object is properly balanced and will stand in a stable, up-right position. Artists, designers and architects use this to their advantage to produce surprising and elegant designs that seem to defy gravity [Smithson 1968; von Meiss 1990; Kedziora 2011]. A well-known design principle to this effect, *asymmetric balance* [Lauer and Pentak 2011], consists in achieving balance by contrasting sizes and weights on either side of a composition. When considering physical objects, this process is not only concerned with aesthetics, but also with structural soundness: the weights of each part must exactly compensate each other, balancing the design in its intended, stable pose.

With the advent of 3D printing technologies, it becomes very simple to produce physical realizations of 3D models. Unfortunately, they most often fail to stand, making it mandatory to glue the printed objects onto a heavy pedestal. The delicate process of balancing, already difficult with physical objects, is very challenging when



2013 walking automata - kinematics



2013 walking automata - **kinematics**

Computational Design of Mechanical Characters

Stelian Coros*[1] Bernhard Thomaszewski*[1] Gioacchino Noris[1] Shinjiro Sueda[2] Moira Forberg[2]
Robert W. Sumner[1] Wojciech Matusik[3] Bernd Bickel[1]

[1]Disney Research Zurich [2]Disney Research Boston [3]MIT CSAIL

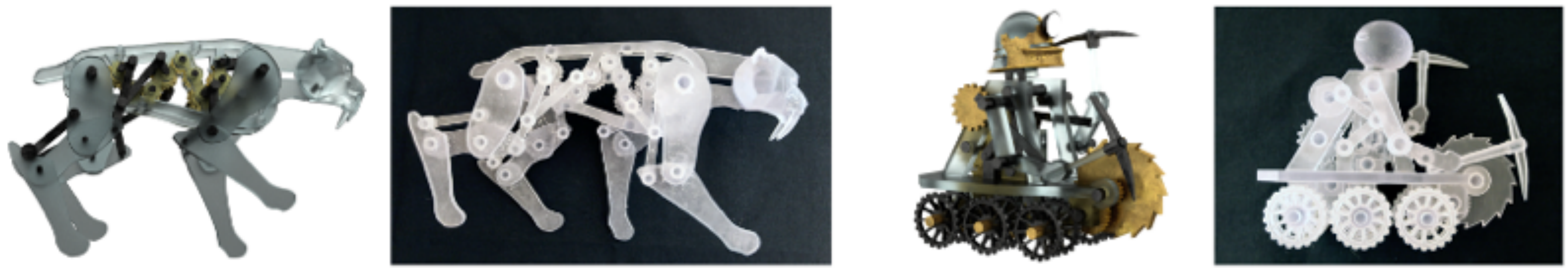


Figure 1: *The interactive design system we introduce allows non-expert users to create complex, animated mechanical characters.*

Abstract

We present an interactive design system that allows non-expert users to create animated mechanical characters. Given an articulated character as input, the user iteratively creates an animation by sketching motion curves indicating how different parts of the character should move. For each motion curve, our framework creates an optimized mechanism that reproduces it as closely as possible. The resulting mechanisms are attached to the character and then connected to each other using gear trains, which are created in a semi-automated fashion. The mechanical assemblies generated with our system can be driven with a single input driver, such as a hand-operated crank or an electric motor, and they can be fabricated using rapid prototyping devices. We demonstrate the versatility of our approach by designing a wide range of mechanical characters, several of which we manufactured using 3D printing. While our pipeline is designed for characters driven by planar mechanisms, significant parts of it extend directly to non-planar mechanisms, allowing us to create characters with compelling 3D motions.

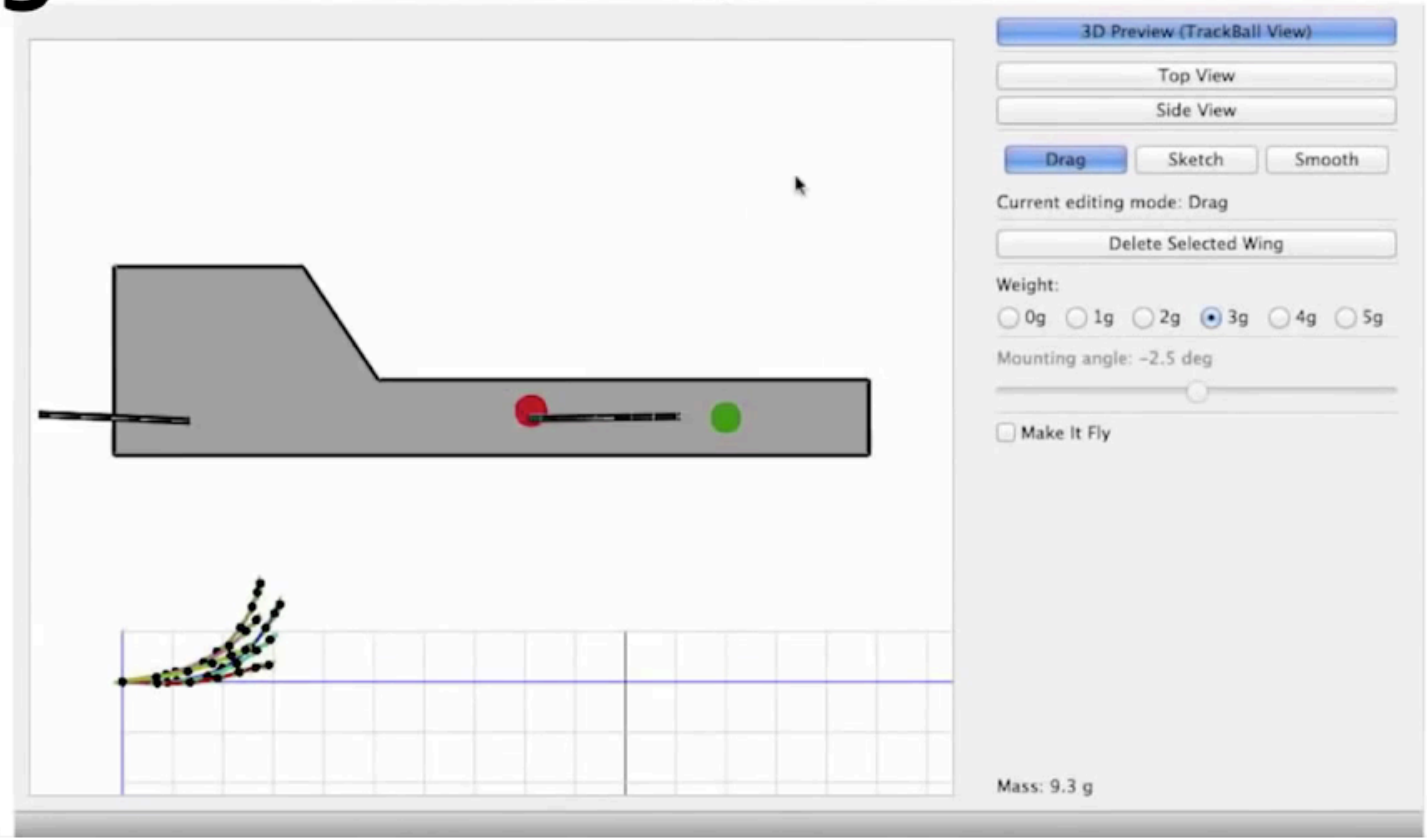
CR Categories: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques; I.3.5 [Computer Graphics]:

1 Introduction

Character animation allows artists to bring fictional characters to life as virtual actors in animated movies, video games, and live-action films. Well-established software packages assist artists in realizing their creative vision, making almost any digital character and movement possible. In the physical world, animatronic figures play an equivalent role in theme parks and as special effects in movies and television. While these sophisticated robots are far from becoming household items, toys that exhibit mechanical movement are extremely popular as consumer products. However, unlike virtual characters, creating complex and detailed movement for *mechanical characters*, whose motion is determined by physical assemblies of gears and linkages, remains an elusive and challenging task. Although mechanical characters have been part of the toy industry since the nineteenth century [Peppe 2002], design technology for these characters has changed little and is limited to expert designers and engineers. Even for them, the design process is largely trial and error, with many iterations needed to produce an acceptable result. Since iteration times increase greatly as the complexity of the design space increases, mechanical characters are limited in scope and complexity, which in turn limits the range of

2014 Pteromys - aerodynamics

x5 Concurrent Flight Simulation



Pteromys: Interactive Design and Optimization of Free-formed Free-flight Model Airplanes

Nobuyuki Umetani[1,2*] Yuki Koyama[1] Ryan Schmidt[2] Takeo Igarashi[1]
[1]The University of Tokyo / JST ERATO [2]Autodesk Research

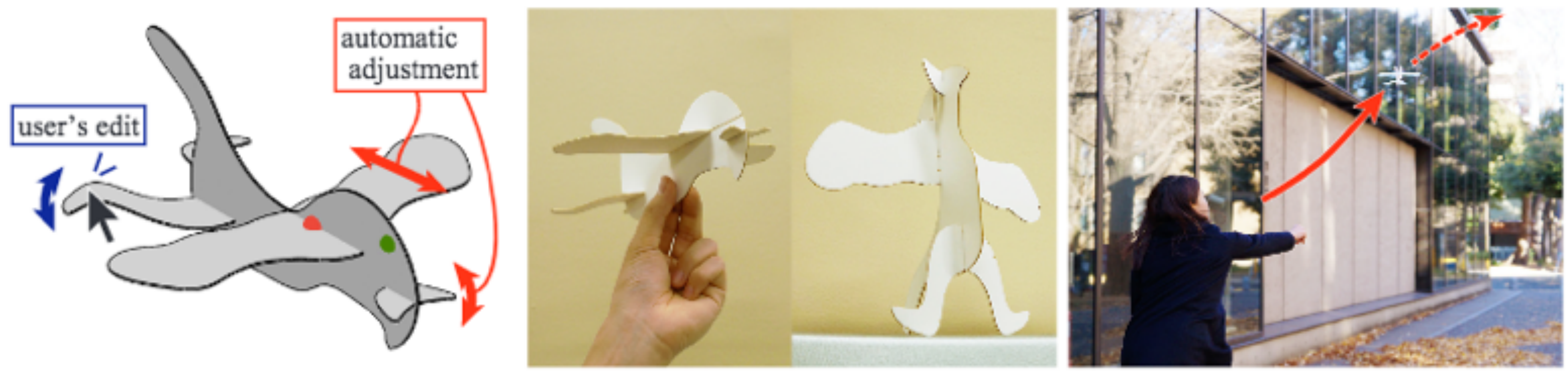


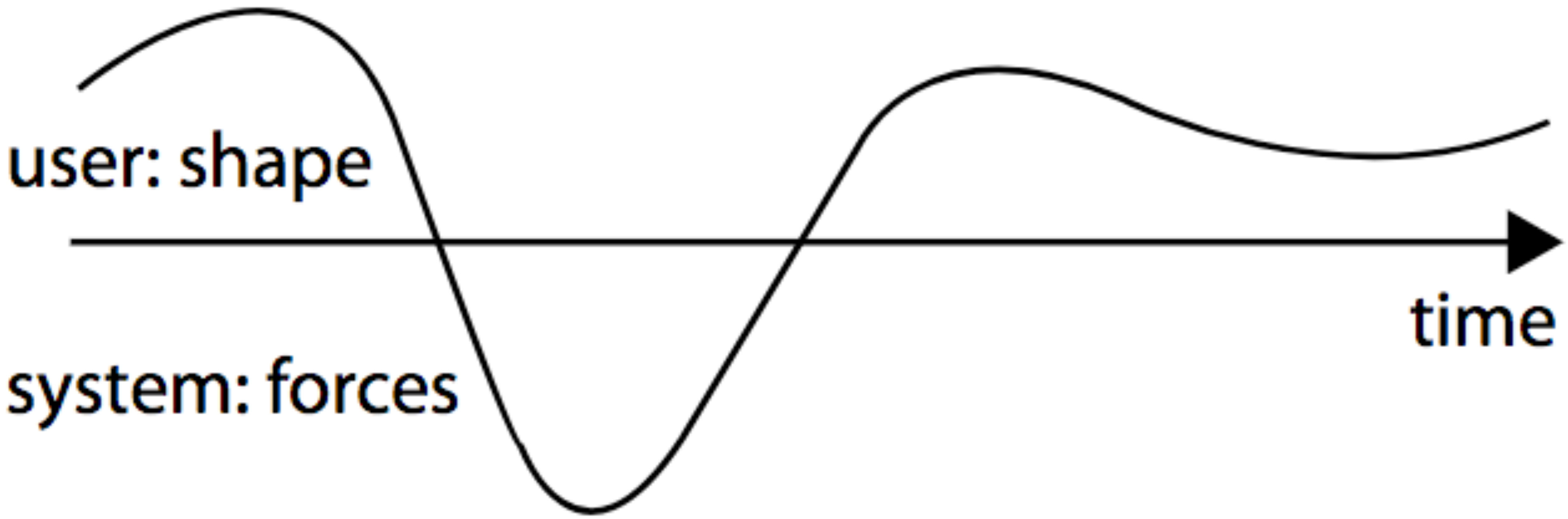
Figure 1: *(Left) Our model airplane design tool analyzes the aerodynamic properties of a glider and optimizes while the user interactively designs the plane. (Center) The user fabricates the airplane. (Right) The airplane actually flies.*

Abstract

This paper introduces novel interactive techniques for designing original hand-launched free-flight glider airplanes which can actually fly. The aerodynamic properties of a glider aircraft depend on their shape, imposing significant design constraints. We present a compact and efficient representation of glider aerodynamics that can be fit to real-world conditions using a data-driven method. To do so, we acquire a sample set of glider flight trajectories using a video camera and the system learns a nonlinear relationship between forces on the wing and wing shape. Our acquisition system is much simpler to construct than a wind tunnel, but using it we can efficiently discover a wing model for simple gliding aircraft. Our resulting model can handle general free-form wing shapes and yet agrees sufficiently well with the acquired airplane flight trajectories. Based on this compact aerodynamics model, we present a design tool in which the wing configuration created by a user is interactively optimized to maximize flight-ability. To demonstrate the effectiveness of our tool for glider design by novice users, we compare it with a traditional design workflow.

1 Introduction

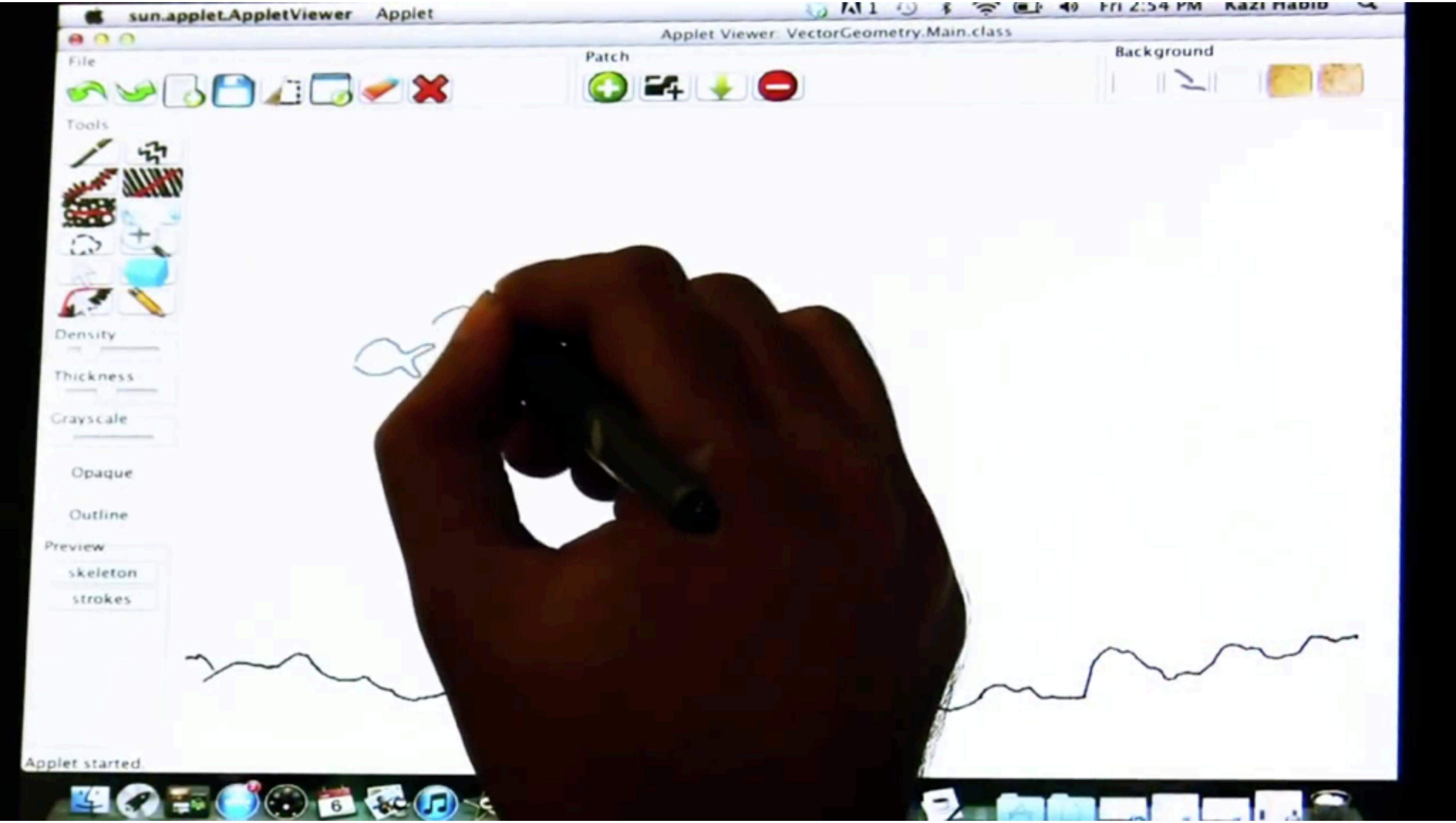
Humanity has always been fascinated with flight, and most of us have experienced the joy of creating simple flying machines in the form of paper airplanes. One only has to take model aircraft slightly more seriously to discover the wide range of forms that simple hand-launched gliders can take on (Figure 2). The advent of personal fabrication devices, such as desktop 3D printers and CNC cutters, has greatly expanded the ability of individuals to construct precise glider aircrafts. However, it is surprisingly complicated to design a simple glider that will actually fly (let alone fly *well*). There are complex constraints between the shapes, positions, and mass of the various plane components, which must obviously be satisfied. Without domain knowledge of advanced aerodynamics, or extensive experimentation, novices (such as the authors) find designing even simple gliders to be quite frustrating. Designing more complicated free-formed gliders is prohibitively difficult for novices because the data and required knowledge for estimating their aerodynamics have not yet been well established.



- let users design the shape
- abstract away forces -> **automate functional optimization**

still need support:
traditional media
e.g. drawing

2012 Vignette: facilitate **texturing**



2012 Vignette: facilitate **texturing**

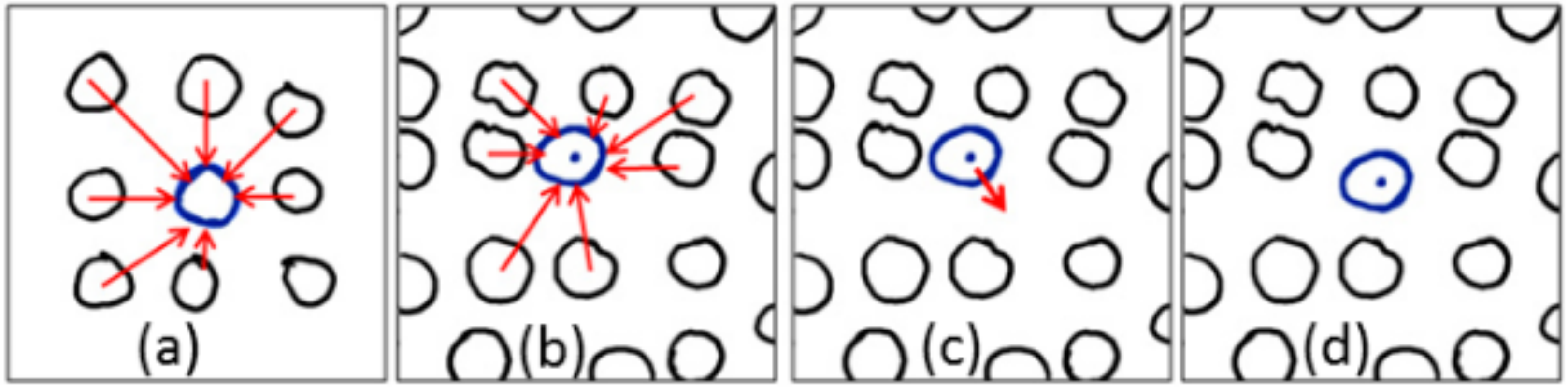


Figure 13: (a) The input example patch. (b) The output texture after initialization. In the *search step* for output element s_0 (marked blue in (b)), the algorithm finds the corresponding element s_i in the input patch (marked blue in (a)) with most similar neighborhood. (c) The *assignment step* computes the new position of the output element that minimizes the energy between corresponding input elements. (d) Finally, the element is moved into its new position.

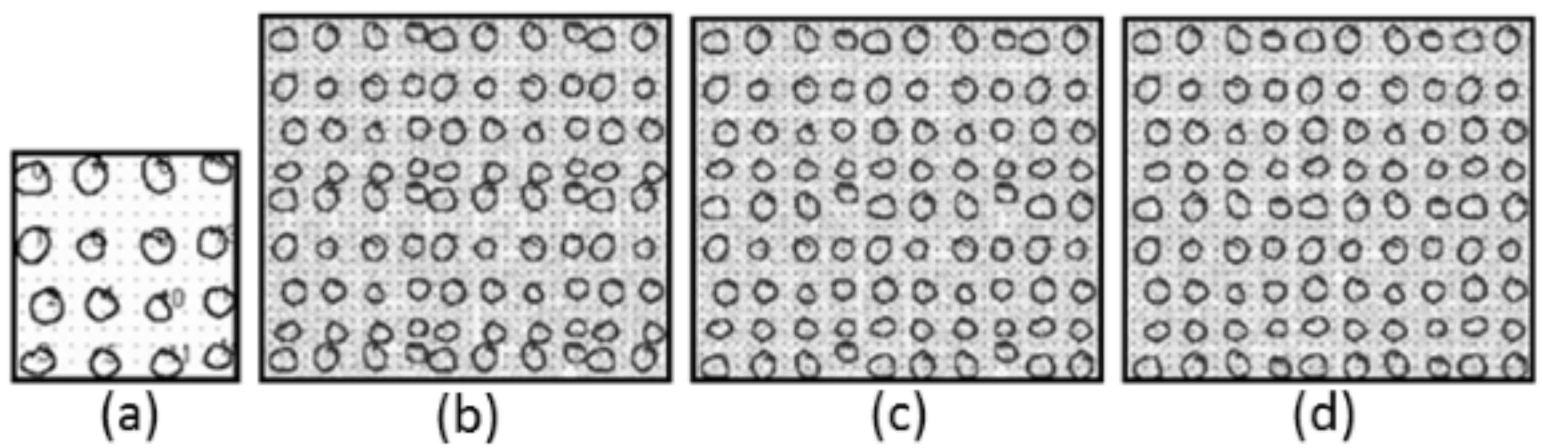


Figure 14: The iterative progression of texture optimization. (a) Input patch (b) Output texture after initialization (c) Output texture after iteration 2 (d) Output texture after iteration 4.

Vignette: Interactive Texture Design and Manipulation with Freeform Gestures for Pen-and-Ink Illustration

Rubaiat Habib Kazi[1,2], Takeo Igarashi[1,3], Shengdong Zhao[2], Richard C. Davis[4]
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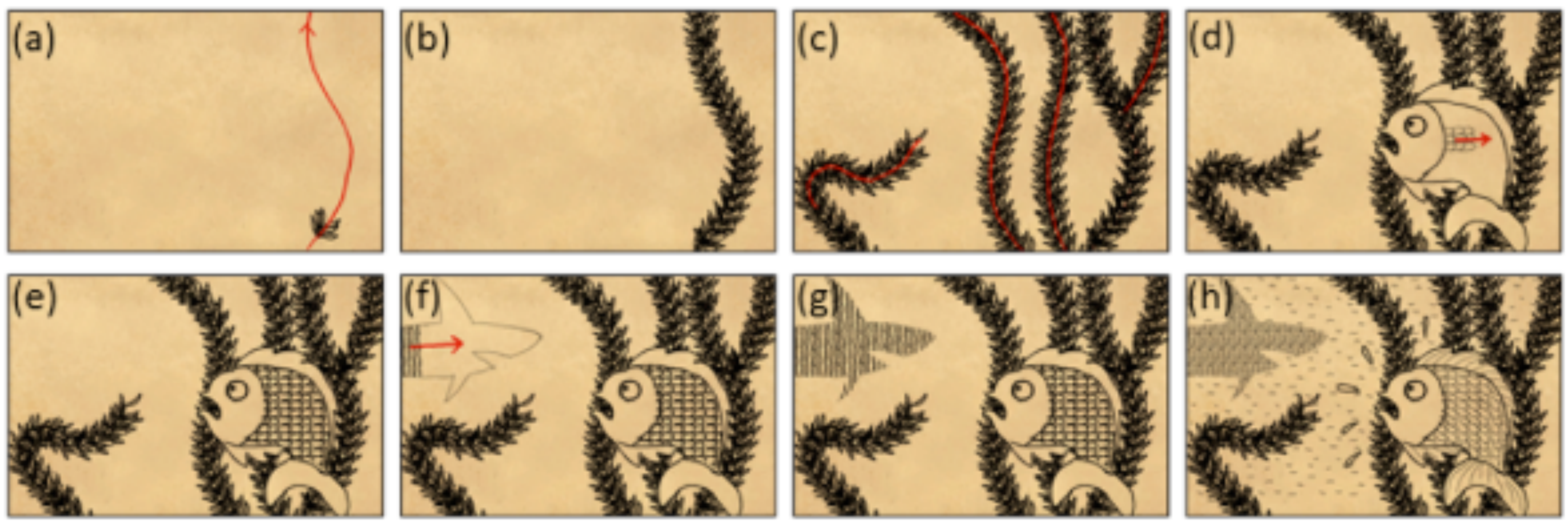


Figure 1: The steps of a pen-and-ink illustration with Vignette from scratch (a) Draw leaf strokes (black) and gesture (red) (b) Texture created from gesture and strokes(c) More textures (d) Draw scale strokes and gesture (e) Region filed with scales (f) Draw hatching strokes and gesture (g) Fill region with hatching (h) Final illustration created in minutes.

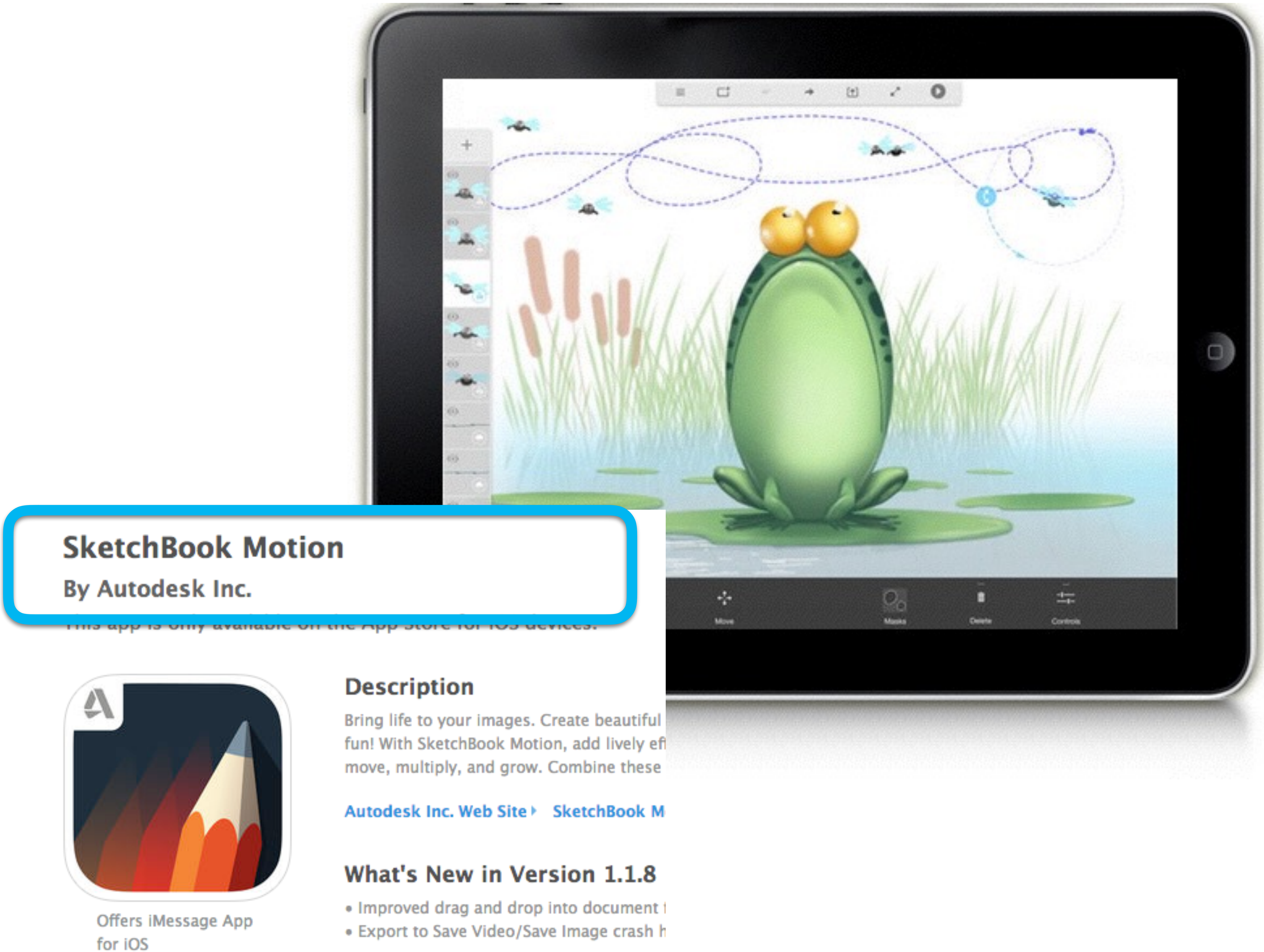
ABSTRACT
Vignette is an interactive system that facilitates texture creation in pen-and-ink illustrations. Unlike existing systems, Vignette preserves illustrators' workflow and style: users draw a fraction of a texture and use gestures to automatically fill regions with the texture. We currently support both 1D and 2D synthesis with stitching. Our system also has interactive refinement and editing capabilities to provide a higher level texture control, which helps artists achieve their desired vision. A user study with professional artists shows that Vignette makes the process of illustration more enjoyable and that first time users can create rich textures from scratch within minutes.

INTRODUCTION
Pen and ink illustration is a popular artistic medium that can be seen in textbooks, repair manuals, advertisements, comics, and many other printed and digital media. Illustrations typically incorporate a wealth of textures, tones and artistic styles. These effects take significant amounts of skill, artistry, and *patience* to create.

Many research systems [2, 3, 21, 22, 30, 31] can render scenes in the style of pen-and-ink illustrations. Also, professional tools like Illustrator, Photoshop, Comic Studio and InkScape can synthesize customized textures. These tools are powerful and widely used, but they fall short of preserving two key properties of traditional paper-based

2014 Draco: **animated textures**

2014 Draco: **animated textures**



SketchBook Motion
By Autodesk Inc.
Description
Bring life to your images. Create beautiful
fun! With SketchBook Motion, add lively ef
move, multiply, and grow. Combine these
Autodesk Inc. Web Site
SketchBook M
What's New in Version 1.1.8
• Improved drag and drop into document
• Export to Save Video/Save Image crash
Offers iMessage App for iOS

Draco: Bringing Life to Illustrations with Kinetic Textures

Rubaiat Habib Kazi[1,2], Fanny Chevalier[3], Tovi Grossman[1], Shengdong Zhao[2], George Fitzmaurice[1]
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{rubaiat, zhaosd}@comp.nus.edu.sg, fanny@dgp.toronto.edu, {tovi.grossman, george.fitzmaurice}@autodesk.com

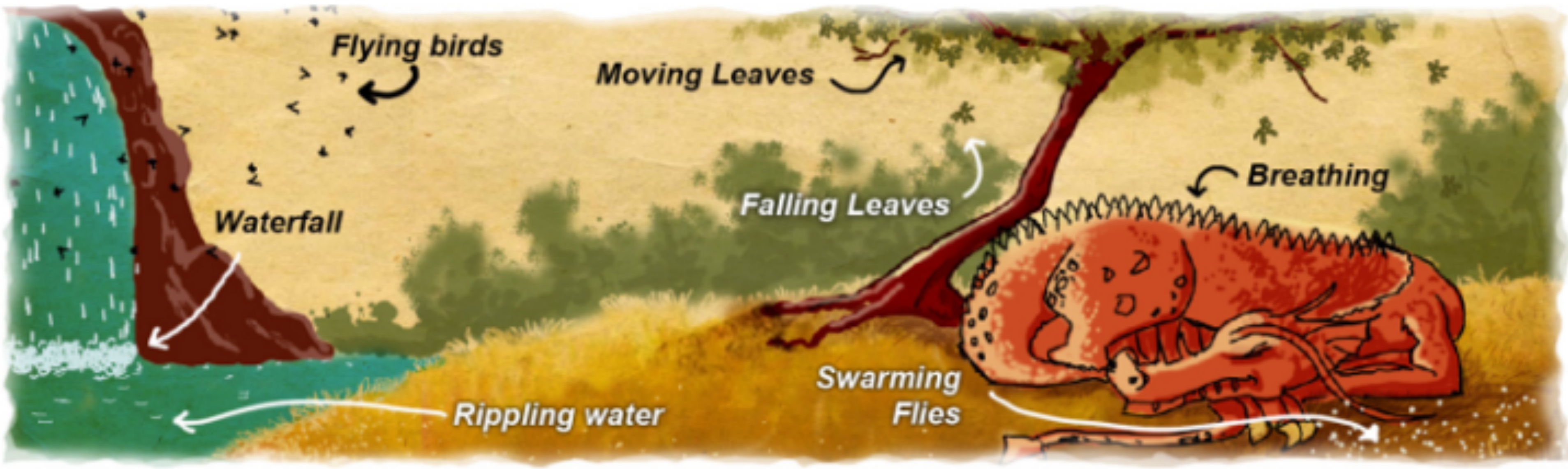

Figure 1. A dynamic illustration authored with Draco, capturing the living qualities of a moment with continuous dynamic phenomena, yet exhibiting the unique timeless nature of a still picture. This animated figure is best viewed in Adobe Reader.

ABSTRACT
We present Draco, a sketch-based interface that allows artists and casual users alike to add a rich set of animation effects to their drawings, seemingly bringing illustrations to life. While previous systems have introduced sketch-based animations for individual objects, our contribution is a unified framework of motion controls that allows users to seamlessly add coordinated motions to object collections. We propose a framework built around *kinetic textures,* which provide continuous animation effects while preserving the unique timeless nature of still illustrations. This enables many dynamic effects difficult or not possible with previous sketch-based tools, such as a school of fish swimming, tree leaves blowing in the wind, or water rippling in a pond. We describe our implementation and illustrate the repertoire of animation effects it supports. A user study with professional animators and casual users demonstrates the variety of animations, applications and

INTRODUCTION
For centuries, people have attempted to capture the living qualities of surrounding phenomena in drawings. Sketching, in particular, is a popular art medium that has also been widely adopted as a powerful tool for communication, visual thinking and rapid design, due to its minimalistic yet greatly expressive nature [6]. While sketches do afford many techniques to convey dynamic motion of objects, such as speed lines [20], arrows [14] or afterglow effect [5], they are inherently static. The goal of this paper is to enable artists and casual users alike to enrich static illustrations with intricate and continuous animation effects, while preserving the unique timeless nature of still illustrations (Figure 1).

In recent years, researchers have developed new tools and techniques for casual animation authoring using sketching [11, 21, 33] and direct manipulation [15, 29]. Such tools

2014 Kitty: making **drawings interact to events**
(visual programming)

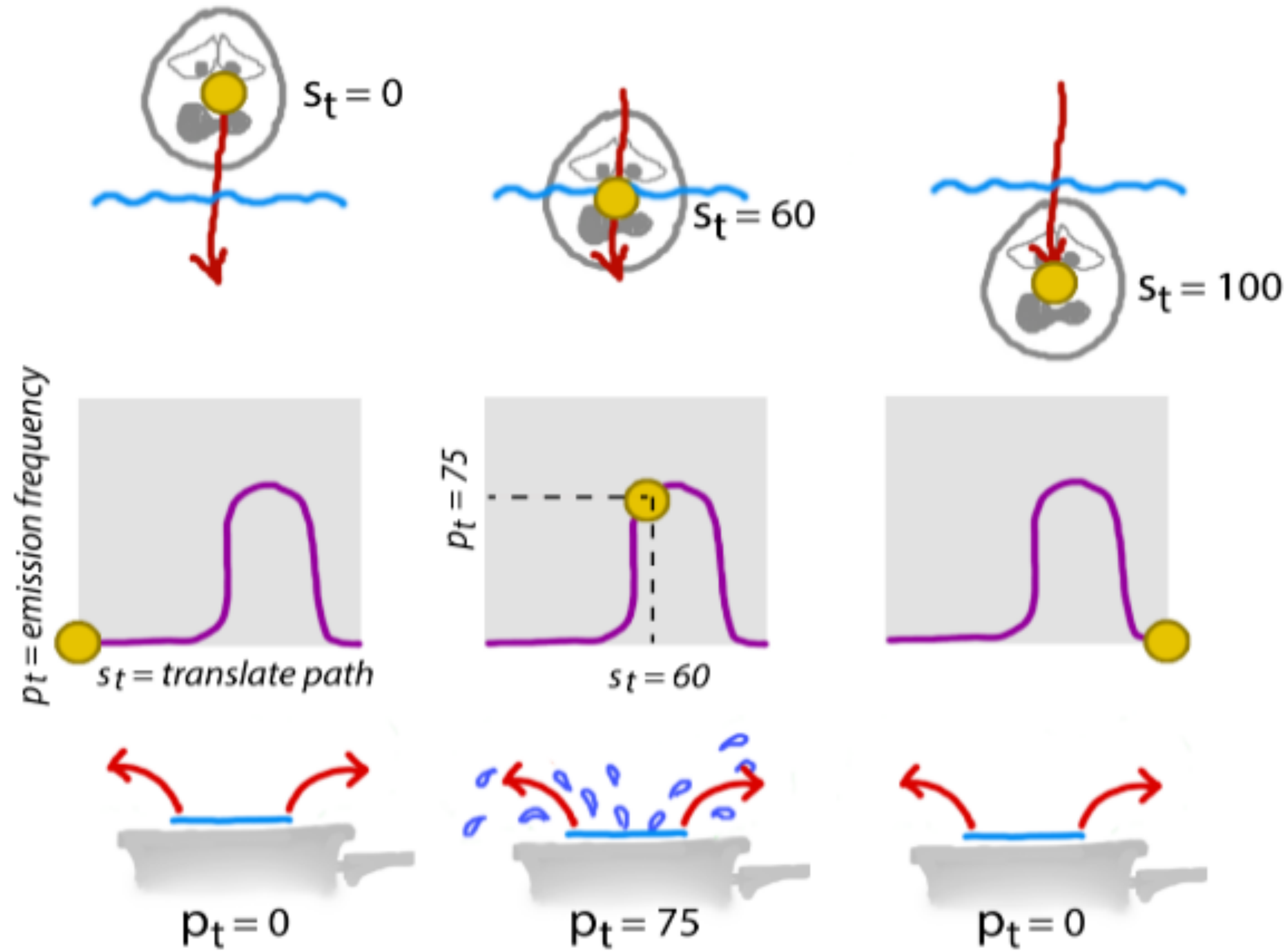

Figure 5: Functional relationship between the translation path of the egg and the emitting frequency of soup splashes.

Kitty: Sketching Dynamic and Interactive Illustrations

Rubaiat Habib Kazi[1], Fanny Chevalier[2], Tovi Grossman[1], George Fitzmaurice[1]

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rubaiat.habib@gmail.com, fanny.chevalier@inria.com, {tovi.grossman, george.fitzmaurice}@autodesk.com

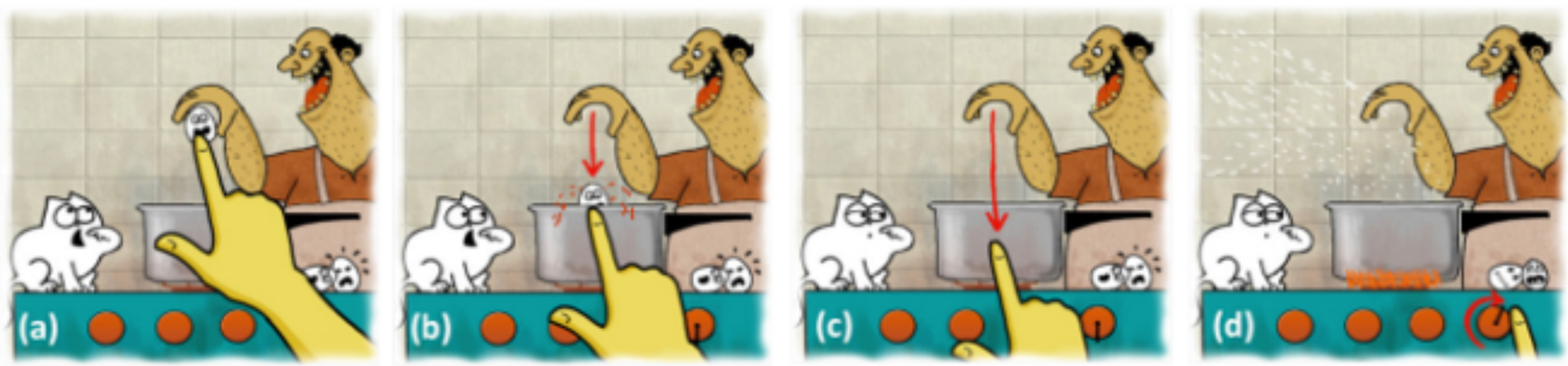


Figure 1: Example of a dynamic interactive illustration authored with Kitty. (a) Objects in the scene are interactive: the egg held by the cook can be dragged down, as if falling into the pot, triggering subsequent animations, such as soup splashes (b) and closing of the cat's eyelids (c). Turning the knob increases the fire and steam (d). The resulting dynamic illustration captures the living nature of the scene, where the gas stove flames burn and steam emits from the pot.

ABSTRACT

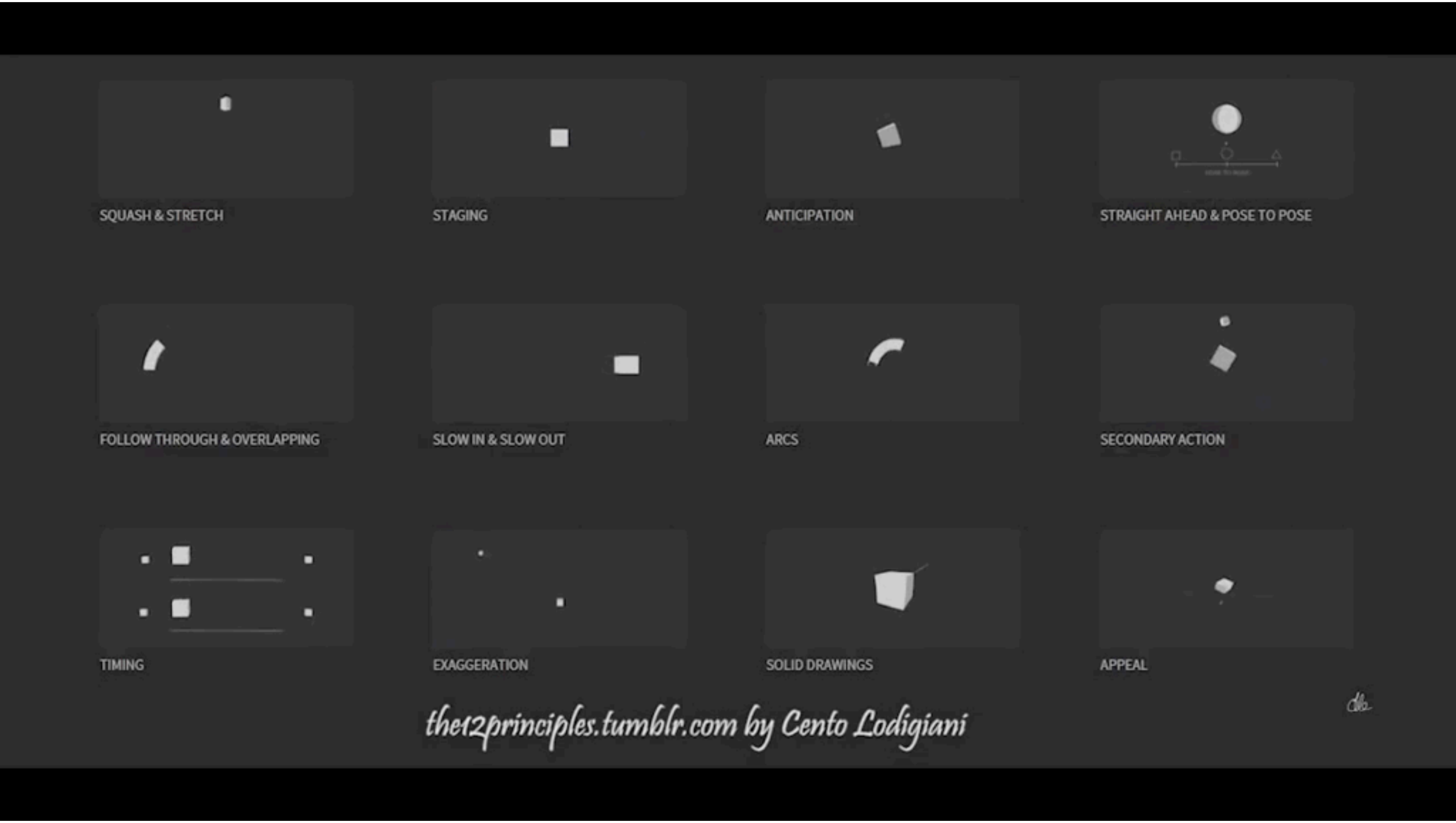
We present Kitty, a sketch-based tool for authoring dynamic and interactive illustrations. Artists can sketch animated drawings and textures to convey the living phenomena, and specify the functional relationship between its entities to characterize the dynamic behavior of systems and environments. An underlying graph model, customizable through sketching, captures the functional relationships between the visual, spatial, temporal or quantitative parameters of its entities. As the viewer interacts with the resulting dynamic interactive illustration, the parameters of the drawing change accordingly, depicting the dynamics and chain of causal effects within a scene. The generality of this framework makes our tool applicable for a variety of purposes, including technical illustrations, scientific explanation, infographics, medical illustrations, children's e-books, cartoon strips and beyond. A user study demonstrates the ease of usage, variety of applications, artistic expressiveness and creative

"Dynamic pictures will someday be the primary medium for visual art and visual explanations" – Bret Victor [24]

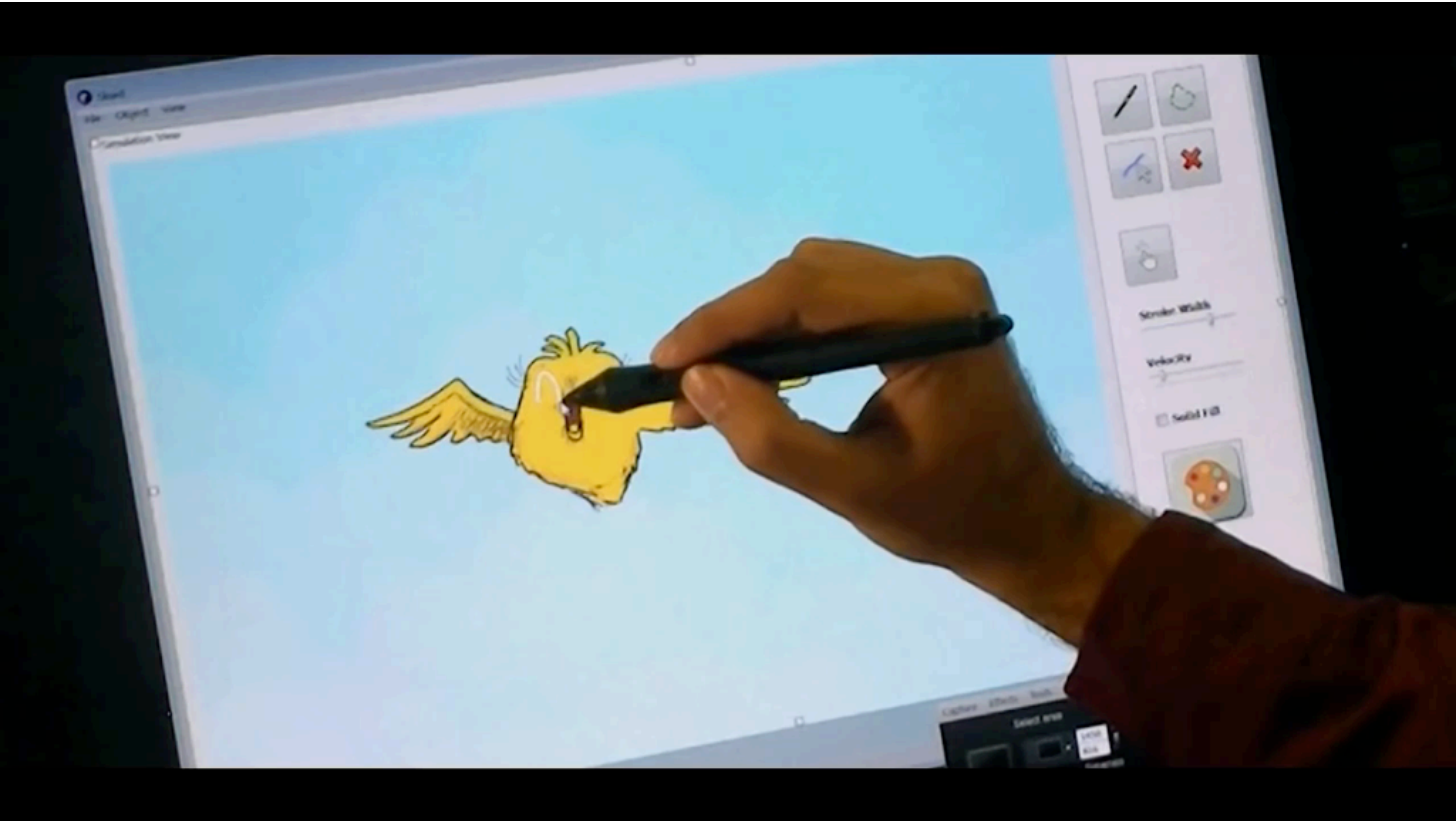
INTRODUCTION

Due to the recent advances in mobile devices and web technologies, there is a growing demand for interactive illustrations to enrich the content found on mediums such as websites, e-books, and teaching materials. In contrast to static pictures and videos that are consumed by a passive observer, interactive illustrations respond to a user's input, providing a more playful or informative experience. For example, an interactive illustration of a mechanical system invites exploration through interaction as users investigate hypotheses, which may help develop insights about significant relationships and causal patterns [11].

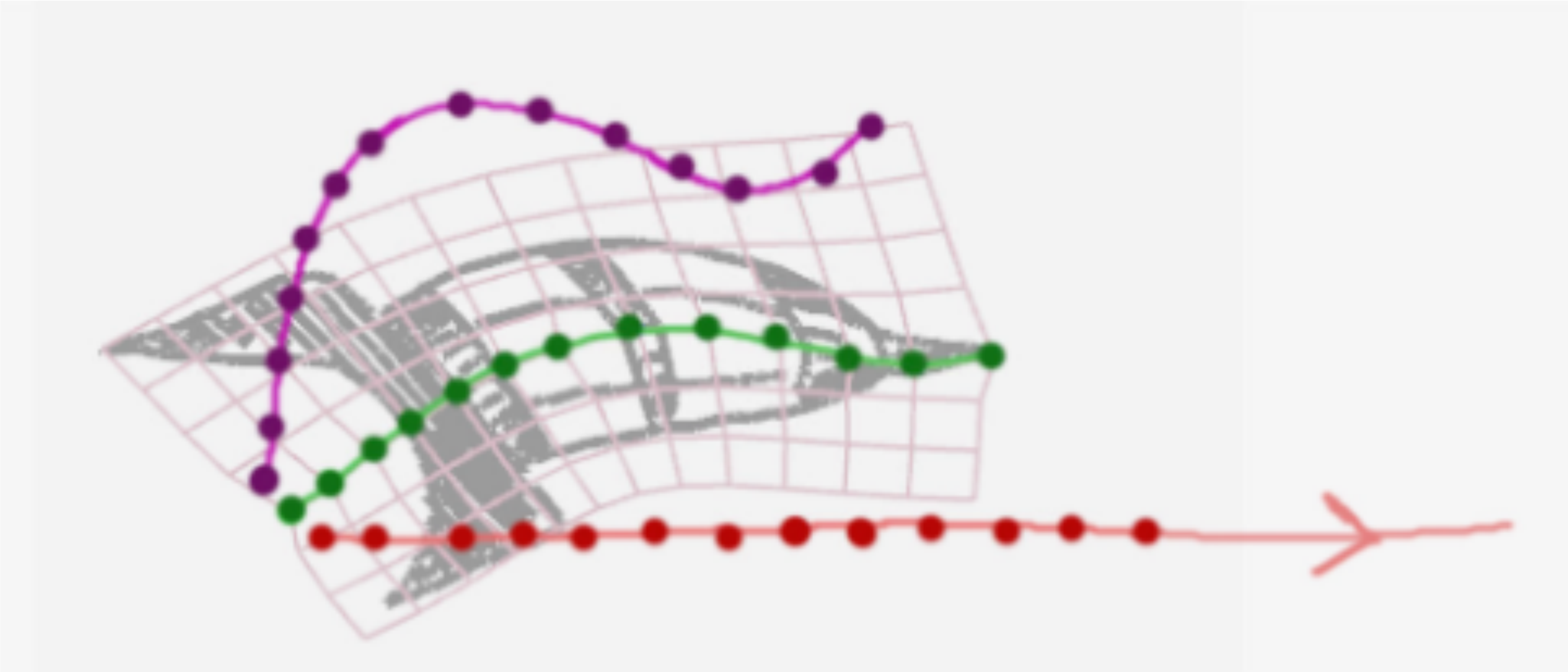
Traditionally, crafting such interactive illustrations is achieved through programming or scripting. This requires the artist to work with abstract textual representations of visual entities, their interactive behavior, and their



2016 Motion Amplifiers: more **expressive animations**



2016 Motion Amplifiers: more **expressive animations**



map drawing to a grid, deform the grid

Motion Amplifiers: Sketching Dynamic Illustrations Using the Principles of 2D Animation

Rubaiat Habib Kazi, Tovi Grossman, Nobuyuki Umetani, George Fitzmaurice
Autodesk Research
{rubaiat.habib, tovi.grossman, nobuyuki.umetani, george.fitzmaurice}@autodesk.com

Figure 1. Motion amplifiers produce the stylized and exaggerated dynamics of classical 2D animations.

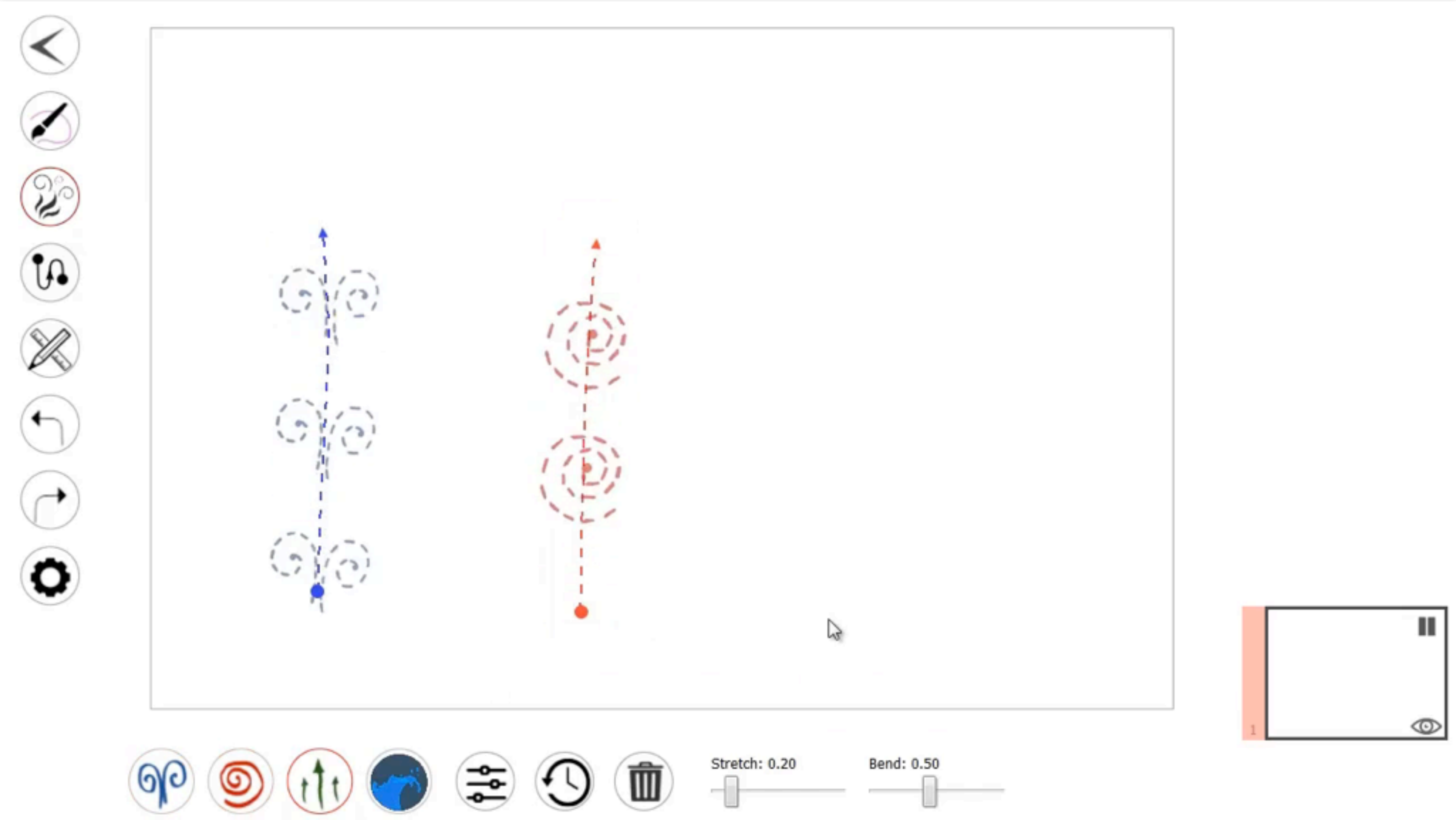
ABSTRACT
We present a sketching tool for crafting animated illustrations that contain the exaggerated dynamics of stylized 2D animations. The system provides a set of motion amplifiers which implement a set of established principles of 2D animation. These amplifiers break down a complex animation effect into independent, understandable chunks. Each amplifier imposes deformations to an underlying grid, which in turn updates the corresponding strokes. Users can combine these amplifiers at will when applying them to an existing animation, promoting rapid experimentation. By leveraging the freeform nature of sketching, our system allows users to rapidly sketch, record motion, explore exaggerated dynamics using the amplifiers, and fine-tune their animations. Practical results confirm that users with no prior experience in animation can produce expressive animated illustrations quickly and easily.

Author Keywords
Sketching; amplifiers; principles of animation; stylized.

ACM Classification Keywords

INTRODUCTION
In the early days of 2D animation, crude technical limitations compelled master animators to push the limits of the medium by developing a number of expressive techniques [27]. By exaggerating the dynamics of the physical world, these techniques, known as the *principles of animation* [27], turned hand-drawn 2D animation into a communicative, sophisticated art form. As described by Thomas and Johnston [27], twelve principles of animation guide the motion design, visual design, as well as the clarity and communicative aspects of 2D animation. A master animator can compose the performance (animation) of a character by applying these principles to various extents.

The importance of 2D animation stylization is well recognized, and it has been widely used in 3D animation [20]. However, producing stylized 2D animations is tedious, even today, requiring specialized skill and manual key-framing. In the computer graphics community, researchers have explored a number of approaches to simulate cartoon-style animation [1, 2, 4, 10, 30]. However, much of the focus



2016 EnergyBrushes: more **dynamic effects**
(flow particle simulation)

Energy-Brushes: Interactive Tools for Illustrating Stylized Elemental Dynamics

Jun Xing[1,2], Rubaiat Habib Kazi[1], Tovi Grossman[1], Li-Yi Wei[2], Jos Stam[1], George Fitzmaurice[1]

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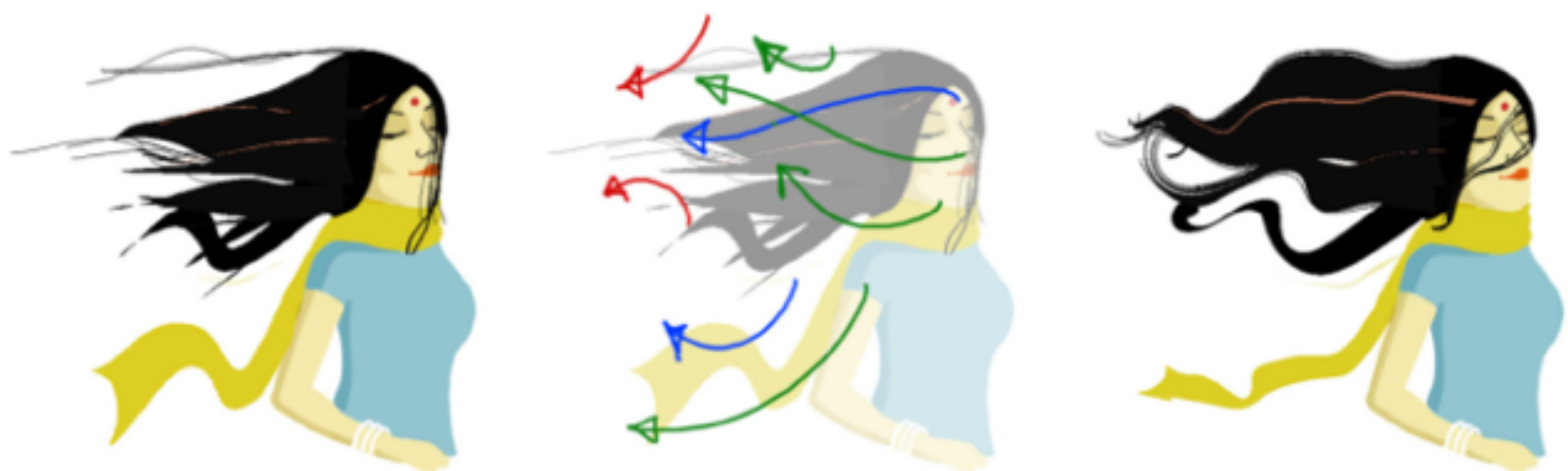


Figure 1: Example of a dynamic illustration authored with our system. Left: original user drawing. Middle: the *energy brush* gestures to specify the underlying forces and detail effects. Right: the resulting dynamic illustration.

ABSTRACT
Dynamic effects such as waves, splashes, fire, smoke, and explosions are an integral part of stylized animations. However, such dynamics are challenging to produce, as manually sketching key-frames requires significant effort and artistic expertise while physical simulation tools lack sufficient expressiveness and user control. We present an interactive interface for designing these *elemental dynamics* for animated illustrations. Users draw with coarse-scale *energy brushes* which serve as control gestures to drive detailed *flow particles* which represent local velocity fields. These fields can convey both realistic and artistic effects based on user specification. This painting metaphor for creating elemental dynamics simplifies the process, providing artistic control, and preserves the fluidity of sketching. Our system is fast, stable, and intuitive. An initial user evaluation shows that even novice users with no prior animation experience can create intriguing dynamics using our system.

INTRODUCTION
"*As special effects animators, we do not animate things, we animate energy. Understand the energy behind the effect and stick to it with every stroke of the pencil*" – Gilland [9].

Dynamic special effect animations, such as waves, splashes, fire, smoke, hair, and explosions, are a sublime art form and an important aspect of animation. We refer this class of effects as *elemental dynamics*. In general, authoring these effects require mastery and deep understanding of the natural forces and elements. Despite considerable progress in the simulation of natural phenomena in computer graphics, user interaction and control remain challenging research problems. Traditional hand-drawn animation offers full artistic control and expression, but requires significant expertise and manual labor. Physical simulation can produce realistic animations, but can be hard to control and understand by

2016 ChronoFab: **depicting movement in 3D printing**

includes **structural strength** analysis

ChronoFab: Fabricating Motion

Rubaiat Habib Kazi, Tovi Grossman, Cory Mogk, Ryan Schmidth, George Fitzmaurice

Autodesk Research

{rubaiat.habib, tovi.grossman, cory.mogk, ryan.schmidth, george.fitzmaurice}@autodesk.com

Figure 1: We bring the stylized motion visualization techniques of 2D pictures into the physical world of 3D printed models. Motion sculptures crafted with our tool from 3D animated objects explicitly visualize objects' motion in static artifacts

ABSTRACT

We present ChronoFab, a 3D modeling tool to craft *motion sculptures*, tangible representations of 3D animated models, visualizing an object's motion with static, transient, ephemeral visuals that are left behind. Our tool casts 3D modeling as a dynamic art-form by employing 3D animation and dynamic simulation for the modeling of *motion sculptures*. Our work is inspired by the rich history of stylized motion depiction techniques in existing 3D motion sculptures and 2D comic art. Based on a survey of such techniques, we present an interface that enables users to rapidly explore and craft a variety of static 3D motion depiction techniques, including *motion lines*, *multiple stroboscopic stamps*, *sweeps* and *particle systems*, using a 3D animated object as input. In a set of professional and non-professional usage sessions, ChronoFab was found to be a superior tool for the authoring of motion sculptures,

INTRODUCTION

"In sculpture, therefore, we are not necessarily looking for pure form, but for pure plastic rhythm, not the construction of an object, but the construction of an object's action."

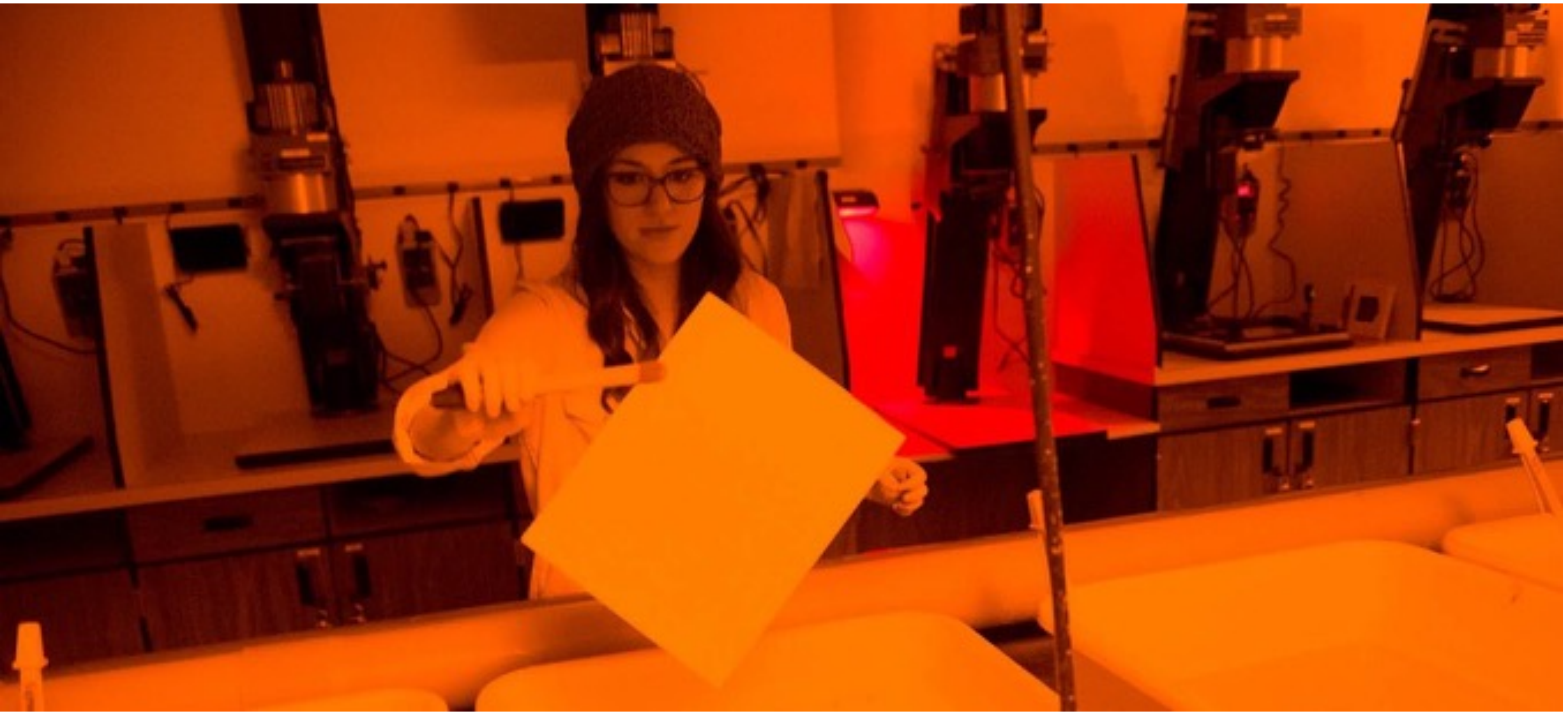
-Futurist art movement manifestos, 1909 [14]

3D design and digital fabrication is gaining popularity among researchers and makers for rapid prototyping and designing a wide range of artifacts - including toys, jewelry, miniature figurines, mechanical parts and prosthetics. In general, such static, moving [6, 7, 33, 36], or interactive [24, 25, 35] 3D printed artifacts do not reflect movement over time. In contrast, a number of sculptors and artists have explored the notion of physically visualizing motion in static 3D sculptures (Figure 2), often adopting the styles and abstraction techniques used in 2D visual art which depict motion [8]. We refer to such artifacts as *motion sculptures*. Traditionally, sculpting motion sculptures

Rubaiat Habib (Autodesk Research):
PhD thesis as comic book :)

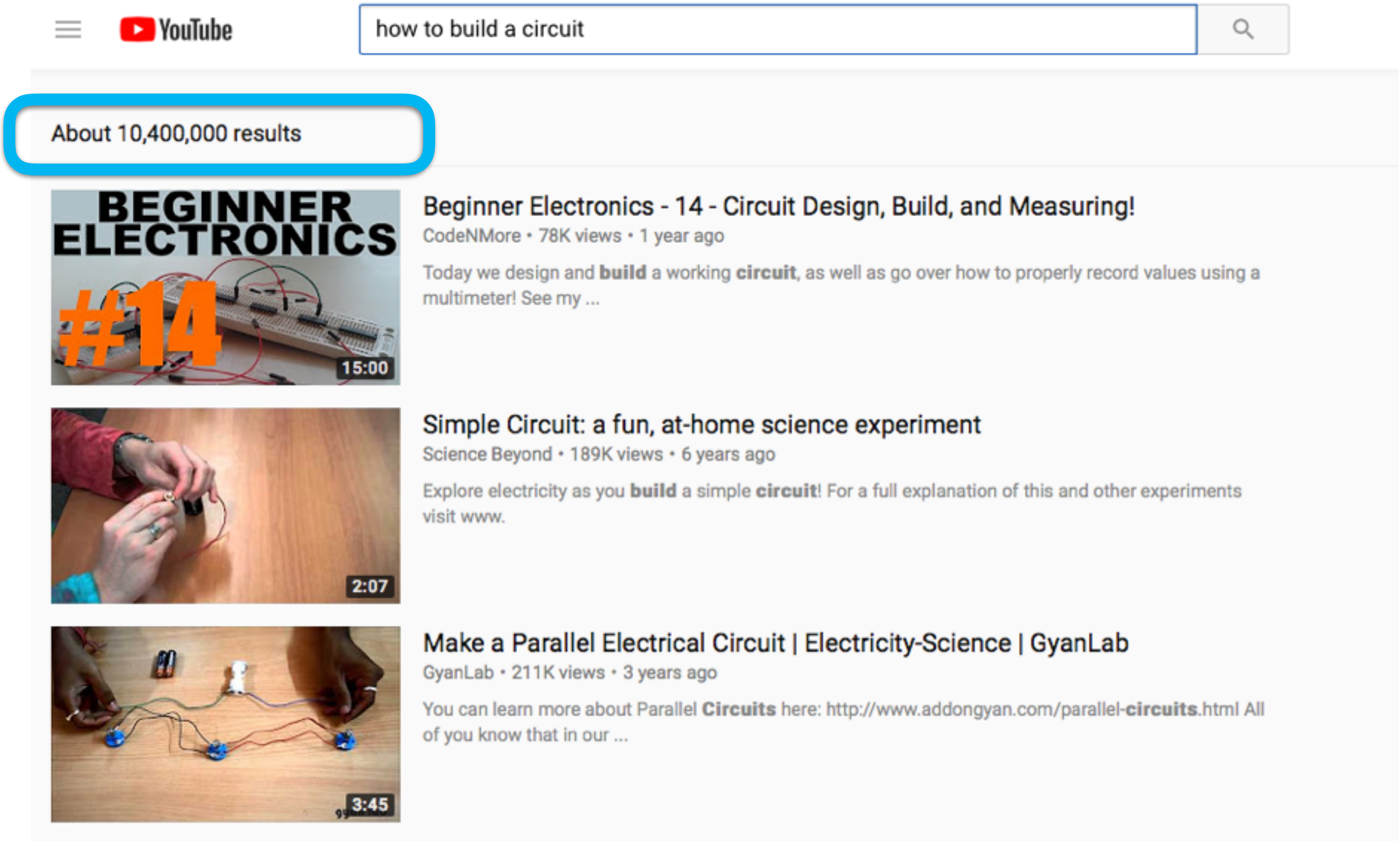
conclusions

past of **text editing:** expert user + special machine

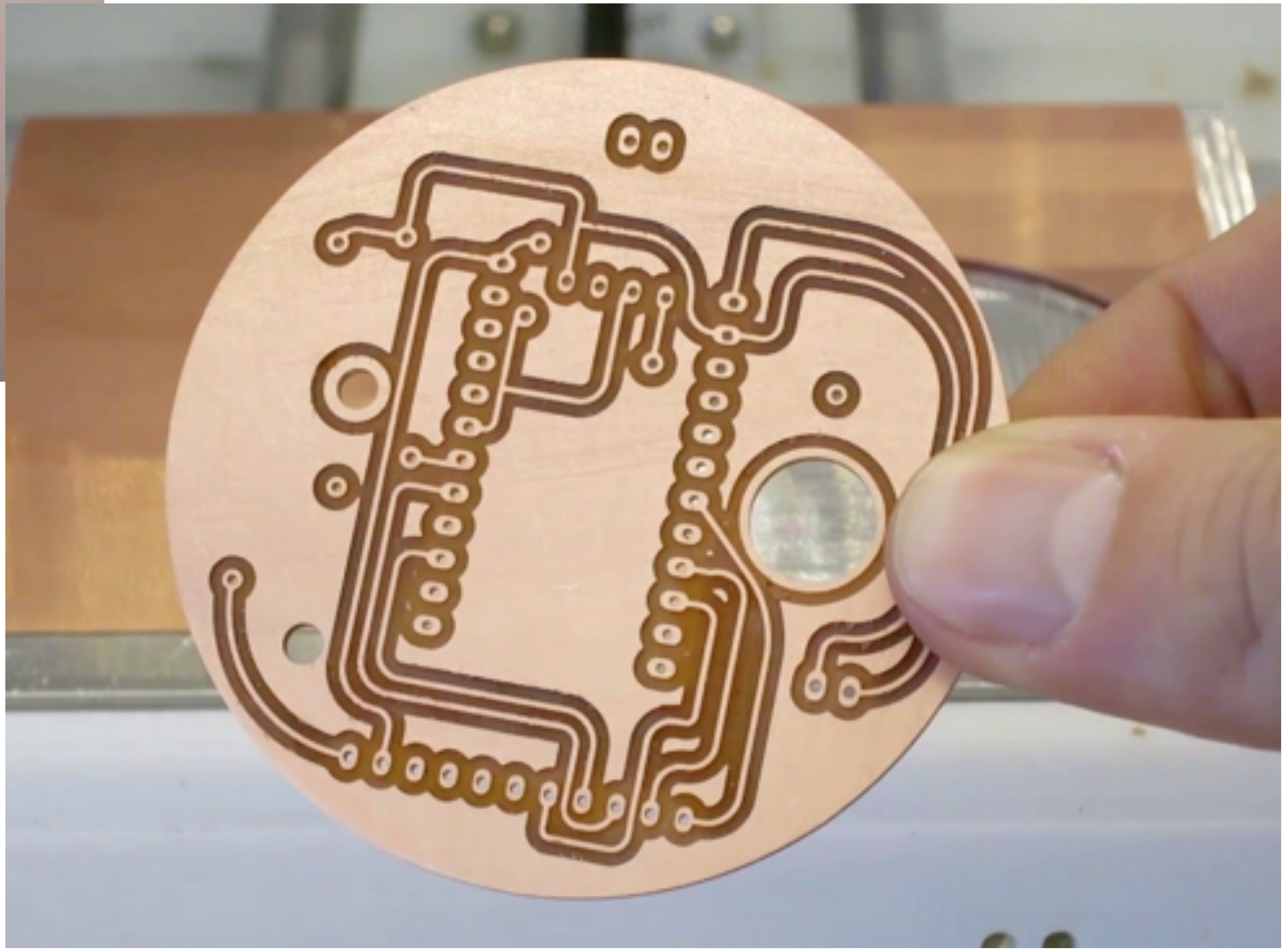


past of **photography:** expert user + special machines

past of **video editing:** expert users + special machines



today: **everyone** can contribute!



next: physical object design **(3D printing + electronics)** end.