TouchTokens: Guiding Touch Patterns with Passive Tokens

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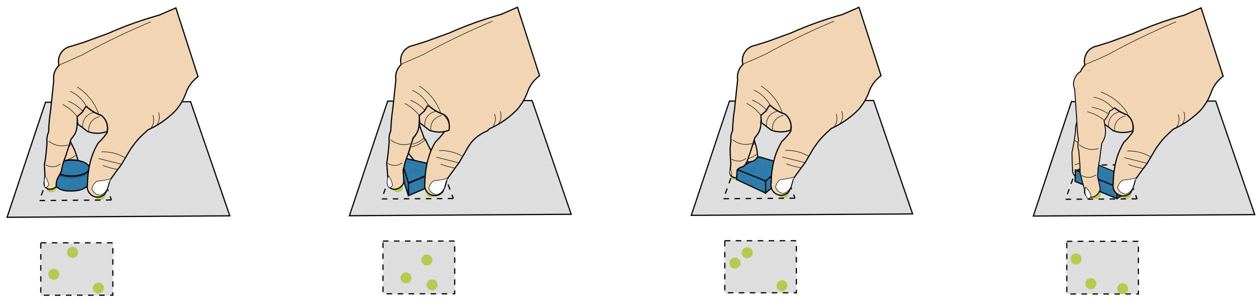

Figure 1. TOUCHTOKENS **are passive tokens that guide users' fingers to specific spatial configurations, resulting in distinguishable touch patterns.**

ABSTRACT
TOUCHTOKENS make it possible to easily build interfaces that combine tangible and gestural input using passive tokens and a regular multi-touch surface. The tokens constrain users' grasp, and thus, the relative spatial configuration of fingers on the surface, theoretically making it possible to design algorithms that can recognize the resulting touch patterns. We performed a formative user study to collect and analyze touch patterns with tokens of varying shape and size. The analysis of this pattern collection showed that individual users have a consistent grasp for each token, but that this grasp is user-dependent and that different grasp strategies can lead to confounding patterns. We thus designed a second set of tokens featuring notches that constrain users' grasp. Our recognition algorithm can classify the resulting patterns with a high level of accuracy (>95%) without any training, enabling application designers to associate rich touch input vocabularies with command triggers and parameter controls.

Author Keywords
Tangible interaction; Multi-Touch input

ACM Classification Keywords
H.5.2 : User Interfaces - Graphical user interfaces.

INTRODUCTION
The main characteristics of multi-touch gestures performed on the capacitive screens that typically equip tablets, smartphones, touchpads, as well as some tabletops, are the number of fingers involved and the individual trajectories of those fingers. Examples include 2- or 3-finger slide, and 2-finger pinch. But to the exception of a few research projects that consider touch points as chords [19, 21], interactive systems ignore the relative spatial configuration of contact points; what we call a *touch pattern*.

Our goal is to enable users to perform gestures based on a set of distinct touch patterns, thereby increasing the richness of input vocabularies for tactile surfaces. Our approach relies on physical guidance, as it would be unrealistic to expect touch patterns to be executed consistently across users, or even over time by the same user. As the literature suggests that users adopt grasp strategies that depend on the object to manipulate [39, 47], we investigate the potential of tangible tokens held on the surface to act as physical guides constraining the relative position of users' fingers.

We present TOUCHTOKENS, a novel interaction technique based on a set of easy-to-make passive tokens and a fast and simple recognition algorithm that can discriminate the unique touch pattern associated with each token in the set.[1] The approach features several advantages. First, physical tokens can provide space-multiplexed input by associating different controllers with different functions [18]. Second, tokens can alleviate issues related to discovery, exploration and learning inherent to gesture-based interaction [56]. Finally, tokens provide haptic feedback that promotes eyes-free interaction [28].

TOUCHTOKENS make it easy to implement applications that combine multi-touch and tangible input at low cost. Such a combination has the potential to foster collaboration, support distributed cognition, and enhance the user experience [1, 29, 46]. As opposed to other tangible systems that require electronic instrumentation (e.g., [9, 34]) or specific conductive material (e.g., [17, 33]), our system relies on an algorithm

Rafael Morales González, Caroline Appert, Gilles Bailly, and Emmanuel Pietriga. 2016. TouchTokens: Guiding Touch Patterns with Passive Tokens. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). ACM, New York, NY, USA, 4189-4202.

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Passive yet Expressive TouchTokens

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ABSTRACT
TouchTokens are passive tokens that can be recognized on any capacitive surface based on the spatial configuration of the fingers that hold them. However, interaction with these tokens is confined to the basic two-state model of touch interaction as the system only knows the tokens' position and cannot detect tokens that are not touched. We increase the expressive power of TouchTokens by introducing laser-cut lattice hinges in their design, so as to make them flexible. A new recognizer, that analyzes the micro-movements of the fingers that hold the tokens, enables the system to detect when a token is left on the surface rather than taken off it. It can also detect *bend* events that can be mapped to command triggers, and a *squeezed* state that can be used for quasi-modal interaction.

ACM Classification Keywords
H.5.2 : User Interfaces - Input devices and strategies.

Author Keywords
Tangible interaction; Multi-Touch input; Micro-movements

INTRODUCTION
TouchTokens [9] provide a simple means to develop tangible interfaces. The approach relies on easy-to-make passive tokens that feature notches constraining how users grasp them. Manipulating the tokens while maintaining the fingers in contact with the touch-sensitive surface leads to specific multi-touch spatial patterns that can be uniquely identified using a relatively simple software recognizer. However, users are limited in how they can manipulate these tokens, as is often the case with approaches based on capacitive sensing.

In this article, we aim at increasing the expressive power of TouchTokens by making the system able to detect: 1) when a token is left *on* or lifted *off* the surface, 2) when it is *squeezed* and 3) when it is *bent*. We achieve this without introducing any kind of instrumentation, thus preserving the simplicity of the original approach, which relies exclusively on passive tokens, and which works with any off-the-shelf capacitive surface. Our solution relies on the hardware side on making the tokens flexible by introducing lattice-hinges in their design, and on the software side on a novel recognizer that analyzes the micro-movements of the token-holding fingers that remain in contact with the surface.

After a short overview of related work, we describe the design of our flexible tokens, based on lattice hinges which can easily be obtained using fabrication processes such as laser cutting. We then report on a formative study in which we collected a sample of finger micro-movements that are representative of the manipulations afforded by our flexible tokens. Finally, we describe our recognizer, and evaluate its performance.

RELATED WORK
The most common approach to enabling tangible interaction on surfaces that use diffuse illumination technology consists in augmenting the objects with fiducial markers, and using a vision-based algorithm to identify them and track their location (see, *e.g.*, [5]). Other projects have investigated tangibles that reflect incoming light to the surface in a specific way in order to support more manipulations, such as TZee tangibles [14], which have the shape of a truncated pyramid and support gesturing on their sides, or Lumino blocks [1], which can be stacked. Diffuse illumination is a solution that is usually reserved to large setups such as tabletops.

Another approach involves augmenting tangibles with magnets. When coupled with a force-resistive screen, the system can detect pressure and gestures performed on top of the tokens [6]. When coupled with a surface augmented with a Hall sensor grid, the system can track tokens hovering over the surface [8]. GaussBricks [7], which also rely on a display equipped with Hall sensors, are bricks that can be assembled together to create larger objects featuring both deformable and rigid parts. While this approach enables very rich interactions, it requires augmenting the surface with specific sensors, and ensuring that the device's environment is free of any ferrous object that could interfere with the tangibles' magnetic field.

Solutions based on capacitive sensing are more affordable, but usually more limited. The system will often only be able to track the tokens that users are touching. There are, however, a few exceptions that go beyond these limitations. CapStones and ZebraWidgets [3] are capacitive units that can be assembled to configure different conductive circuits, enabling more manipulations with the tangibles that can, for example, be stacked or feature moving parts. PUCs [13] widgets rely on the principle of mutual capacitance so as to be detected

Rafael Morales González, Caroline Appert, Gilles Bailly & Emmanuel Pietriga. Passive yet Expressive TouchTokens. In CHI '17: Proceedings of the 35th Annual ACM Conference on Human Factors in Computing Systems, 3741-3745, ACM, May 2017.

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CONCLUSION

As discussed in [9], TouchTokens can play different roles in an application. They can be used to control parameters or filter data in a visualization. They can be used as controllers in games, as data receptacles to hold any kind of content, and even as an access control mechanism. Our new events enable developing more powerful interfaces where tokens can be dragged (*squeeze*) or clicked (*bent*, *squeezed*), and where several tokens can be laid on the surface (*on/off* enabling the system to keep track of them). This extended vocabulary can be used for different purposes, such as concurrently activating several filters, invoking commands on specific items or transferring data using drag-and-drop, click actions or contextual controls that take the tokens' relative layout into account.

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LeviProps: Animating Levitated Optimized Fabric Structures using Holographic Acoustic Tweezers

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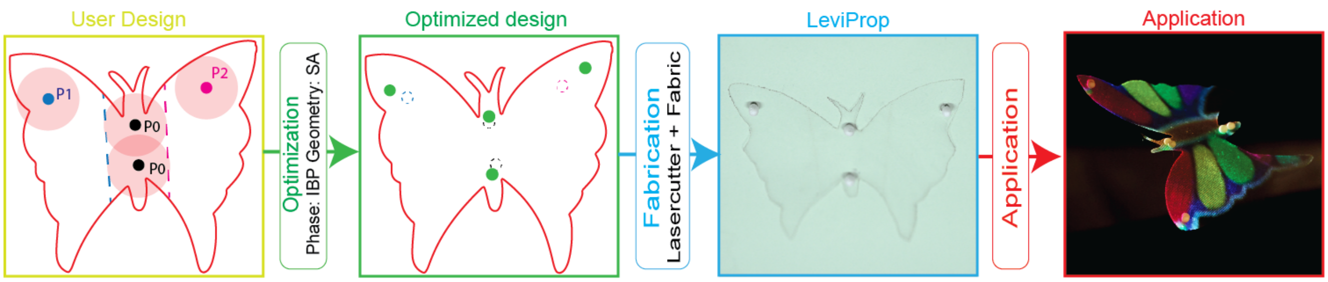

Figure 1. ***LeviProp*** **provides a design method for creating levitated props combining a light piece of fabric with attached anchor beads: (a) We input the outline design and animation constraints (i.e. moving parts and rotations); (b) Our novel algorithm optimizes the location of the anchor beads on the fabric, obtaining maximum trapping forces on the structure (c) The final design is easy to build with a laser cutter; and (D) can be levitated in an interactive way.**

ABSTRACT

LeviProps are tangible structures used to create interactive mid-air experiences. They are composed of an acoustically-transparent lightweight piece of fabric and attached beads that act as levitated anchors. This combination enables real-time 6 Degrees-of-Freedom control of levitated structures which are larger and more diverse than those possible with previous acoustic manipulation techniques. *LeviProps* can be used as free-form interactive elements and as projection surfaces. We developed an authoring tool to support the creation of *LeviProps*. Our tool considers the outline of the prop and the user constraints to compute the optimum locations for the anchors (i.e. maximizing trapping forces), increasing prop stability and maximum size. The tool produces a final *LeviProp* design which can be fabricated following a simple procedure. This paper explains and evaluates our approach and showcases example applications, such as interactive storytelling, games and mid-air displays.

Author Keywords

Levitation, design methods, tools, fabrication, mid-air UIs.

UIST '19, October 20–23, 2019, New Orleans, LA, USA

ACM ISBN 978-1-4503-6816-2/19/10…$15.00
https://doi.org/10.1145/3332165.3347882

INTRODUCTION

The idea of controlling matter to create advanced user interfaces has inspired HCI research, from concepts like the Ultimate display [30] to Radical Atoms [11]. Magnetophoresis [12] has been explored as a method for contactless control of matter. Ultrasonic levitation is another method [2,9,24,34] that has received significant attention for several reasons: a) no specific physical properties (e.g. ferromagnetic or dielectric) are required for the manipulated matter, allowing manipulation of materials ranging from polystyrene beads to coloured liquids [8,25], or even food [32]; b) it is low-cost compared to optical manipulation [14]; c) it is not harmful for the human health [3]; d) can reach tens of centimetres [6]; and e) it can manipulate multiple particles with fine control on the position [17]. However, apart from some exceptions which require high-power and can control only one particle [1,7,10,15], acoustic techniques are limited to small spherical particles (i.e. ~2mm) and shapes made of points, greatly limiting their expressiveness as interfaces.

This paper presents *LeviProps*, which are tangible levitated props created by combining lightweight and acoustically-transparent fabric (e.g. Super Organza) with attached polystyrene beads. The fabric provides a continuous and free-form 2D surface, adding to its expressiveness or even acting as optical diffusers for mid-air displays. The beads act as levitated anchors that support the fabric and enable dynamic control of the props. *LeviProps* can be manipulated in mid-air with up to 6 Degrees-of-freedom (DoF) and be composed of multiple moving parts called levitation primitives. A primitive is a set of one or more beads attached to the fabric that retain their relative position (i.e. move and rotate together). Primitives can be animated independently, e.g. the butterfly in Figure 1d is composed of 3 primitives:

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UltraPower: Powering Tangible & Wearable Devices with Focused Ultrasound

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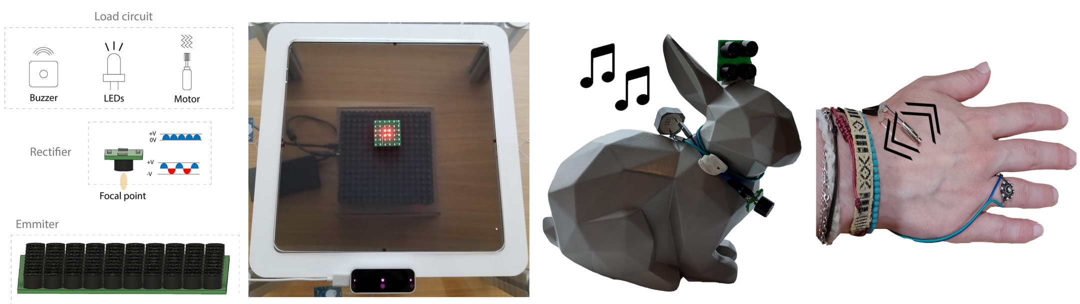

(a) (b) (c) (d)

Figure 1: UltraPower uses focused ultrasound to wirelessly transfer power to components in tangible and wearable devices (a): e.g., lights in a tabletop tangible object (b), loudspeakers on a physical object (c), and vibration motors in wearable devices (d).

ABSTRACT

Wireless power transfer creates new opportunities for interaction with tangible and wearable devices, by freeing designers from the constraints of an integrated power source. We explore the use of focused ultrasound as a means of transferring power to a distal device, transforming passive props into dynamic active objects. We analyse the ability to transfer power from an ultrasound array commonly used for mid-air haptic feedback and investigate the practical challenges of ultrasonic power transfer (e.g., receiving and rectifying energy from sound waves). We also explore the ability to power electronic components and multimodal actuators such as lights, speakers and motors. Finally, we describe exemplar wearable and tangible device prototypes that are activated by *UltraPower*, illustrating the potential applications of this novel technology.

TEI '21, February 14–17, 2021, Salzburg, Austria

ACM ISBN 978-1-4503-8213-7/21/02…$15.00
https://doi.org/10.1145/3430524.3440620

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; • **Hardware** → *Power and energy*; *Wireless devices.*

KEYWORDS

Energy; Ultrasound; Tangible Device; Wearable Device; Wireless Power Transfer

ACM Reference Format:
Rafael Morales, Asier Marzo, Euan Freeman, William Frier, and Orestis Georgiou. 2021. UltraPower: Powering Tangible & Wearable Devices with Focused Ultrasound. In *Fifthteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21), February 14–17, 2021, Salzburg, Austria.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3430524.3440620

1 INTRODUCTION

Power is a crucial requirement for almost every interactive computing device. Provision of power has a significant impact on the device form factor and use: batteries need to be integrated, charged or replaced, whereas wired alternatives may constrain the range of interactions with the device. Moreover, power integration continues to affect a device after its functional life-cycle has ended as it can prevent or increase the cost of its recycling. To that end, wireless power transfer (WPT) is an appealing alternative, pioneered by N. Tesla in the 1890s, whereby power is transferred without physical

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