Imaginary Interfaces: Touchscreen-like Interaction without the Screen

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Abstract

Screenless mobile devices achieve maximum mobility, but at the expense of the visual feedback that is generally assumed to be necessary for spatial interaction. With *Imaginary Interfaces* we re-enable spatial interaction on screenless devices. Users point and draw in the empty space in front of them or on the palm of their hands. While they cannot see the results of their interaction, they do obtain some visual feedback by watching their hands move. Our user studies show that Imaginary Interfaces allow users to create simple drawings, to annotate with them and to operate interfaces, as long as their layout mimics a physical device they have used before. We demonstrate how this allows an imaginary interface to serve as a shortcut for a physical device and we believe that ultimately Imaginary Interfaces will lead to the development of standalone ultra-mobile devices.

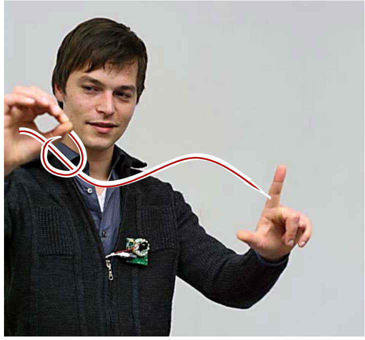

Figure 1. When users draw using an Imaginary Interface, they retain an image of their creation in their minds. This image allows users to interact with the otherwise invisible content, such as to annotate it.

CHI'12, May 5–10, 2012, Austin, Texas, USA.
ACM 978-1-4503-1016-1/12/05.

Keywords

imaginary interfaces; mobile; wearable; spatial memory; screenless; memory; non-visual; touch.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces - Interaction styles;

Introduction

In order to achieve ultimate mobility, researchers have proposed abandoning screens [10]. Such wearable devices are operated using hand gestures, voice commands, or physical buttons. Gesture Pendant [13], for example, allows users to perform gestures that invoke commands, such as "open door".

However, screenless mobile devices traditionally do not support spatial interaction, such as tapping on a button, because, seemingly, there is nothing to tap on. This is a substantial loss as spatial interaction is the main interaction paradigm across all of today's form factors, including desktops, tabletops and mobile devices.

Imaginary Interfaces (UIST 2010)

In our paper presented at UIST 2010 [3], we introduced *Imaginary Interfaces*, screenless devices that allow users to perform spatial interaction without visual feedback. Instead of receiving feedback from a screen, all visual "feedback" takes place in the user's imagination.

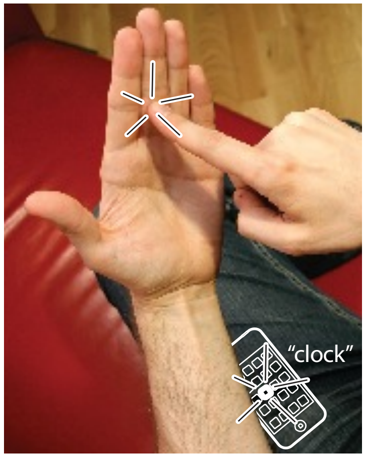

Figure 2. The *Imaginary Phone* allows this user to operate the phone while it remains in his pocket. Instead, he invokes an app by tapping on the corresponding location on his hand. The similarity between four fingers and four columns of icons on the physical device simplify this.

Figure 1 illustrates the interaction. The user is drawing a stock price curve which he is then annotates. While he cannot see the drawing he has created, watching his hands interact creates a mental after-image that provides enough of a spatial reference to allow him to interact with the invisible drawing.

The figure also shows our early device prototype. The user is wearing a brooch containing an infrared illuminant and an infrared camera that observes the space in front of the user. The device extracts the user's hands using computer vision techniques.

In three user studies, we had participants create simple drawings, annotate existing drawings, and point at locations described in a coordinate system of finger and thumb units ("one finger up and two thumbs right").

Imaginary Phone and Transfer Learning (UIST 2011)

Given that imaginary interfaces offer no visual output, one of the key challenges is how users can learn their layout. In our UIST 2011 paper [4] we proposed learning by *transfer*. We designed imaginary interfaces that mimic the layout of a physical device that users are already familiar with, such as an iPhone. Figure 2 shows the *Imaginary Phone,* a prototype that users operate by tapping on their hand; the relative position of the touch event is then transmitted wirelessly to an actual iPhone, here located in the user's pocket.

Unlike our earlier system that had users interact in empty space, we moved the interaction onto the user's hand. The hand not only provides users with tactile feedback but also allows them to associate functions with physical landmarks, such as finger segments.

For the new prototype we replaced the infrared camera with a time-of-flight depth camera, which helps separate the hands from each other. We also found time-of-flight cameras work well in direct sunlight, allowing for truly mobile use.

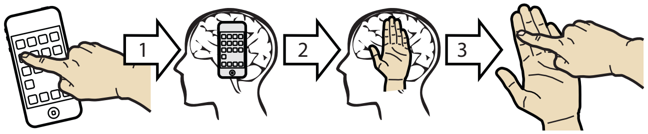

Figure 3. The three assumptions of transfer learning.

The concept of transfer learning introduced in our paper is based on the three assumptions illustrated by Figure 3. We validated each of them in a user study: (1) Users build up spatial memory automatically while using a physical device; in our study, participants knew the correct location of 68% of their own iPhone home screen apps by heart without training. (2) Spatial memory transfers from a physical to an imaginary interface; in our study, participants recalled 61% of their home screen apps when recalling app location on the palm of their hand. (3) Palm interaction is precise enough to operate a typical mobile phone; in a second study, participants reliably acquired 0.95cm wide iPhone targets on their palm—accurate enough to operate standard iPhone widgets.

Research topic and expected contribution: standalone ultra-mobile devices

These findings illustrate what is conceptually possible on screenless mobile devices, namely interactions ranging from drawing to the operation of more or less traditional GUIs. This is beneficial because GUI interaction can be more expressive than gesture interaction, where interaction is typically limited by the fact that one gesture maps to one function. Additionally, a GUI-inspired model allows us to leverage users' experience with more traditional devices, such as desktops and mobiles.

These abilities suggest two different use cases.

On one hand, imaginary interfaces could serve as a shortcut mode for physical devices. In such a use case, users continue to carry their physical device but to save time execute functions on the imaginary counterpart without retrieving the physical device.

Figure 4. With collaborative imaginary interfaces, users can come together and co-opt any surface or space for their use.

On the other hand, our findings have inspired us to think more broadly. With sufficient training based on a physical device, shouldn't users be able to operate an imaginary device standalone? In the future, such devices should allow for *extremely* small form factors that leave the user's hands free, allowing for truly ubiquitous use. At the same time, by leveraging the interaction paradigm discussed above, such devices could allow for a reasonably expressive interaction, closer to what we find on today's phones, desktops and tabletop computers.

The goal of my work is to explore this space, i.e., to create standalone ultra-mobile devices with powerful interaction.

The work described in the preceding sections represents the first steps toward this goal. In the remaining time of my PhD, I plan to push the concept further by exploring how to author imaginary interfaces on the fly, how to browse interfaces, and how to allow multiple users to collaborate.

1. Authoring: draw-your-own interface

We have started to explore *draw-your-own* imaginary interfaces that allow users to draw interface elements and then later use them. As a side effect, since users create the interface themselves they are already familiar with its layout and there is no need for explicit learning.

2. Exploring unfamiliar interfaces

Transfer learning, as described earlier, allows users to leverage their experience with a familiar physical device. To allow users to operate an *unfamiliar* interface, we are porting audio-based browsing techniques intended for blind users (e.g., Apple VoiceOver [1]) to imaginary interfaces.

3. Collaborative imaginary interfaces

The designs described so far all assume a single user, but conceptually multiple imaginary interfaces could be used in concert with multiple users. As shown in Figure 4, we imagine two users coming together, each wearing their own sensor and co-opting an arbitrary surface or space for interaction.

By watching each other interact, we expect users to form a common understanding of the interface and to be able to combine their previous experiences (e.g., "the Save button is over here").

Possible implications for visually impaired

While our main goal is to create and explore ultra-mobile devices, Imaginary Interfaces and interfaces designed for the visually impaired have interesting similarities and differences worth exploring. In particular, we plan to explore the value derived from the extra feedback users obtain from watching their hands interact. Exploring this and related questions will help us better understand Imaginary Interfaces and at the same time it will allow us to discover which aspects of our technology can inform the design of interfaces for the visually impaired.

Related Work

Highly mobile devices have supplied visual feedback by utilizing projectors. For instance, Skinput [5] with vibration-based touch sensing on the hand and forearm and Sixth Sense [9] with computer vision based sensing both use mobile projectors to provide visual feedback. OmniTouch [6] provides similar functionality with a robust depth-camera-based sensing algorithm that detects interaction surfaces and touch.

The goal of *screenless* devices has been explored in the field of wearable computing. GesturePad [12] is one example of a technology users could always carry with them. Gesture Pendant [13] introduced the chest-worn camera to sense hand interaction; our tracking hardware is directly inspired by it. Virtual Shelves [7] lets users place objects in a finite number of containers that exist at precise locations in the hemisphere in front of them.

Our future prototypes will rely on auditory feedback and will therefore draw from audio-based mobile interfaces [11] and interfaces for the visually impaired [1].

Research Situation and Dissertation Status

At the time of this writing I have published two UIST full papers on Imaginary Interfaces [3][4] and an exploration into one-handed form factors (PinchWatch [8]). My PhD work builds on my Master thesis on visualizing off-screen targets on maps (Wedge [2]).

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