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TCieX: An Environment for Designing and Experiencing A Variety of Visuo-Haptic Sensory Conflicts

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ABSTRACT

The goal of our project is to use visual interaction to communicate weight, stiffness, or viscosity by exploiting pseudo-haptics in human-computer interaction design. Currently, interaction designers have a very limited understanding of what multimodal conflicts we should produce for the type of haptic illusion we want to create. TCieX (Touch-Centric interaction embodiment eXploratorium) is a collection of simple interaction test suites that help us experience different combinations of multimodal interactions. In TCieX, a user produces a variety of combinations of temporal, visual, and auditory representations for different types of simple object movement with different C/D (Control/Display) ratios and mapping profiles, and interacts with the object to experience how one "feels" weight or viscosity.

KEYWORDS: Interaction design, pseudo-haptic feedback, communication of weight through visual interaction, touch-centric interaction embodiment exploratorium.

INDEX TERMS: H.5.2 [Information interfaces and presentation]: User Interfaces — Interaction styles; I.3.6. [Computer Graphics]: Methodology and Techniques — Interaction techniques

1 INTRODUCTION

Our project concerns communicating *weight* in interaction design. Weight has been communicated primarily through three means in human-computer interaction: symbolic representation (e.g., "240 g"), kinesthetic interaction (e.g., by wearing a physical actuator), or haptic feedback (e.g., by applying low-frequency stimuli to the forearm).

Our approach is to use a fourth means: using visual interaction to communicate weight by exploiting pseudo-haptic feedback [3]. Pseudo-haptic feedback, which stimulates haptic sensations such as stiffness or friction without necessarily using a haptic interface but incorporating visual feedback, is an effective means to communicate information that may not physically present with the brain [2].

Lécuyer [2] describes three steps to design a pseudo-haptic system that simulates a given haptic property (p. 51): (1) to identify a law that controls that haptic property and associates it with spatial parameters; (2) to set up a visuo-haptic sensory conflict focusing on a spatial parameter associated with this haptic property; and (3) to modify the perception of the targeted haptic property and create pseudo-haptic feedback by simply modifying the visual feedback of this spatial parameter. In modifying the visual feedback, the notion called the C/D (Control/Display) ratio, which refers to how to change the speed of hand movement (Control) in relation to the speed of cursor movement (Display), is introduced.

Currently, interaction designers have a very limited understanding of what visuo-haptic and/or audio-haptic sensory conflict we should produce for the type of haptic illusion we want to create.

We have been building TCieX (Touch-Centric interaction embodiment eXploratorium), which is a collection of simple interaction test suites that help us experience different combinations of multimodal interactions. In TCieX, a user produces a variety of temporal, visual, and auditory representations for different types of object movement with different C/D ratios and mapping profiles (in the "Setting" mode), and interacts with the object to experience how one "feels" the weight (in the "Trial" mode).

2 THE TCIEX TOOL

This section gives an overview of two of the interaction test suites currently implemented on TCieX, which runs on the Apple iPad.

2.1 TCieX: *two panes*

Figure 1 shows one of the interaction test suites implemented on TCieX, *two panes*. The basic interaction *two panes* provides in the "Trial" mode is that when the user touches the lower pane with a fingertip and moves the finger, a ball-like object in the upper pane moves accordingly. *two panes* allows the user to create different mapping between the movement of the fingertip in the lower pane and that of the object in the upper pane by using the right column in the "Setting" mode.

For instance, suppose a user moves a fingertip from left to right with constant speed in the lower pane (see Figure 1). The object in the upper pane starts moving faster when the object enters the area displayed with the reddish contour. The degree of redness represents the scale of the increase in speed. Selecting one of the four "Profile" radio buttons (flat, Gaussian-curve, bell-curve, and triangular shapes) in the right column determines which mapping profile to apply for the acceleration. Conversely, when the object enters the bluish contour area, the object starts to slow down. By changing the mapping (i.e., changing the C/D ratio) the user feels a hole (by speeding up) and a bump (by slowing down) on the surface in the upper pane, thus experiencing pseudo-haptics.

With the Setting mode, one may change where to put such colored contour areas, the size of the areas, and where the apex is. When the user touches the upper pane and holds the fingertip still, a color-gradient contour appears. It can either be reddish or bluish, depending on the "+" or "-" option the user selects in the right column of the pane.

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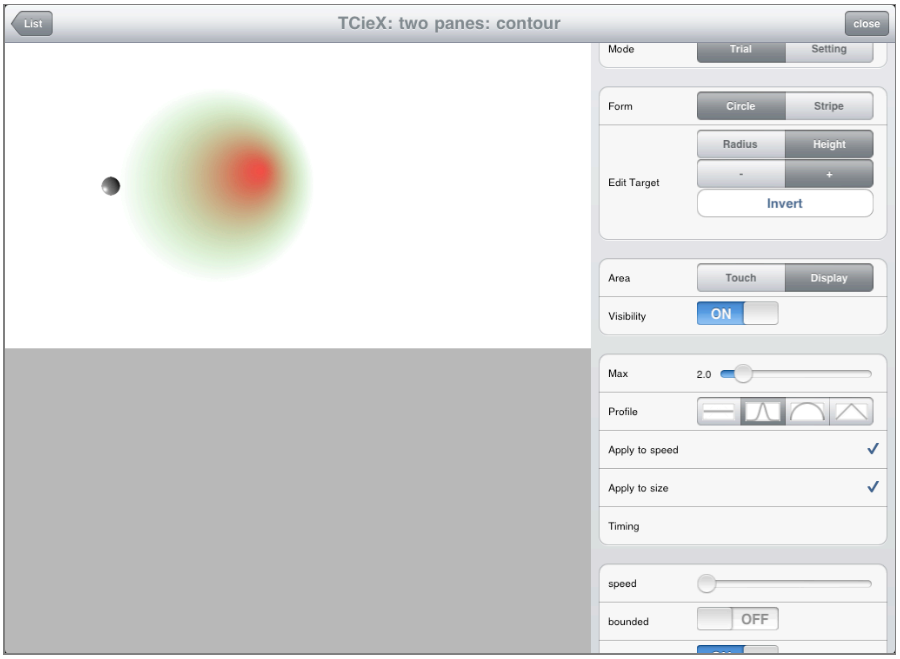


Figure 1. TCieX: *two panes* (1)

In addition to changing the speed of the object movement, we may also change the visual size of the object. Then, the movement of the object remains the same, but the visual display dynamically changes (Figure 2(a)). We may feel the interaction with the object a little differently, as reported in [1].

We may even apply the contour drawing in the lower pane. When a bluish contour is created in the lower pane, mechanically it is not the movement of the object that starts slowing down, but the movement of the fingertip that slows down (Figure 2(a)).

An alternative to drawing a contour for producing different mapping is to place stripe patterns in the lower panel (Figure 2(b)). Again, when the fingertip is touching the reddish part, the object increases the speed, and when the fingertip is touching the bluish part, the object starts slowing down. One may change the width of the stripe and the degree of redness (or blueness) through touch interactions. This mode creates a feeling as if one is dragging the object over the surface of a wavy tin roof, an experience similar to the one exhibited by [5].

Other options the user may try with *two panes* include changing the maximum degree of magnification of the speed and size (default is 2.0), changing the default mapping between the fingertip movement and the object movement (default is 1:1), changing the appearance of the object (red dot or metal-like 3D texture), or changing the behavior of the object when the user releases the fingertip from the display (either disappear, remain, or reset). The user may turn off the visual display of the contour or the striped pattern by turning off the visibility. Finally, the user may place an image as a background to see how it affects feeling the object's behavior (Figure 2(c)).

2.2 TCieX: *water coin*

Other series of test suites of TCieX are for interacting with objects captured by a high-speed camera. Figure 3 shows a short video of dropping a coin into a glass of water, captured at the rate of 420 fps. Since a regular video runs at 30 fps, if we play this video with the regular speed, we can experience the object captured in the video at a speed 14 times slower than the real speed, which gives us a great view of the world that we normally do not perceive.

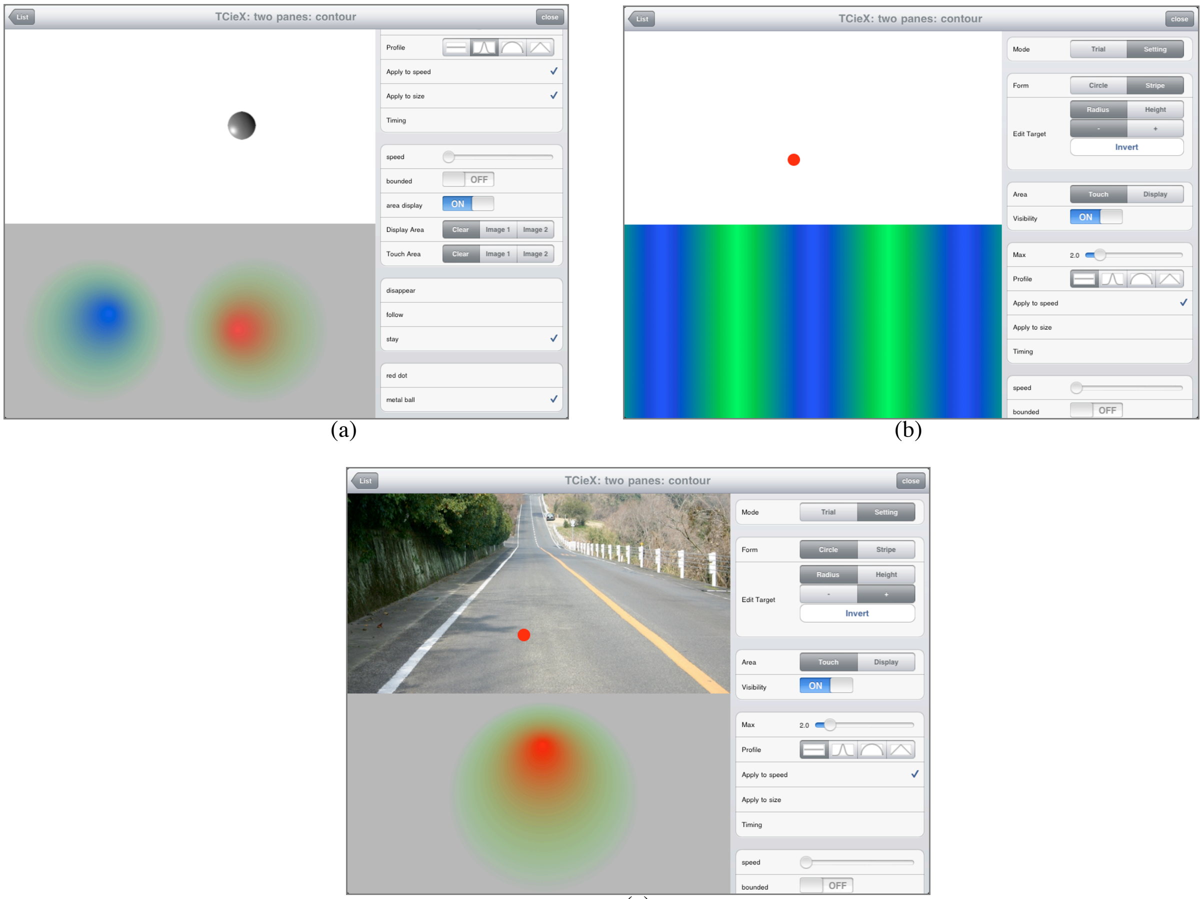
In *water coin*, the user plays the video by sliding the fingertip from left to right in the lower pane. By moving the fingertip toward the left and right, the user starts to feel in control of the vertical position of the coin. Although not empirically tested yet, it was interesting for us to discover that we feel the coin as being a bit heavier when moving it upward than moving it downward.

The user may also change the mapping between the movement of the fingertip and the speed of the movie play in terms of the frame position of the video by using a line-graph type of interface. For instance, the user may play the video with the normal speed (e.g., by displaying every 14th frame per 1/30 sec) for the most part, but mapping the moment of the impact of the coin into the surface of the water at a slower speed, such as 30 fps.

3 Discussion

This paper presents TCieX, a test suite for experiencing various kinds of pseudo-haptics by producing different types of visual interactions. Other types of test suites of TCieX currently include *ball & square*, in which the user directly interacts with the ball colliding into the square box with different levels of stiffness of the edges (Figure 4(a)); *slip boxes*, in which the user interacts with the ball with boxes that keep slipping away (Figure 4(b)); *snow*, in which the user accumulates falling snowflakes by attaching the side of the hand against the screen (Figure 4(c)); or *shinkansen*, in which the user moves the train endlessly by turning the wheel (Figure 4(d)). Figure 4(e) shows a part of the menu list of the lineup of TCieX test suites.

Our immediate future plans include developing more varieties of test suites and conducting empirical studies for some of the implemented test suites to see whether users perceive pseudo-haptics by using EMG (electromyograph).



(a) (b) (c)

Figure 2. TCieX: *two panes* (2)

Our goal is to apply pseudo-haptic feedback mechanisms and other types of illusions to more effectively communicate weight in a variety of application systems. The concept of weight is useful in human-computer interaction design. Examples include: (1) showing how heavy an object is to a remote design team member, (2) showing how stiff a vein is in remote operation, or (3) showing how important a class is in a programming environment. For example, if there is a class on which a large number of classes are dependent, we may assign a large weight to the class so that it is heavier to move and edit than other, less-dependent classes [3].

Illusions have been regarded as something to be taken care of in interaction design [4], because illusion may cause a wrong interpretation of the information presented to a user, and therefore may not be desirable. The use of illusion as perceived through pseudo-haptic feedback, however, makes us consider how a user perceives the world through multiple sensory channels. The physical world is not necessarily the ideal situation for a user. We may need to alternate information on some of the channels so that the user would perceive the world more effectively. We think that properly situated illusion should be explored and used more in interaction design. The notion of direct manipulation in interaction design, then, may need to be recontextualized.

We believe that illusion, together with delicate interpretation and feedforward, would be essential concepts toward multimodal, embodied interaction design [4].

Delicate interpretation, or liberal, mindful interpretation, is necessary to generate meaningful feedback to the user when using data collected by external sensors. Human body movement has certain characteristics, and fingers are no exception. When a person thinks he or she is drawing a straight line with an index finger on a touch-sensitive display, the coordinates collected through a series of touched areas may constitute not a straight line but a number of crooked segments. This is not because of the inaccuracy of the touch sensors, but because of the characteristics of finger movement. Visually displaying the segments in accordance with the coordinates might be an accurate reflection of the user's physical activity, but it would not be what the user really meant to do.

People interact with the external world based on the preunderstanding of the world. *Feedforward* is the presentation of information for the user to develop such a preunderstanding. The human brain plans how much force to put on the muscles of the forearm before holding a book so that the arm neither tosses the book up nor drops the book. This planning is possible only by looking at the book, with the preexperienced knowledge of the relation between the look of a book and its weight.

So far, interaction designers know very little about how to incorporate illusions into their design. TCieX would help us design, generate, experience, and evaluate different types of haptic illusions in the early stages of designing and building application systems that would more effectively communicate information to users.

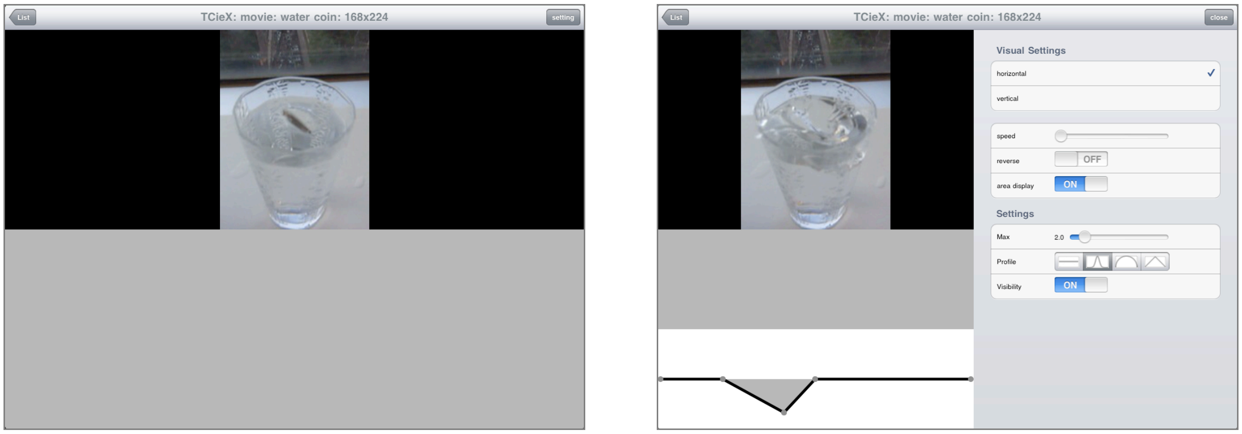
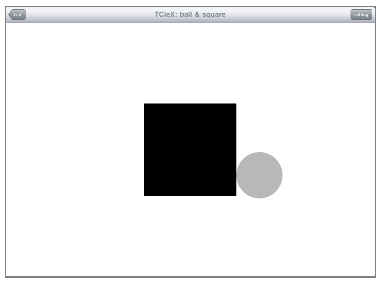
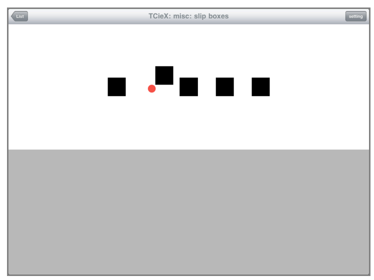


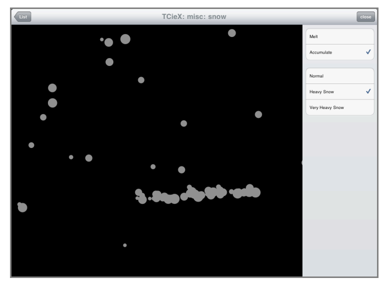
Figure 3. TCieX: *water coin*



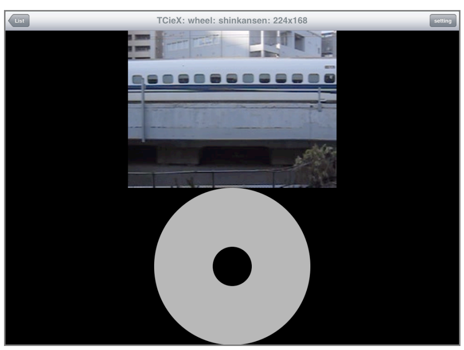
(a) *ball & square*



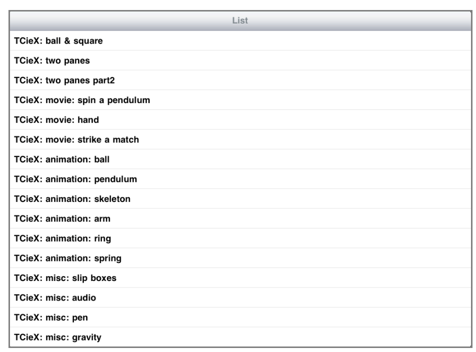
(b) *slip boxes*



(c) *snow*



(d) *shinkansen*



(e) menu list

Figure 4. Other test suites in TCieX

Acknowledgements

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