Multi-touch Interaction

Tomer Moscovich

Brown University

Box 1910

Providence, RI 02912, USA

tm@cs.brown.edu

Abstract

Many everyday activities rely on our hands' ability to deftly control the physical attributes of objects. Most graphical interfaces only use the hand's position as input. For my dissertation, I study how multi-touch input lets us make better use of our dexterity.

Keywords

Multi-touch interaction, touchpads, coordination.

ACM Classification Keywords

H.5.2 User Interfaces—Interaction styles.

Introduction

Our everyday interaction with the world is complex, fluid, and often transparent. But when we interact with modern graphical interfaces, we are stripped of our dexterity, and are left poking clumsily at the digital world with the single index finger of the mouse pointer. Imagine tying your shoes with only one finger. Even with one finger on each hand, most of us would be hard-pressed to get dressed in the morning. The goal of my research is to make interaction with a computer more facile and satisfying than this by using abilities of the hand beyond simple position control.

While multi-finger interaction is a common experience for most touch-typists, typing, clicking a mouse, and executing key commands are discrete serial actions. In
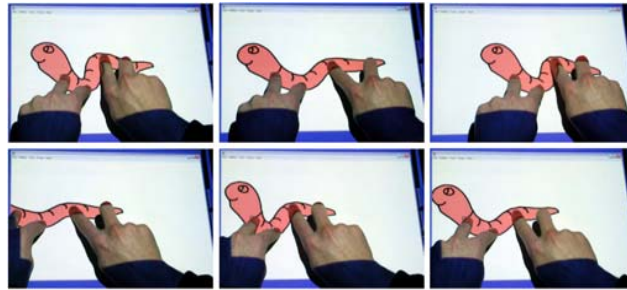
Figure 1. A user bends a drawing by touching it with his fingers. Multi-touch control makes it easy to perform simple expressive animations.

my work I focus on interactions that are continuous and coordinated like the movements of an artist controlling a paintbrush. Multi-point touchpads make this type of interaction possible. By touching different parts of the interaction surface, users of these touchpads can control many more parameters than they can with traditional pointing devices.

My research program progresses along two supporting paths. I first develop multi-finger interfaces for graphical manipulation. I have developed a deformation and animation interface that lets novice users easily create expressive animations. I have also explored multi-finger cursor techniques for fluid multi-parameter interaction with graphical objects, as well as novel methods for lightweight grouping. Guided by these applications, I design experiments aimed at establishing principles of multi-finger interaction. The study of whole-hand interaction has generally been limited to gesture-based techniques, we still know little about continuous manipulation. My research extends our understanding of continuous multi-finger interaction, and places it within the context of bimanual interaction, and other types of high-parameter input such as tangible interfaces.

Multi-touch Performance Animation

When people want to express motion, they often act it out using gestures and props. However, creating computer animations is a tedious task that requires significant training. The goal of this project is to make it easy for people to create simple 2D animations by relying on their natural sense of timing, and their experience with real-world flexible objects. Using a multi-point touchpad and a novel deformation algorithm, my system allows users to move and bend drawings by touching them with their fingers as though they were physical rubber props. This interface is very easy to learn, yet it lets even novice users create expressive animations. While traditional key-framing techniques tend to produce stilted motions in the hands of novices, my technique yields more believable results, since it preserves all of the nuances and imperfections of the user's hand motion.

I have demonstrated this system to a wide audience, and found that people grasp the concept immediately, needing no more instruction than the phrase "try touching it." Observers were eager to try out the system, and explore the many ways they can bend and animate the drawings.

The internet today is full of ideas expressed using words, sounds, and pictures, yet relatively little motion. Our daily conversations, however, are full of varied and nuanced movement. Using a multi-point touchpad we can translate the motion of the hand into animated digital expression.

Figure 2. Multi-finger cursor techniques let users control many degrees of freedom simultaneously.

Multi-finger Cursor Techniques

Direct touch interaction is appealing, since it is a simple concept that reflects our daily interaction with real objects. However, it is common today to control a graphical interface through some mediating device such as a mouse or touchpad. There are good reasons for this indirection. Early scribes began writing with a reed rather than dipping their finger in ink because it was easier to control, and produced lines of higher resolution. Likewise, the mouse cursor lets users indicate small UI elements with more precision than a finger. It also occludes less of the screen and lets the hand rest on the table. The mouse pointer is the visible end-effector of a digital tool for moving and activating screen objects. Using multi-point touchpads we can create tools that use more of the hand's parameters to control more than just position. For example, in current drawing programs translation and rotation are separate operations. A multi-finger cursor can unify them into a single action.

I have devised several multi-finger cursor techniques to illustrate this idea. An important feature of these methods is that hand parameters are not mapped directly to the manipulated object; instead, they control an intermediary representation, the cursor, which in turn controls the object. The cursor is used to simultaneously select the object to control, and then to transfer its properties to it. The measured properties of the hand can play a role in both selection and manipulation.

Figure 2 (left) shows a hand cursor, which displays the finger touch-points (black dots) relative to the hand position on the screen. To the user, moving objects on the screen feels like sliding flat objects on a table. Users can select multiple objects using individual fingers, and can simultaneously translate and rotate objects. Users can also control objects with many degrees of freedom, for example the animated drawings described in the previous section, or the control points of a curve.

Since users generally control only one object at a time, it is useful to abstract the parameters of the hand into a single point cursor. The cursor shown in figure 2 (right) allows the user to focus on a single target, while simultaneously controlling its position, rotation, and scale. In commercial systems these operations must be performed separately. With this cursor, all three may be accomplished in a single smooth motion.

The technique shown in Figure 3 extends the idea of area cursors by allowing the user to control the size of the cursor's activation area. As with a real hand, the size of the cursor's activation area is proportional to the span of the fingers. Users need not be precise when selecting small isolated targets. They simply spread their fingers and move to the vicinity of the object. Users can select a specific object in a crowded area by bringing their fingers together and minimizing the area of the cursor. Since the adjustable area cursor can distinguish the intentional selection of a single object
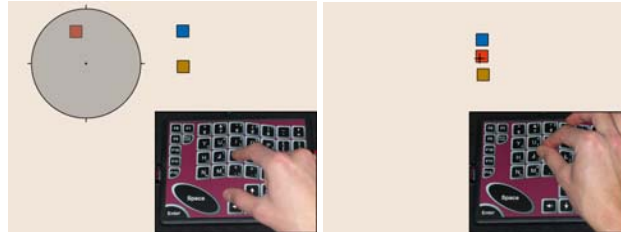
Figure 3. An adjustable area cursor makes it easy to select isolated targets (left) while seamlessly allowing for precise selection of individual targets (right).

from the intentional selection of many, users can easily grab ad-hoc groups of adjacent objects. Groups are simply determined by the radius of the cursor, so they may be quickly created or modified without a separate grouping step.

Principles of Multi-touch Interaction

The techniques I have described show the possibilities created by multi-touch interaction. However, they also bring up many questions about this form of interaction. What types of tasks are best suited for multi-touch interaction? What are the physiological and cognitive limits on this type of multi-parameter control? How does it compare and relate to other high degree-of-freedom methods such as bimanual interaction?

There are many possible directions of research. My first experiments will examine properties of interaction using two fingers on one hand. This configuration is interesting since it serves as a base case for multi-finger interaction and is, in some ways, analogous to well studied bimanual interaction techniques. Studies have shown symmetric bimanual methods to be useful for various manipulation tasks. Some of these tasks may be more easily accomplished using two fingers of

one hand, while others may be more difficult to perform this way. For example, the motion of two fingers on the same hand may be more difficult to separate than the motion of two hands. In a task such as adjusting a rectangle to tightly enclose an ellipse, the user may need to focus on each side individually. My initial explorations indicate that while users may be able to coordinate the motion of two fingers better as they approach the target, they perform the final matching better using two hands, since it is easier to separate the degrees of freedom.

For a more integrated task, such as simultaneous rotation and translation, using one hand may have some advantages. The ability of a user to coordinate the motion of two hands depends on different factors than does finger coordination. I am studying coordination in multi degree-of-freedom actions using a segment tracking task. This experiment will explore the effect of task difficulty on bimanual and multi-finger coordination, as well as the effects of stimulus-response compatibility on these two methods of interaction.

Future Work

Multi-touch interaction has many possible applications. I am currently investigating methods for 3D manipulation, and am studying physically-inspired whole hand interaction techniques.

Based on the results of the experiments described in the preceding section, I will plan further studies of the properties of multi-touch interfaces. I wish to understand the extent of human control of finger motion and the factors affecting it, and then use this understanding to develop models that will aid in designing future multi-touch interfaces.