

Slider-based Foot Input Devices:

Methods for Stand-up Mousing

Leslie Wu

Stanford University
lwu2@cs.stanford.edu

ABSTRACT

This technical note presents a novel plastic-slider based mouse input device which may be used as a classical hand mouse (on a pad) or as a foot mouse (typically, on carpet). Our motivation is two-fold: first to understand the imagined versus feasible design space of constrained and unconstrained input technologies, and then to propose a novel sliding-based input device which we explicitly designed for standing. Unlike most mice, the slider mouse is designed to be easily used *while standing* rather than whilst seated, as an exertion interface which encourages hip and ankle mobility, lower body proprioception and single-leg strength & balance. We use this foot-based slider mouse as a research probe into questions of constrained-to-a-plane versus unconstrained input devices, and standing versus seated postures. Finally, we discuss results from the iterative prototyping process, and a qualitative pilot study of slider-based foot input devices and interaction techniques.

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INTRODUCTION

For several decades, researchers and computing practice has begun to shift focus away from seated analog keyboard and mouse input to input devices and techniques that allow human-computer interaction while standing, walking, or in other positions and environments beyond the office cube [13]. These efforts have included mobile or small-form factor input devices [9], speech, as well as sensor-based gesture-based input technologies. However, while low-resolution gesture-based input technologies have become successful for gaming consoles such as the Nintendo Wii, they have yet to reach the mainstream of human-computer interaction. In this paper we hypothesize that this may be because many gesture-based input schemes offer modeless interaction and unconstrained degrees of freedom rather than modal interaction and constrained input. By unconstrained we mean that body motions are not generally physically constrained to a single plane of movement. For example, during gait, the foot is unconstrained, whereas whilst mousing, the hand has a planar (table) constraint.

As a probe into this question and hypothesis, we present a explicitly modal and constrained foot-based input technology and set of interaction techniques that offers the ability

for users to perform mouse-type interactions (2D target acquisition plus click gestures) whilst standing: an exertion interface [8] for “serious” computing. However unlike

hand mice, the foot mouse technology we present can also be

used while operating on the constrained surface of a carpet floor, which means that a user is not tethered to a desk. We motivate the foot mouse by a review of the known literature on repetitive stress and movement impairment syndromes from the physical therapy and strength coaching world. Given the rampant rise of obesity, any input technologies that can further support hip/ankle mobility and a standing rather than seated position may contribute to the general, long-term health of ICT users due to the preventative mobilization inherent in foot mouse usage.

RELATED WORK

Decades ago, Card et al. evaluated the mouse relative to a joystick and step/text keys for the task of text selection, showing that these pointing devices followed Fitts’s law [3]. In terms of human biology, a disproportionate amount of human “body map” of touch receptors located in the cerebral cortex (homunculus) is typically dedicated to the face, lips, hands, and feet, relative to the rest of the body. This, in addition to experimental work and mousing evolution, perhaps begins to explain the popularity of hand-held mice in the last few decades.

More recent work has explored the use of even more increased dexterity for hand mice [12], and other researchers have investigated input designs for disappearing / miniaturizing mobile devices [9], as well as for muscle-based [11] and step-based [2] interfaces, but these have yet to allow the precise control that a hand-held mouse affords.



Figure 1– the SlideMouse: plastic slider + IR emitter]



Figure 2: SlideMouse + Optical Sensor Prototype

Free-form gesture interfaces use many tracking modalities, such as computer vision, but have traditionally suffered from a lack of precision as well as spatial and temporal resolution [14]. These interfaces have found their way into the gaming input world, but have yet to be used as everyday, always-on input devices.

MOTIVATION

Two research questions motivate this work. First, how might we understand why various imagined visions of unconstrained, free-form gesture interfaces remain science fiction rather than pragmatic fact? Second, in what important dimensions, such as health, should the HCI community evaluate and understand the design and implementation of user input devices and interaction techniques?

Extended mouse or keyboard use has led to reports of RSI (repetitive stress injury), and both software solutions [7] and hardware innovations (ergonomic designs) have been proposed. However we believe that it is at least as important to investigate how the design of input technologies may subtly nudge the rising obesity rates and increasingly sedentary nature of modern, techno-industrialized life.

Exertion interfaces have been proposed which support physically challenging, multiplayer competitive games [8], but more exertion interfaces need to be developed for everyday or ubiquitous computing scenarios.

In practice, several foot mice exist, such as the “Slipper Mouse” design with a Velcro strap and huge pad (http://www.bilila.com/foot_mouse_slipper_mouse). However, not much is known about the long / short-term impact of non-hand-centric input. Furthermore, foot mice today are designed just for seated postures, and thus only partially address issues of RSI, health, and exertion interfaces.

From a biomechanical perspective, sitting in a chair for extended periods of times is one of the worst postures in terms of lumbar spine compressive load [8]—notably worse than standing. From a neurological and developmental perspective, many modernized humans lead excessively sedentary lives, underutilizing many body parts whilst overtraining and overworking their mousing hand & arm. In sum, modern humans do not move enough. As a first step towards encouraging more movement, we argue that humans first need to simply stand slightly more often.

HUMAN HEALTH FACTORS IN INPUT DEVICE DESIGN

Many input device and techniques have focused on Fitt’s law and task performance. However, they have often been designed for a seated user, and optimized for target acquisition on a 2D interface. For example, page one of Card’s seminal text [3] makes the convincing argument that a psychology of HCI ought to facilitate the design of interfaces that are “easy, efficient, error-free—even enjoyable”; arguably, here the seated, hand-mouse WIMP interface has succeeded. However, in addition to these human factor desiderata for ease-of-use and efficiency, we suggest that in

the design of interfaces and in particular input technologies, *health ought to be of paramount concern*.

While a hand mouse is fit for the task of 2D pointing, it can encourage seated, immobile positions possibly leading to or compounding lower back pain. In the long term, such an interface may encourage tight hip flexors and gluteal inhibition [10], or more generally movement impairment disorders from disuse/misuse. Furthermore, the sedentary nature of such seated work leads to an eventual loss in hip mobility, lower-leg strength/stability [1], as well as a poorer proprioceptive awareness of body form and function [5].

Inspired by design requirements specified by Consolvo et al. [4] and athletic development progressions discussed by Cook [5], we suggest some human *health* factors / desiderata for the design of input tech: from hardware and design to interaction techniques. Input technologies for an everyday, ubiquitous computing world ought to:

- + Encourage healthy, balanced [5] movement patterns
- + Facilitate many multi-joint mobility movements
- + Challenge single-leg and double-leg stability
- + Allow for multiple postures: standing, seated, supine
- + Support high precision & spatiotemporal resolution input
- + Offer planar constraints for range-of-motion
- + Permit additional resistive or spatiotemporal loading

As has been said in the physical therapy world, “Motion is lotion.”

HARDWARE DESIGN PROTOTYPES

We explored the design space of standing, lower-body input devices through a series of hardware design prototypes for foot-based mice. While hand mice can be used on the floor (designs such as the slipper mouse work in this fashion), study participants found somewhat them bulky and inaccurate. Our technical contribution here is the use of a slippery, all-plastic surfaced bottom in conjunction with sensing technology to offer a high-precision and yet lightweight and usable foot input device.

We made use of a Wii controller for the IR sensor/tracking technology, where the IR sensor bar was attached to a ValSlide™, a device used in the personal training industry to allow trainees to perform exercises on a semi-stable surface (grippy oval above green, slippery plastic). This device is essentially a modified version of a furniture slider used to move around heavy furniture in a carpeted area.

A wireless, battery-powered Wii sensor bar was attached to the ValSlide™ to emit infrared beams, which were sensed by the Wii controller, which interoperates with a computer using Bluetooth.

The Wii-mote provided high-quality sensing, and the ValSlide™ has already been designed to be mobile/slippery on the bottom and grippy on top. Prototyping with optical mice attached to sliders proved initially unsuccessful, as they struggled to be mobile and track on carpet-based sur-

faces. Later, we found that the newer Microsoft BlueTrack™ and Logitech Darkfield™ mice both well supported carpet-based input sensing, and attached them to the side of these elliptical plastic slider with electrical tape.

We also briefly experimented with multi-touch and capacitive sensing technologies, but ran into the “*fat toe*” problem for pointing and selection, analogous to the “*fat finger*” problem previously described in the literature [9].

Advantages Unlike hand-mice, the slider mouse can easily be used while standing, whether or not a desk is nearby. It encourages movement of the lower extremities, including multi-joint mobility, contralateral (opposite) leg stability, and yet still affords high precision. Since the slider is constrained to the floor, users need not spend excessive energy stabilizing the device in 3-D, and the device is lightweight and can be portably transported to different locations (across a large room or theater).

Drawbacks Current designs rely on remote IR sensing or optical (laser) technologies rather than direct movement sensing on carpet, thus requiring a separate device or complex hardware. Many users also may have poor balance, lower-body proprioception, mobility, and stability. Clicking may not be an obvious activity, and mouse gestures were implemented using Wizard of Oz techniques. Finally, few users have been exposed to foot-based interaction hardware, and may have untrained foot musculature.

DESIGN VARIANTS—MOUSING

We now describe several foot-mousing design variations, in hardware / form factor as well as mouse gesture design.

The FootBaller

In this design variant, users simply manipulated a trackball with their feet, hence, the *footBaller* design. This simplistic scheme focuses research attention on the unconstrained nature of the foot relative to the footBaller trackball.

SlideMouse

The SlideMouse prototype attaches a sensing device (IR and/or optical) to a very light and low-friction plastic base, below a thin layer of non-skid foam (the ValSlide™, Figure 1). Users would then manipulate the mouse via the non-skid foam layer. The optical sensor placement varied spatially, but in our experiments was placed on the long edge of the elliptical, plastic base. Note how the low-friction plastic base constrains the foot motion to a general horizontal plane (the floor) while still permitting rapid movement.

DESIGN VARIANTS—CLICKING

Stubbing - Kick your foot forward, as if you were to “stuck your toe”.

Toe Press - Press your big toe downwards

Rotation - Rotate left (right foot) to single-click

Toe Pull - Flex the big toe, as if “scrunching” to pick up a towel

EVALUATION

We ran a simple first-use pilot study (n=3) in the lab. Participants completed several information seeking tasks; many received strawberries in return for their participation.

The tasks involved browsing/searching the web using Google Chrome: navigating YouTube, or using of the Amazon.com shopping cart & wish list interfaces. Each participant tried permutations from the 2x2 condition matrix (i.e. all 4 different conditions), where the variables were (a) posture—seated or standing and (b) foot input device—trackBaller or SlideMouse.

Various single click, dragging, and mouse wheel gestures were tested, using spoken Wizard-of-Oz (a user would say *click* or make the gesture; an observer would click).

DISCUSSION

In this study, we hoped to understand the feasibility of using light-weight, friction-minimal plastic technology as a base layer for a grippy, movable foot mousing shell. More broadly, we wanted to explore the design space of: (1) constrained vs. unconstrained input, (2) the qualia / qualitative results of first and/or early-use of foot-based interaction & hardware, as well as (3) the practical concerns and design requirements for designing input technologies for standing, or more generally, non-seated computing technology users.

While users may never widely adopt foot-based input schemes for desktop computers, the use of foot input provided a useful lens and probe into human factor and interaction design aspects of grounded interaction and for ubiquitous and/or mobile, literally *on-the-move*, technologies.

We hypothesized originally that from a physiological perspective, the constrained input device would be superior, as users could rely on their muscular “prime movers” [5], not small “stabilizer” muscles. However, each device proved useful in different situations. For example, for small on-screen movements, the *footBaller* offered the ability to simply rub through the bottom part of the foot, but users were hesitate to place much weight on the trackball element. On the other hand, users seemed more willing to varying bodyweight on the plastic slider—more weight would lead to smaller, more controllable motions, whereas less weight lead to larger, quick movements.

Originally, gestures such as stubbing or rotating seemed natural, but participants would mistakenly translate their mice spatially, as it was difficult to make the precise stubbing or rotating gesture without any other associated motion. In practice, toe-pull versus toe-push proved very similar, but participants seemed to prefer making clicking gesture with the same foot that also moved the device. Note: this is *not* how current commercial foot mice operate—instead they have separate pedals or buttons for the opposite (typically, left), making standing use difficult.

We found that input device sensitivity was important to control for, and that users took time to feel out how to balance on both legs. However, target acquisition for sites such as Amazon.com was not generally problematic once the input gain (mouse “sensitivity”) was modulated.

One unexpected finding was that variation in the optical sensor (taped-on mouse) placement lead to different usage

patterns and limb postures. It was not obvious how to best place the sensor relative to the foot and slider (big toe versus ball-of-foot, heel, or side?)

Both shoe type and usage varied: some participants kept on their shoes, while most experimented with both shod and unshod gesturing. Interestingly, one participant reported more ease of use whilst shod, relative to spatial motion in the slider case, but participants attempting clicking gestures would generally do so in lightweight socks.

Users' relationships to their toes and feet, functionally and otherwise, varied, but points to interesting design considerations for hand-based multi-touch mice. In particular, users attempted simultaneous toe flexion / motion and foot movement, preferring to use toes versus foot complex for different situations. This design perspective could be applied to hand-held mice, where finger flexion is sometimes used for fine control and hand waving is used for less granular movement, even though this differential has not yet greatly affected hand-based mouse design.

DESIGN FOR HEALTH, DESIGN FOR FITNESS?

The foot mouse designs did seem to encourage healthy movement patterns in lab participants, as rated by a certified personal trainer / assistant strength coach, who also observed the pilot participants. The designs also supported full-body movements, in multiple postures (standing and seated), with high resolution and planar constraints—the other design health factors proposed earlier in this note.

Lab participants all reported that standing was, unsurprisingly, “a little bit” or “somewhat more” effort than sitting (one participant did report occasional laptop use whilst standing), but many had not thought through long-term implications of a sedentary culture and input technology.

CONCLUSION / FUTURE

There is much to be done in making better use of the information bandwidth of our various limbs, in particular the dexterous fingers and toes, while still keeping health at the forefront. This work is a simple probe in this direction. It is hoped that the reader has brought away new perspectives on mousing and input device design, with an eye towards a 21st century of more mobile and ubiquitous computing. We hope that this and other work keeps humans as mobile as their newfound information technologies.

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