Accessible Touch Input for People with Motor Impairments

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Abstract

Touch input has emerged as a dominant form of interaction for billions of interactive computing devices like smartphones, tablets, and interactive surfaces. Although touch input is widely used, it remains largely inaccessible for many people with motor impairments such as cerebral palsy, muscular dystrophy, and multiple sclerosis. For my thesis, I will employ advanced pattern matching techniques to create intelligent touch interaction techniques that allow users with motor impairments to touch the screen in whichever way is most comfortable and natural to them, and for the system to respond as if the screen was touched precisely. My thesis research aims to improve the accessibility of touch-enabled devices for users with motor impairments, broadening access to these devices like never before.

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Research Situation

I am a fifth yeah Ph.D. candidate in the Information School at the University of Washington. I have successfully completed the coursework required for promotion to candidacy in my department. I have also successfully passed my departments General Exam—a written exam intended to judge a student's ability to conduct original research in the information sciences.

I am an active member of the Mobile & Accessible Design (MAD) Lab as well as the design: use: build: (DUB) Group at the University of Washington. My advisor is Prof. Jacob O. Wobbrock. My research takes an ability-based design [12] approach towards improving the accessibility of touch-enabled devices for people with motor impairments. I strive to understand how users with motor impairments naturally interact with touch-enabled devices so that I can create intelligent interaction techniques that leverage users' innate abilities to overcome accessibility challenges.

Context and Motivation

Touch-enabled devices such as smartphones, tablets, and interactive kiosks are some of the most ubiquitous technologies in the world today. As a result, touch input has emerged as one of the most dominant forms of interaction for computing devices, rivaled only today by the mouse and keyboard. Touch, unlike the mouse, is a natural form of input for many users. As an input mechanism, however, the accuracy of touch input pales in comparison [1]. The relative inaccuracy of touch input can be attributed to its uncertain nature [7]. A finger on a screen does not indicate a single pixel like a mouse cursor. Instead, a finger produces a large and ambiguous contact area [4,7], requiring the system to infer the user's intended (x,y) touch location (typically produced as the centroid of the finger's contact area [4]). These *predicted* touch locations often differ from users' *intended* touch locations [4], causing inaccurate touch input—especially when attempting to acquire small targets [1,4,10].

Although touch input can be inaccurate, many users are still able to operate touch-enabled devices effectively. For people with motor impairing disorders such as cerebral palsy, muscular dystrophy, and multiple sclerosis, however, touch input can pose a serious challenge. People with motor impairments face accessibility challenges through no fault of their own. The fault lies with the ability-assumptions embedded in the design of touch-enabled systems. Touch systems presume their users can extend a single finger and accurately control that finger to land-on and lift-off the screen. These ability-assumptions, however, do not match the abilities of many users with motor impairments. While interacting with touch-enabled systems people with motor impairments may inadvertently touch the screen with multiple fingers, or intentionally touch with various parts of their hand [2,6]. As a result, touch systems are unable to accurately predict users' intended touch locations, rendering many touch-enabled devices inoperable by people with motor impairments [6].

In my research, I aim to improve the accessibility of touch-enabled devices for people with motor impairments by using advanced pattern-matching techniques to create intelligent touch interfaces. Unlike current touch systems, which require users to adapt to fit the needs of the system, I will uphold the principles of ability-based design [12] to create techniques which will allow users to accurately interact with touch systems in whichever way is most comfortable and natural to them. Through my research I hope to expand the access of touch-enabled devices to users with motor impairments for which touch input was previously difficult or impossible.

Related Work

Significant research has been conducted in an attempt to understand the accessibility challenges touch screens pose to people with motor impairments. Research efforts have included understanding how people with motor impairments interact with touch-enabled devices in their everyday life [2,5]. In these works, the authors describe how the use of touch-enabled technologies—smartphones and tablets in particular—can be empowering and can lead to more independence. These works also highlight different strategies users employ to overcome accessibility challenges. To understand these strategies and challenges at scale, Anthony *et al*. [2] analyzed over 100 homemade YouTube videos of people with motor impairments interacting with touch-enabled devices. They discovered that people with motor impairments employ strategies such as using their nose to touch the screen to overcome accessibility challenges. They also observed several different touch behavior strategies, such as users attempting to touch the screen with the back and sides of their hands, with multiple fingers, and with knuckles.

In addition to understanding touch screen use in natural settings, researchers have also conducted lab studies to understand how accurately users with motor impairments can acquire on-screen targets. Researchers discovered on-screen target sizes must be increased significantly over previous recommendations [3] in order to improve touch screen accessibility. Researchers also discovered that certain user touch behaviors resulted in inaccurate touch predictions and misclassifications of user intent [9]. For example, inadvertently touching a screen with multiple fingers may cause the system to trigger a multi-touch gesture [9].

Although there has been significant research interest in understanding the accessibility challenges of touch-enabled devices, significantly less research has been conducted to overcome these challenges with new accessible touch techniques created specifically for people with motor impairments. One such technique created to improve touch interaction for people with tremor is *swabbing* [11], an approach which allows users to slide their finger on the screen towards their target and to lift their finger once they've neared it to select it. Techniques such as swabbing are difficult to implement in practice, as these techniques require awareness of all on-screen targets—information which is difficult for applications to access even through the use of accessibility APIs.

My research addresses the need for accessible touch techniques which can allow users to interact with the screen however they please, and for the system to accurately respond to each users' unique touch behavior.

Problem Statement

My thesis intends to answer the following research question: *How can intelligent, ability-based touch techniques be developed to overcome the inaccessibility of touch-enabled devices for people with motor impairments?* To answer my research question, I intend to (1) study how people with motor impairments naturally interact with touch-enabled systems, and (2) create novel touch-based interaction techniques which leverage users' innate abilities, allowing users to touch in whichever way is most comfortable and natural to them.

I have already made progress toward answering my research question. I conducted a study [6] with 10 people with motor impairments to understand the different touch behaviors employed by users with motor impairments when attempting to acquire on-screen targets. In my study I found that users employed various touch behaviors, such as touching with a closed fist or dragging a hand across the screen. Based on the touch data collected from my participants and from my own personal observations I created *Smart Touch* [6], a novel template matching algorithm that maps any number contact areas—regardless of their size or location—to users' intended touch locations. Smart Touch allows users to touch however they are capable, eliminating the inaccessible ability constraints currently embedded in touch-enabled systems. I found that Smart Touch was able to significantly improve touch accuracy for participants with motor impairments compared to the system's built-in touch sensors.

Although Smart Touch takes a step toward improving touch screen accessibility for people with motor impairments, I intend to make two more contributions toward improving the accessibility of touch-enabled devices. First, I believe Smart Touch can provide benefits not only for people with motor impairments, but for non-disabled people experiencing situational impairments [8], such as while walking. I am currently creating an augmented version of Smart Touch that incorporates accelerometer data captured from smartphones to estimate a user's gait pattern, allowing Smart Touch to more accurately predict user's intended touch locations while walking.

Second, I intend to create, test, and deploy *Smart Shift*, a significant extension to my Smart Touch algorithm which affords users even more accurate touch input through continuous visual feedback. Occlusion of on-screen targets is a problem due to the *fat finger problem* [10]. This problem is exacerbated when entire hands are used to acquire on-screen targets—a touch behavior exhibited by many users with motor impairments [2,6]. My Smart Shift technique will extend the functionality of Smart Touch by intelligently creating callouts with inset cursors on non-occluded regions of the screen—a feature of the original Shift technique [10]—when the user has neared their intended target. This additional visual feedback, along with precise cursor control, will allow users to more accurately select on-screen targets, especially for targets occluded by parts of users' hands.

Expected Contributions

My thesis research will contribute new knowledge on the touch behaviors of people with motor impairments. By understanding how people with motor impairments intuitively interact with touch enabled systems, designers and developers can think of new ways to make their systems and interfaces more accessible to people with a wide range of abilities. My research will also contribute new intelligent, ability-based interaction techniques which will allow users with motor impairments to interact with touch-enabled devices in whichever way is most comfortable and natural to them.

Overall, my thesis research aims to improve the accessibility of touch-enabled devices by removing their inaccessible ability-assumptions. My research removes the burden of adaption from the user and places it on the system, allowing users to interact with touch-enabled devices like never before.

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