Shaun Kane: Research Statement

My research primarily addresses the design, development, and deployment of technologies for people with disabilities. This work is situated within the framework of ability-based design, which I co-created as a Ph.D. student [30] and continue to develop [31]. Ability-based design is an approach to researching and designing technology that supports individuals with a wide range of abilities, including people with disabilities and chronic health conditions, as well as typically-abled individuals who may be situationally impaired. For example, a person driving a car may have temporarily reduced attention and motor ability. The ability-based design approach focuses on designing technologies that work for the widest range of people possible by first understanding users’ abilities, and then developing systems that can intelligently adapt to a specific user’s ability.

As an example of ability-based design, consider the project known as the Gest-Rest [7]. The Gest-Rest is a gesture-enabled armrest that can be installed over the existing armrest of a power wheelchair. The Gest-Rest enables its user to provide gesture input to control his or her wheelchair, smart home, or mobile device. Key to the development of the Gest-Rest is a custom hardware device, which consists of a dense array of pressure sensors, and the gesture recognition software, which can be customized to support a wide range of physical motion. People who use power wheelchairs often experience impaired upper body motion, and may vary greatly in their ability to move their hands and arms. The Gest-Rest accepts many different types of possible movements as valid input. For example, one user might interact with the Gest-Rest by keeping her arm on top of the armrest, and pressing down firmly when she wishes to interact, while another user may interact by lifting his arm slightly. Similarly, one user might perform a directional swipe gesture by dragging a finger across the surface of the armrest, while another user might perform the same gesture by making a fist and rolling her hand in the specified direction. In all of these cases, the Gest-Rest device is designed so that the burden of interpreting the user’s intention is placed upon the system designer: the user simply performs the movements that she is able to, and the system adaptively interprets these gestures.

My research is further motivated by the belief that it is possible to have a positive influence on the lives of real people while engaging in rigorous and impactful research. In many cases, people with disabilities are excluded from participation in public life (such as in school, work, or social interaction) because the technologies used in these activities are not accessible. However, the inaccessibility of these technologies is often due to a lack of imagination or effort on the part of the designer, rather than any inherent limitation of the affected individual. My research seeks to identify opportunities where both existing and emerging technologies can be leveraged to empower people with disabilities and others.

Finally, my work is guided by the belief that developing technologies for, and with, people with disabilities presents an ideal environment for exploring innovative computer science research. People with disabilities are often early adopters of emerging technologies [26], and are often more willing to try new technologies than others. Furthermore, solving accessibility problems for people with significant impairments often requires solving problems in core areas of computer science such as machine learning, computer vision, and natural language processing.
Overview of My Research Program

My research considers a variety of research methods (field work, qualitative interviews, lab experiments), technologies (PCs, mobile devices, wearable computing devices, fabrication tools), and user populations (typically-developing adults; visual, motor, communication, and cognitive disabilities). The unifying thread across these projects is the focus on understanding accessibility challenges and overcoming them through the design of improved user interface technology.

Since arriving at the University of Colorado Boulder, I have continued to extend my previous work on non-visual interaction, alternative input devices, and do-it-yourself fabrication technologies. I have also developed new research threads in areas such as eye gaze interaction, accessible collaboration, and accessible images and multimedia.

Non-Visual Interaction

Much of my Ph.D. work, and early work as a faculty member, has revolved around the creation of accessible, non-visual touch user interfaces. This work began with the development of Slide Rule [17], a set of accessible gestures that enabled users to interact with touch screens without any visual feedback. Using Slide Rule or similar systems, even individuals who are fully blind may use existing touch screens. These accessible touch gestures can be implemented entirely in software, and require no changes to the underlying hardware. Since I began this work in 2007, my work on accessible touch screen gestures has had significant impact within the accessibility research community. Our 2008 paper introducing the Slide Rule prototype and gesture set is the most cited article from the ACM ASSETS conference. In my own research, I have extended this work to explore access to other technologies, including providing non-visual access to large touch screen tabletops [18], designing dynamic audio feedback for teaching and learning gestures [14], and designing a wearable computing system that enables blind individuals to read objects in the physical world using gestures [19]. My research in exploring non-visual touch screen accessibility was cited as motivation for receiving the Alfred P. Sloan Fellowship in 2016.

Non-visual accessibility remains an active part of my research program. My recent work has focused on combining accessible touch input with tangible user interactions. GUI Robots [12] is a system that uses small, low-cost robots to provide tactile feedback for graphical user interface-based applications. Initially developed to provide enhanced haptic feedback for traditional PC games and applications, the GUI Robots system is currently being adapted to provide non-visual access to games, videos, and interactive simulations for people with vision impairments. A related project, Story Blocks [23], uses 3D-printed tactile objects, combined with audio feedback, to teach blind children to create computer programs.

Earlier this year, I received an NSF CAREER Award, “A New Interaction Model for Eyes-Free Exploration of Touch Screens,” to support further work in developing non-visual touch screen interactions. In this project, we will develop new input models and new forms of speech output to support efficient non-visual interaction with large datasets on touch screens and interactive tactile graphics. I have also co-authored a book on access technology for blind and low vision people [1] that will be published in 2018.

Alternative Input Methods for People with Mobility Impairments

A second major focus of my work has involved developing alternative user input methods for people with mobility impairments. Due to the high variability of mobility impairments, and the
associated variability of accessibility challenges, my work in this area has covered a wide range of approaches, including automated typing correction [15], augmented touch screen input [11], and adaptive user interfaces for typing while walking [16].

My recent work in this area has focused on two primary threads: flexible input for users in power wheelchairs, and adaptive touch screen input. Since 2014, I have worked with my colleagues at the University of Maryland, Baltimore County to develop the concept of chairable computing [6]. Our work in chairable computing has been motivated by the question “how can we consider use of a power wheelchair as an advantage rather than an impediment?” In seeking an answer to this question, we have explored how power wheelchairs can be leveraged to create powerful and accessible computing platforms. Taking this view, a power wheelchair offers a compelling platform for wearable computing, offering a variety of interaction surfaces and the capability to easily carry components such as sensors, screens, and power supplies. We have also explored the development of more accessible input devices that can be used by power wheelchair users, including the Gest-Rest armrest [7] and alternative forms of accessible gesture input [9].

A second focus has involved the development of algorithms to support touch input by non-traditional users. Much of the software underlying our current touch screen devices relies upon a series of assumptions about the end user: that they will be able to reach up and touch the screen, that they will be able to reach all points of the screen without needing to rest their hand on the screen, that they will be able to reliably provide pressure on the screen with one or multiple fingers, and many others [31]. However, many individuals are unable to satisfy all of these assumptions simultaneously, even if they have significant motor ability. Our recent work on Smart Touch [13] has sought to address this issue by enabling users to specify templates based on their ability to touch the screen. For example, consider a user who is able to move her arm freely, but whose hand is permanently fixed in a clenched-fist posture. Using current technology, if this user touched a touch screen with her hand, the system would either register a touch at some random point on her fist, or might ignore the touch entirely. Smart Touch enables the user to register their touch pattern and recognize it later, so that the user could train the system to recognize her grip. Later, she could touch the screen using her normal posture, and Smart Touch would recognize her hand and register the touch at a predefined point, such as at the tip of her thumb. Smart Touch and similar approaches can enable existing touch screen devices to support users with a wide range of motor ability.

Looking forward, I am currently exploring further applications of accessible touch input for people with mobility impairments, including recognizing and supporting touch on non-planar objects, and leveraging pressure-based input for non-disabled users. My ongoing work in eye gaze input, discussed in detail below, addresses similar issues.

Accessibility, Fabrication, and Do-It-Yourself Culture
Over the past several years, my research has explored issues at the intersection of accessibility, fabrication, and “do-it-yourself” or “maker” culture. This topic has been extremely popular within the accessibility community, as the proliferation of low-cost fabrication tools presents an opportunity to enable everyday users to design and produce their own physical assistive devices.

To date, much of my work in this area has explored how communities that support people with disabilities are learning to use fabrication tools. In this work, my colleagues and I have explored how schools that serve children with disabilities learn about fabrication tools such as 3D printers,
and how school staff can incorporate these technologies into their existing practices [4]. We have also explored how individuals design, develop, and share 3D models of assistive technologies via open source repositories [5].

Recently, we have begun to explore how members of these do-it-yourself communities become involved in these communities, what motivates them to participate in the communities, and what barriers they encounter in their practices. Much of this work has occurred in collaboration with an online community dedicated to the modification of hearing aids and cochlear implants [25]. Our work in this community has shed light on the roles that customization can play in the lives of assistive technology users. In our ongoing work, we are exploring how individuals move from customizing their own devices to helping others, and how customization roles may vary based on gender, age, and other demographic factors [27].

One common theme throughout this work is that individuals rarely have the tools or expertise to implement more complicated customizations for their devices. Building on some of my early work in developing more end-user-friendly 3D design tools [8], we are continuing to explore how new tools can make it easier for individuals to safely modify their assistive technologies.

**Eye Gaze Input and Communication**
Many individuals with severe mobility impairments, such as Amyotrophic Lateral Sclerosis (ALS) and other neurodegenerative disorders, are unable to use any type of physical user interface. For these individuals, eye gaze input using an eye tracker is often the only accessible mode of computer input. Unfortunately, eye gaze input is often extremely slow and error prone.

As part of an ongoing collaboration with Microsoft Research, I have been conducting research on the use of eye gaze input both by the general population and by people with disabilities. In considering eye gaze input for the general population, we have studied performance of eye gaze input technology across a range of hardware platforms, and using a diverse sample of end users. This work has led to improved guidelines for creating eye gaze-based user interfaces with high performance and low error rates [10].

The majority of my work in eye gaze input has involved collaborative work between our research team and a group of people with ALS, along with their families, caregivers, and physicians. Eye gaze input is especially important for people with ALS, as the disease typically causes individuals to lose their ability to speak and to move their body. As a result, people with ALS often rely upon eye gaze input to use any technology, and even use eye gaze to communicate with others via an eye gaze-enabled communication device. As part of this project, I have conducted extensive field work with people with ALS and their families. Findings from this research have been used to identify design guidelines for creating communication devices that better support the communicative needs and preferences of people with ALS [21]. We are continuing to build upon this work through the development of improved communication devices, such as SceneTalk [22], which uses computer vision techniques to identify a communication device user's context and to predict likely phrases that the user might wish to say. We are also exploring eye gaze-based input methods for other types of user interfaces, such as musical instruments and games.

**Accessible Collaboration**
A major limitation of much existing assistive technology is that it is designed to support only a single user. By focusing on how to make an inaccessible technology accessible to a given user,
assistive technologists often overlook the social contexts of how technologies are actually used. For example, a blind person will often use screen reader software to read out the text on their computer screen. Most blind computer users can efficiently use a screen reader to perform most computing tasks. However, the design of current screen readers presents a barrier to collaboration between a screen reader user and a sighted partner: the blind user cannot see what the sighted partner is doing in their graphical user interface, while the sighted user cannot follow along with the rapid speed and limited visual feedback of the screen reader.

Our formative studies of collaborative work between blind and sighted partners [2,3,29] uncovered several persistent barriers to collaboration between people with differing visual abilities, including a lack of shared awareness, an inability to understand the partner’s technology, and difficulties in appropriately assigning roles in a complex task. The impact of these challenges often results in the visually impaired person withdrawing from collaborative activities, instead choosing to work on their own, even though that may prevent them from completing some tasks or participating in their community.

Based on this preliminary work, we are continuing to explore the challenges to this type of “cross-ability collaboration.” Currently, we are developing a set of reference tasks, software tools, and collaboration metrics to analyze collaborative computer tasks between a blind screen reader user and a sighted partner. After this work is completed, we will begin to design software tools that may increase the quality of collaboration between blind and sighted individuals by sharing awareness information about the partner’s activities and by identifying opportunities for each person to contribute to a shared task. This work is supported by an NSF award (CHS: Small: Cross-Ability User Interfaces for Improving Collaboration Between Blind and Sighted People, 2016-19).

**Improving the Accessibility of Images and Media**

While tools exist to convert images into accessible formats, it is often unclear what makes a “good” translation of a visual image. For example, while a bar chart can be translated from an image to an informationally-equivalent text representation, the same may not be true for an artistic portrait or an image from social media. Several of our ongoing and projects are exploring issues around translating visual information into alternative formats such as speech, non-speech audio, and tactile images.

One thread of this research is exploring how to identify the rules for good translations between different types of media. The criteria for translating an image to text may depend on the type of image, the content of the image, and the context of use. Our recent work has explored image captioning in several distinct domains that each present a unique challenge: social media images, which require knowledge of the subject and of informal communication norms [24]; visual media such as movies and comics, which require knowledge of the interplay between image and dialogue and knowledge of the underlying story [28]; and visual questions from the real world, which rely upon knowledge of the asker’s context and intent.

A second research thread involves exploring methods to create and represent image captions. Existing image captions, such as those provided for web image, are often created by a single web developer and published without any testing. In a current study, we are exploring how teams of blind and sighted individuals can caption images together. This collaborative captioning may result in better captions, and may provide an environment to understand what distinguishes bad
captions from good captions. In the future, we may incorporate this collaborative captioning technique into online tools for creating better captions, such as by creating an online game in which multiple crowd workers compete to write the best caption.

Finally, we are exploring alternative methods for creating tactile graphics, including hardware prototypes to support the creation of tactile graphics while on the go, and software tools to support teachers of the visually impaired in rapidly creating effective tactile graphics.

**Future Directions**

In addition to the ongoing projects described above, there are several additional topics that I am eager to explore in the coming years.

First, I am interested in exploring accessible technologies that support creative activities such as art, music composition and performance, and athletics. The majority of accessibility research focuses on domains such as work, education, and transportation, while recreational activities are often overlooked. Creating accessible versions of creative tasks also requires overcoming significant human-computer interaction challenges: for example, performing live music requires the user’s input to be both very fast and very accurate. I plan to explore various input methods to support expressive input for creative tasks, even for users with significant impairments.

Second, I intend to explore the tensions between the aesthetic qualities of an assistive technology and social perceptions, specifically in the context of customizing one’s own devices. Our research within existing do-it-yourself communities has shown that the appearance of an assistive device, and the ability to customize that device, can significantly affect the wearer’s perception of the device and even their own self-perception. I am interested in exploring how changing the design of an assistive device itself, such as by explicitly incorporating customization features, could change perceptions of the assistive device and its wearer.

Finally, I am interested in exploring how notions of accessibility and inaccessibility will change as our modes of interaction with computers change from a set of predefined set of inputs and outputs to systems that model users and their behaviors. For example, new technologies such as the Microsoft Kinect infer a model of a human being based on sensor data. Any user who does not fit the established model may be recognized incorrectly, or may not be recognized at all. This shift in how our computer systems detect and interact with users may present significant accessibility challenges [20]. I intend to explore how sensor-based systems may mis-identify users, and how this identification problem can be addressed in the creation of machine learning data sets and in the design of sensing-based systems.

**References**


