Invisibility, Conspicuousness, and Accessibility: How Sensing Systems Fail for Non-Traditional Users

Shaun K. Kane
University of Colorado Boulder
Boulder, CO, USA
shaun.kane@colorado.edu

ABSTRACT

The rise of sensing user interfaces promises more natural interactions by tracking users' presence, as well as enabling users to control computing devices using only their own bodies. As these technologies reach a critical mass in our society, we must consider who is affected or excluded by these technologies. This talk is based on my own personal experiences and thoughts after struggling to use sensing-based systems over the past several decades. I consider three primary challenges (lack of access, lack of anonymity, and lack of training data) and three possible solutions (public datasets, parameterized models, and overrides).

Author Keywords

Sensing; internet of things; disability; accessibility.

ACM Classification Keywords

K.4.2. Social issues: assistive technologies for persons with disabilities.

INTRODUCTION

This talk was prompted in part by my own recent sabbatical at an industrial research laboratory. This lab has several prototypes of smart technology, including a smart elevator that can automatically open its doors as a passenger approaches, and a direction-giving robot that can direct visitors to a specific office number or researcher (Figure 1). I discovered that neither of these systems worked at all for me, a 4-foot-tall adult male.

While the designers clearly did not intend for these systems to exclude users, aspects of their interaction design and training data may have inadvertently led to some users such as myself being excluded. For the elevator, it is likely that my walking pattern does not match any found in its training set. The directions robot can see me from a distance, but as I approach, I fall out of view of the camera and the robot seems to decide to ignore me.

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Figure 1. Two sensing systems that present emergent accessibility challenges. Top: Smart elevator recognizes individuals approaching by gait. Bottom: Direction-giving robot expects users at a typical adult height.

RELATED WORK

Concerns about how sensing systems may exclude certain types of users has existed for some time. When the original Microsoft Kinect sensor launched, it was originally dogged by accusations that the sensor could not track dark-skinned individuals, although further testing found this claim to be untrue [3]. However, optical sensors that cannot detect dark skin have appeared numerous times in the popular press [5,6], and studies have shown that skin tone can impact optical sensing algorithms [1]. Some popular press articles have reported challenges experienced by those with certain accents, such as a Scottish accent, using speech recognition [4]. Even when the sensing system can detect the user, the system may still not enable the user to interact. For example, while Microsoft's Kinect can support a user seated in a wheelchair, many games do not fully support use by gamers in wheelchairs. This oversight has been addressed by researchers, who added new interactions such as wheelchair movement to the Kinect's repertoire [2].

UNDERSTANDING THE SCOPE OF THE PROBLEM

In each of these cases, it seems clear that excluding any specific user population was not intentional. It is likely that these problems occurred due to lack of foresight from the designers, lack of testing, or lack of sufficient training data. However, as we continue to develop systems that respond to a user's presence, movement, or speech command, we should expect to encounter challenges when users do not fit a typical shape, pattern of movement, or tone of voice.

While the examples provided above are relatively minor in their severity, as these systems become more ubiquitous, we increase the chances that these types of problems become more serious. For example, consider a fire suppression system that seals off an area once it has detected that no one remains in the area, but which cannot easily identify a child or a person in a wheelchair.

To begin a discussion about how we might consider and address this problem, I present three distinct challenges related to how sensing systems might fail for atypical users: two reflect problems experienced by users themselves, while the third affects designers who wish to address these problems.

Lack of Access

The most straightforward problem in this space occurs when a sensing system prevents the user from accessing that system, or limits their access to the system. This *invisibility problem* occurs because the system does not recognize the individual as a person, or misclassifies the person, for example classifying an adult of small stature as a child. While people with disabilities often experience challenges when working with inaccessible technology, this particular problem goes beyond in that the system may be making and acting upon incorrect assumptions about the user's state, or may be simply be unaware that a user is present.

Lack of Anonymity

A second problem occurs if the system relies upon some type of privacy-preserving algorithm that has not been tested with an adequate range of users. Many modern sensing systems use sensors that could potentially infringe upon users' privacy, but process or store video in a way such that most individuals cannot be identified. For example, a crowd tracking algorithm may only record the silhouettes of members of the crowd. The *anonymity problem* occurs when these privacy-protecting features cannot account for individuals who fall outside some expected level of individual variation.

As an example, the elevator system shown in Figure 1 captures only the silhouettes of those who walk by in order to preserve their privacy. For most people, this processing is enough to effectively conceal their identity. However, this breaks down for people with distinguishing characteristics, as shown in Figure 2. Here, one individual's silhouette clearly sets that person out from the rest of the crowd, enabling that person to be easily tracked even in the anonymized data set.

Figure 2. Photo from the author's personal collection in which only silhouettes have been retained. The silhouettes effectively anonymize some, but not all, of the people in the photo.

Lack of Training Data

The third problem does not directly affect end users, but rather affects the creators of sensing systems. These systems are often built upon data sets captured by the creators themselves, and may contain hundreds or thousands of samples. However, these problems affect atypical users by definition, and thus it is possible that even a conscientious designer may be unable to account for all possible users, even if users with different body types are included in the design process. Thus, we must consider ways to build better and more adaptable models that can support the widest range of users, even those that the designers may not have explicitly considered.

POSSIBLE SOLUTIONS

As these problems may affect many different technologies and many different user groups, they may therefore require a variety of solutions. Some of these problems may be addressed through traditional means, such as by involving diverse users throughout the design process, and by extending testing to include users who are not effectively recognized by the system. However, these steps will not necessarily take into account all users, and simply being aware of a user who might be excluded does not necessarily address the problem, if the designer cannot obtain appropriate training data. Here I identify several opportunities that may provide more general strategies for addressing these problems.

Public Data Sets

One opportunity to address the lack of training data for users with diverse physical abilities would be to create new public data sets that specifically include a diverse set of user characteristics, such as a computer vision dataset of users with diverse skin tones or a speech dataset containing users with a wide range of voice tones or accents. Another approach would be to create specialized data sets that address underrepresented community, such as a motion activity dataset taken from users of power wheelchairs. In the latter case, researchers might partner with a specific community organization to collect data.

Parameterized Models

A second approach to addressing some of these issues may involve more explicitly surfacing the parameters used in system models. This would enable designers to more explicitly consider the range of possible values, and even to adjust these values beyond their initial settings if new situations were encountered.

Overrides

Yet another approach to addressing these types of problems is to present an alternative interaction method or a way to override the detection mechanism. For example, the smart elevator can still be activated using the traditional elevator button, which is useful when the sensing system is malfunctioning or for users who are invisible to the system. However, relying upon an override presents its own problems, as the override itself may be inaccessible, or may promote a "separate but equal" mode of computer use. However, providing an override may address these problems more immediately, while then providing the designers with data about where their system fails.

CONCLUSION

It is my hope that this talk will spark interesting discussion about the assumptions underlying sensing-based systems, and issues of inclusion and exclusion within these systems. Fundamentally, developing systems that can detect and respond to human beings involves defining implicit or explicit rules about what data signals constitute a human being, and what capabilities that human being is expected to have. While we will likely see more examples in the future of unintentionally racist or ableist algorithms, there is an opportunity to understand the causes and effects of these problems, and to begin to work toward systems that support broadly inclusive and adaptable user models.

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