Thesis Project Portfolio

Understanding Computer Vision Through Optical Character Recognition and Blind-Assistive Technology

(Technical Report)

Treatment and Quality Eyecare for Diabetic Patients from Florida

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Erick Tian

Spring, 2022

Department of Computer Science

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Sociotechnical Synthesis

With the development of many new technologies, it is important for every new idea to be scrutinized and thought through to best understand not just the direct impact of technology, but also the indirect effects through all affected stakeholders and society at large. The technical portion of this paper discusses the development of Blind-Assistive Technology (BAT), a device consisting of distance sensors on a belt, meant to notify visually impaired users of their surroundings. Vibration motors are positioned along the interior of the belt to serve as haptic feedback that points users in the direction of approaching obstacles. The sociotechnical portion of this paper delves into the roots of the rise of blindness within the United States. Specifically, Florida's diabetic population is a contributing cause to increasing blindness cases, at a time when at-birth blindness is decreasing.

The technical portion to this paper serves as a demonstration that newer technologies to promote accessibility are possible. For the visually impaired, traditional modes of navigation include a guide dog or a white cane. However, these inventions are many decades old, and with developing technology, quality of life can be improved for the visually impaired. This portion of the paper is not meant to label the visually impaired as any less-abled, but rather it points out the prospect of creating technology to enhance people's existing abilities. The prototype designed and created by the technical portion of this paper serves as a proof of concept to back existing designs that work toward a similar end goal. The resulting product functions as intended, but not well enough for trials. The existing literature on LiDAR technologies for the blind show there is promise in future developments in similar projects.

The sociotechnical portion of this thesis focuses specifically on the growing blind and diabetic population in Florida. Using the Social Construction of Technology (SCOT), this paper evaluates all actors and stakeholders who contribute to the treatment of diabetic Floridians. As many individuals and groups influence the healthcare received by diabetic patients, we must understand each of their roles to ensure we can improve treatment in a way that appeases each group. The sociotechnical portion of this paper shows how rising cases of late onset blindness is an issue, and so is the lack of proper care for diabetic patients. As the issue continues to grow as a leading cause of death, complications from diabetes, as well as both preventative measures and treatment, must be better addressed by understanding the positions of each stakeholder in the matter.

The technical portion and sociotechnical portion are loosely coupled, as the technical portion aims to improve human sight, while the sociotechnical portion focuses on how to better care for eyesight. Combining these aspects, we can see how technology can influence populations that are overlooked, as well as how SCOT affects the development of a technology in the same way it affects the improvement of policy such as healthcare. As technology becomes better, we can find ways to apply it so that the world becomes more accessible. Likewise, past technologies and processes become refined over time, adapting as key actors and stakeholders change over time. Diabetic care for patients in Florida must undergo that refinement process, after several studies indicate inadequate care for Floridians. In similar fashion, both navigational aids and patient care in Florida must be improved, in order to foster a more inclusive and complete world.

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Nada Basit, Department of Computer Science

Understanding Computer Vision Through Optical Character Recognition and Blind-Assistive Technology

As part of the capstone research project for the University of Virginia Department of Computer Science, I worked with Professor Nada Basit to better understand how computer vision can be used to enhance day-to-day experiences. This technical project consisted of first working with Optical Character Recognition (OCR), and then creating my own system of distance sensors to provide guidance for the visually impaired. The theme across semesters for this project was understanding how computer vision can be trained to understand text, and also how it can be applied through custom components to create a device to aid the blind.

The first component of this technical research was focused on understanding OCR and its applications. Using Pytesseract, I worked to translate pictures of text, starting with screenshots of race results for the game Mario Kart Wii. This proved to be more difficult than expected, due to the low quality of the game, as well as inconsistent capture card software. After consulting with people who have tried to do the same, I determined that this task was too daunting for an introduction to computer vision. Instead, I created a program that could read mock screenshots, as well as screenshots of monospaced scripts found online. With these results, I created a Python program to reach and translate pictures of computer code from a link.

The second component of my capstone project involved working on Blind-Assistive Technology (BAT), an idea I have been experimenting with. BAT consists of a belt, a microcontroller, servo motors, Time-of-Flight (ToF) sensors, and vibration motors. The servo motors are attached to ToF sensors, which scan the user's environment for obstacles. When an object is detected, vibration motors positioned around the belt serve as haptic feedback to notify the users of objects within range, without relying on their sight. In 2018, Katzschmann and his team worked on a similar concept, using ToF sensors combined with haptic feedback to create a fully functional device for the visually impaired (2018, pp. 485-487). Their results concluded that the device was adept at navigating hallways, corridors, and even stairs (Katzschmann et al., 2018, pp. 589-592).

The prototype that I created as part of my capstone research serves as a proof of concept in replicating the device created by Katzschmann and his team. Originally, the inspiration for this system came from a project I worked on in high school, with Edward Tong and Phineas Ulmishek-Anderson. With the increased literature since then, I have confidence that such a product can be used successfully and independently by the blind in the future. The device uses an Arduino Leonardo microcontroller to control the system of servos, ToF sensors, and vibration motors. While there was not enough time in the semester to develop the prototype into a completely functioning product ready for trials, the system created was adequate for the given time frame.

While exploring OCR helped me understand current applications of computer vision, working on BAT allowed me to create my own system of detection. Furthermore, both of these projects can be linked to using technology to empower the visually disabled. In a paper written by Kurlekar and her team, researchers successfully created a reading device for blind individuals using Pytesseract, Google Text-to-speech, and a Raspberry Pi 2 (2020). Furthermore, Katzschmann's team argues that their system of LiDARs and vibrotactile units can provide the same benefits of a white cane with additional sensory data, increasing user independence and serving as a stepping stone toward progress in discrete and functional technology for the visually impaired (Katzschmann et al., 2018, p. 592). Applying computer vision to increase accessibility has not only introduced new concepts to me, but it has also provided me with a holistic view of how technology can be used to empower the blind.

References

Katzschmann, R. K., Araki, B., & Rus, D. (2018). Safe local navigation for visually impaired users with a time-of-flight and haptic feedback device. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 26(3), 583–593. https://doi.org/10.1109/TNSRE.2018.2800665

Kurlekar, S., Deshpande, O., Kamble, A., Omanna, A., & Patil, D. (2020). Reading Device for Blind People using Python OCR and GTTS. *International journal of Science and Engineering Applications*, 9(4), 049-052.

Treatment and Quality Eyecare for Diabetic Patients from Florida

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
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Hannah Rogers, Department of Engineering and Society

Treatment and Quality Eyecare for Diabetic Patients from Florida

Abstract

Diabetes is the leading cause of visual impairment among those aged 20-74. Blindness cases have been rapidly increasing, while accessibility and resources stagger behind. As diabetic patients deal with increasing mental, physical, and financial burdens, it is imperative to create more affordable and higher quality resources and infrastructure to both prevent type 2 diabetes, and address complications and reverse damages. Drawing from historical observations in data as well as professional studies and recommendations, the Social Construction of Technology identifies the various actors who contribute to the improvement of diabetic care. Diabetes causes many complications, affecting both visual and oral health. Care of diabetic patients is overlooked, and many do not receive adequate support. Because of this, it is important to analyze the various avenues that can be used to create, maintain, and lobby for better treatment in Florida.

Introduction

As medical practices improve and become more uniform, at birth blindness cases have decreased. However, the same is not true for adult onset blindness. Cases of visual impairment are on the rise in the United States, with the rate of blindness currently increasing at a rate much faster than the general population (National Eye Institute, 2019). As shown in Figure 1, the number of cases of blindness has increased by 37.6% from 2000 to 2010. From 2030 to 2050, trends indicate that cases are expected to nearly double. This means that the National Eye Institute predicts cases

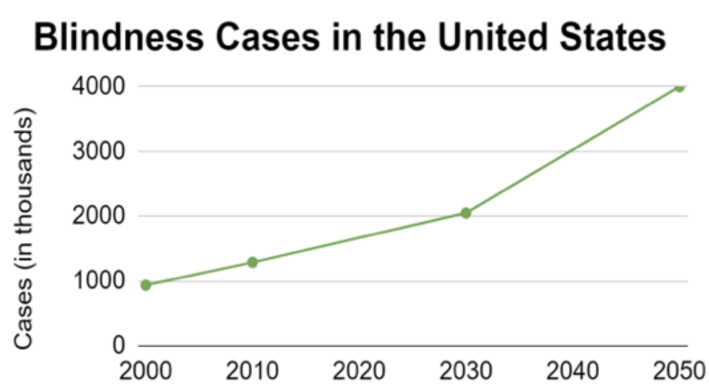


Figure 1: Projected cases of blindness over time in the United States. (Adapted by Erick Tian (2021) from National Eye Institute 2019).

of clinical blindness increasing fourfold from 2000 to 2050, while the population is not even expected to double (2019). Although this contemporary trend shows a general increase in cases of blindness, this is not reflective of previous trends seen in children alone. According to Robinson, Kinnis, and Jan, the rate of congenital blindness in live births has decreased from 0.08% to 0.03% from 1945 to 1984, cutting cases by over half (1987). This shows that despite a decrease in blindness present at birth, cases are still on the rise for adults, who may face adult onset blindness from macular degeneration, cataracts, or diabetic retinopathy (Centers for Disease Control and Prevention, 2020).

In a report from 2016, a survey of visually disabled individuals ages twenty-one to sixty-four showed that 22.3% did not have a high school diploma, and 27.7% are living below the poverty line (National Federation of the Blind, 2019). The state of Florida is working to better aid diabetic patients through affordable, quality means (Shahady, 2008), especially when 45% of Floridians aged 60 and above have diabetes, with both type 1 and type 2 diabetes increasing by 33% in the past decade (p. 29). Combating all the roots of where adult onset blindness develops is a daunting challenge, but tracing complications of diabetes and how they may cause visual disability can both create awareness of how blindness develops, as well as mitigate further increases of cases. This thesis aims to recognize how diabetes originates and is treated in Florida, with a focus on eye care for patients.

Origins and Consequences of Diabetes in Florida

In 2021, the state of Florida created a legislative report on the scope and impact of diabetes among residents. Here, the Florida Diabetes Advisory Council states that over 10% of adults have been diagnosed with prediabetes at some point (2021, p. 10). Individuals with prediabetes are 5 to 20 times more likely to later develop type 2 diabetes compared to someone with healthy blood glucose levels. A 2018 National Survey of Children's Health showed that 0.4% of children are currently diagnosed with diabetes in the United States, which is increasing for both type 1 and type 2 diabetes among youth (Florida Diabetes Advisory Council, 2021, pp. 7-12).

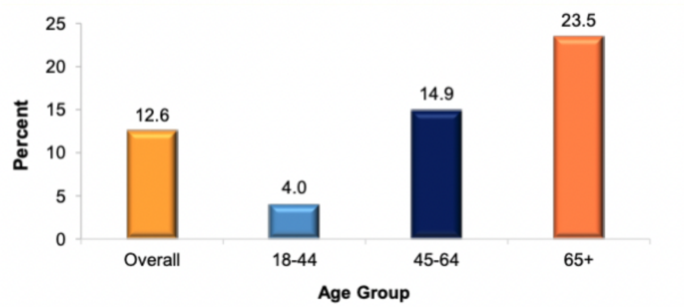


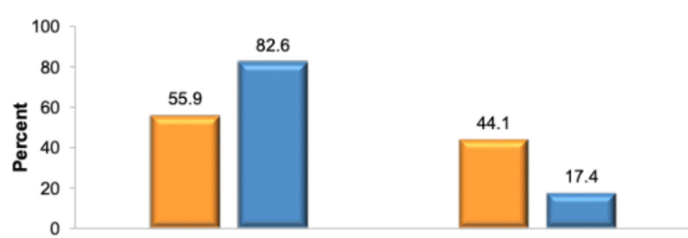
Figure 2: Florida Prevalence of Diabetes by Age Group, 2018

(Florida Diabetes Advisory Council, 2021)

The rate of diabetes in Florida has more than doubled from 1995 to 2018, with a clear trend of increasing cases with increasing age, as shown in Figure 2. In Florida schools, cases of youth diabetes are provided for through unlicensed assistive personnel who may be certified nursing assistants or school staff, with resources such as glucose monitoring, ketone testing, carbohydrate-counting, and insulin administration (Florida Diabetes Advisory Council, 2021, p. 15).

To help prevent type 2 diabetes, the Florida Diabetes Advisory Council suggests that individuals avoid common causes of diabetes, through increasing physical activity, maintaining a healthy weight, eating healthy, and avoiding smoking. Furthermore, type 2 diabetes can be delayed through blood glucose lowering medication, stress management, and lifestyle changes (2021, p. 9).

The consequences of diabetes appear at not just an individual level, but also a societal level. Diabetic individuals are more likely to face comorbidities such as heart disease, stroke, and kidney failure. Furthermore, those with diabetes are much more likely to suffer from poor mental and physical health, and those who have diabetic loved ones carry that worry with them. As



shown in figure 3, nearly 30% more diabetic people face poor health, through self-reported data. Because of the increased health risk, diabetic patients are more than 15% more likely to have visited a doctor in the past year (94.6% compared to 78.3%). On the other hand, diabetic patients are 11.9% less likely to have visited a dentist in the past year (56.0% compared to 67.9%), yet are more likely to develop gum disease and gingivitis. With the increased risk for comorbidities and diseases, the Florida Diabetes Advisory council has found diabetic individuals face a much higher emotional, physical, and financial burden (2021, pp. 21-24).

Eye Care for Diabetic Patients

For eye care specifically, a 1988 study evaluated accessibility for diabetic patients to both optometrists and ophthalmologists. With diabetes being the leading cause of blindness in adults aged 20-74, this paper by Alexander and Duenas determined, “The poor utilization of the primary care optometrist creates a gap in the health care delivery for the patient with diabetes. This gap may contribute to the increase in the complication of diabetic retinopathy.” (1994)

Cheaper and Higher Quality Treatment

Diabetes is the sixth leading cause of death in the United States, with cardiovascular disease accounting for 70% of those diabetes-related deaths (Shahady, 2008). In a study about care for diabetic patients, Shahady determined that despite an increased understanding of diabetes over time, medical aid toward patients has not shown a paralleled increase in quality or affordability (2008). Shahady proposes to decrease appointment length by creating an internet-based registry as well as through group visits, which would make patient care higher quality and more efficient.

The Need to Increase Diabetic Care

Medical resources available are currently outpaced by the rise of diabetes and its associated blindness. However, with research that recognizes the need to increase diabetes-related discussion, we can move forward in how to better take care of the diabetic population. In the Florida Diabetes Advisory Council's 2021 report, several promising interventions are proposed, many of which are implemented by Diabetes Disease Management (seen in Figure 3 on page 5).

Promising Intervention	Program Goal	% of Plans that Implement
Physician Care Gap Reports	Patient compliance	100%
Family/Caregiver Support	Patient compliance	62%
Healthy Behaviors Program	Access to services; Referral to diabetes community programs	54%
Biometric Monitoring/ Glucometers	Diabetes education/self-monitoring	31%
Home Visiting Initiatives	Access to services; Care coordination; Patient compliance	23%
Social Determinants of Health Initiatives	Access to services; Diabetes education/self-monitoring; Patient compliance	15%
Telehealth	Access to services; Diabetes education/self-monitoring; Patient compliance	8%

Source: Plan-reported through Disease Management Programs and Policies, 2018

Figure 4: Promising Interventions by Diabetes Disease Management, 2018 (Florida Diabetes Advisory Council, 2021)

The Florida Diabetes Advisory Council has also shown that diabetic patients may not take care of their specialized needs as much compared to non-diabetic patients, which is demonstrated by the lower rate in which diabetic individuals visit a dentist, which results in poorer oral health (2021, p. 24). This is similar for eye care, where primary care doctors often overlook taking advantage of the practicing optometrist for diabetic examinations (Alexander and Duenas, 1994). This, combined with inconsistent access to eye care, means optical health may not be properly cared for in diabetic patients. Diabetes can result in many complications, from comorbidities to oral and optical health. Through both preventative measures and treatment, a leading cause of death and disease can be mitigated for future generations.

Social Construction of Technology

The Social Construction of Technology (SCOT) was originally introduced by Pinch and Bijker as a fruitful approach to analyzing the sociology of technology (Pinch & Bijker, 1987, p.

431). According to Pinch and Bijker, in the same way that the scientific community shares the impacts of discoveries and progress, technology can be interpreted through a similar manner so that we integrate society with technological advancements (1987, p. 432). Using the Social Construction of Technology (SCOT), we can view blindness not just from the perspective of diabetic patients who directly experience it, but also through the lens of social good at large (Pinch & Bijker, 1987, pp. 410-411). Society aims toward a more inclusive society collectively, including developing better systems to take care of the disadvantaged. Within the development of eye problems in diabetic patients, there are many stakeholders in Florida. Not only does this complication from diabetes impact patients, but also loved ones who care about them, their doctors, insurance companies, and the pharmaceutical industry. Each actor impacts the product and its development in different ways, and using this multi-directional approach, we see how each stakeholder contributes to the development of treatments (Pinch & Bijker, 1987, p. 411). In order to better healthcare for diabetic patients, it is imperative that we understand all actors who play a role in the use of treatment.

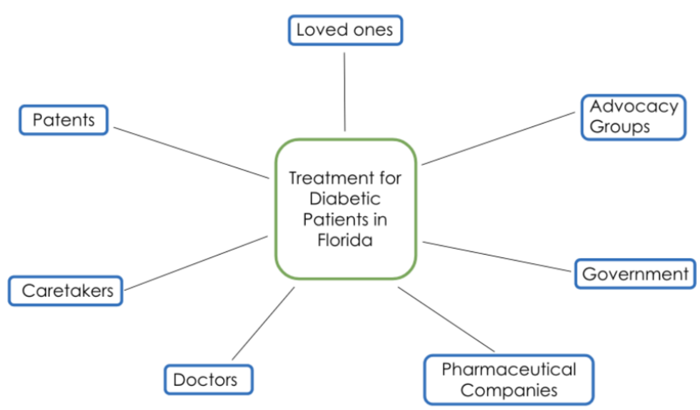


Figure 5: SCOT framework for treatment of diabetic patients in Florida. Every stakeholder impacts the development of technology and policy. (Tian, 2022)

While the Florida Diabetes Advisory Council may provide insight into prevention and treatment of diabetes to prevent vision loss as an advocacy group, funding is provided by state and local governments, private sector investors, and other social groups. Furthermore, doctors, loved ones, and caretakers may lobby to influence government officials who regulate healthcare. As shown in figure 5 on page 6, many actors directly interact with treatment, and patients are only one of many groups who influence the progression of care.

Shahady's proposal for more efficient and effective appointments comes from the perspective of a medical professional (2008), working to improve patient care, which is notably important for loved ones and caretakers. Organizations such as the Centers for Disease Control and Prevention work toward providing unbiased data indicating a rise in late onset blindness cases (2020) as a government agency, similarly to the Florida Diabetes Advisory Council, which serves as an advisory unit to the Department of Health. On the other hand, Alexander and Duenas noted the poor treatment of diabetic patients from the viewpoint of scientific researchers (1994).

References

Alexander, L. J., Duenas, M. R. (1994, August) Eye care for patients with diabetes in the state of Florida: status in 1988. *Journal of the American Optometric Association, 65*(8), 552-558. PMID: 7930364.

Centers for Disease Control and Prevention (Ed.). (2020, June 3). Common eye disorders and diseases. Centers for Disease Control and Prevention. Retrieved April 7, 2022, from https://www.cdc.gov/visionhealth/basics/ced/index.html

Florida Diabetes Advisory Council (Ed.). (2021, January 10). 2021 Florida diabetes Report. Florida Health. Retrieved April 8, 2022, from https://www.floridahealth.gov/provider-and-partner-resources/dac/_documents/2021-dac-report.pdf.pdf

Florida Diabetes Advisory Council (2021, January 10). *Florida Prevalence of Diabetes by Age Group, 2018.* [Figure 2]. *2021 Florida diabetes Report.* Florida Health. Retrieved April 8, 2022, from https://www.floridahealth.gov/provider-and-partner-resources/dac/_documents/2021-dac-report.pdf.pdf

Florida Diabetes Advisory Council (2021, January 10). *Self-Reported Health Status by Diabetes Status in Florida, 2018.* [Figure 3]. 2021 *Florida diabetes Report.* Florida Health. Retrieved April 8, 2022, from https://www.floridahealth.gov/provider-and-partner-resources/dac/_documents/2021-dac-report.pdf.pdf

Florida Diabetes Advisory Council (2021, January 10). *Promising Interventions by Diabetes Disease Management, 2018.* [Figure 4]. *2021 Florida diabetes Report.* Florida Health.

Retrieved April 8, 2022, from https://www.floridahealth.gov/provider-and-partner-resources/dac/_documents/2021-dac-report.pdf.pdf

National Eye Institute. (2019, July 17). Blindness Data and Statistics. Retrieved from https://www.nei.nih.gov/learn-about-eye-health/outreach-campaigns-and-resources/eye-health-data-and-statistics/blindness-data-and-statistics

National Federation of the Blind (Ed.). (2019, January). Blindness Statistics. National Federation of the Blind. Retrieved April 7, 2022, from https://nfb.org/resources/blindness-statistics

Pinch, Trevor J., and Wiebe E. Bijker. (1987). The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other. Social Studies of Science. 14(3), 399-441. https://doi.org/10.1177%2F030631284014003004

Robinson, G. C., Kinnis, C., & Jan, J. E. (1987). Congenital ocular blindness in children, 1945 to 1984. Archives of Pediatrics & Adolescent Medicine, 141(12), 1321. https://doi.org/10.1001/archpedi.1987.04460120087041

Shahady, E. (2008). The Florida diabetes master clinician program: Facilitating increased quality and significant cost savings for diabetic patients. Clinical Diabetes, 26(1), 29–33. https://doi.org/10.2337/diaclin.26.1.29

Tian, E. (2021). *Projected cases of blindness over time in the United States.* [Figure 1]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2022). *SCOT framework for treatment of diabetic patients in Florida. Every stakeholder impacts the development of technology and policy.* [Figure 5]. *Thesis*

(Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

BLIND ASSISTIVE TECHNOLOGY: USING LIGHT-BASED DETECTION AS A NAVIGATIONAL AID FOR THE VISUALLY IMPAIRED

FOSTERING A STIGMA-FREE FUTURE FOR THE VISUALLY IMPAIRED

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
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In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Science

By
Erick Tian

December 2, 2021

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Catherine Baritaud, Department of Engineering and Society

Nada Basit, Department of Computer Science

As the world continues to innovate through technology by creating modern solutions to age-old problems, humanity has been looking for ways to empower those with disabilities. One issue that has been particularly difficult to address is helping those who have lost an entire sense. Specifically, losing sight is an impediment to nearly every daily activity, which is why finding a proper solution could change the lives of millions. In the United States alone, studies suggest there are over 7.5 million people aged 16-75 that have a form of visual disability (Simek et al., 2020, p. 19). Especially when negative stigma around disabilities serves as a massive barrier to entry for many careers and educations, it is more important than ever to re-shape the discussion about people who have visual impairments (Stone & Brown, 2021, p. 43). The difficulty for blind people to exhibit omnipresent spatial awareness lies at the root of many daily difficulties, from general perception to the health and safety hazards of poor design that does not consider the limitations of the visually impaired. If technology were created to allow individuals to garner a sense of direction and spatial awareness, this could pave the way for a new navigational aid to empower the visually disabled through independence, or as an auxiliary guide.

TIME-OF-FLIGHT SENSORS AND HAPTIC FEEDBACK AS NAVIGATIONAL AIDS

The current physical perception of blind people can be represented in Figure 1. Using Blind-Assistive Technology (BAT), I hope to expand this range to the one depicted in Figure 2 on page 2. Blind-Assistive Technology is a navigational system consisting of four components: a vest, a microcontroller, an array of Light Detection and Ranging (LiDAR) sensors, and a set of vibration motors, as depicted in Figure 3 and Figure 4 on

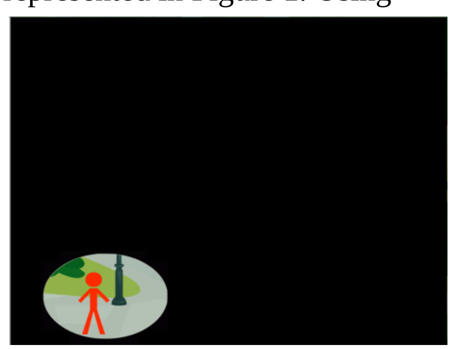

Figure 1: Physical perception of a blind person in a park. (Tian, 2021)

page 2. The vest serves to connect individual components as part of wearable tech, and the microcontroller serves as a computational unit to relay data and commands between the sensors and the motors. At its core, LiDAR is a laser scanner that measures distance using the time elapsed for a beam to hit a surface, reflect, and return to the sensor. For this project, I will be creating my own LiDAR system through an array of Time-of-Flight (ToF) sensors, which detect the distance an object is from the sensor. As Time-of-Flight sensors are LiDAR-based, this means they use laser-based light to detect objects with speed and accuracy (Kane et al., 2010, p. 34) in a fashion similar to echolocation, a method bats use in nature in place of visual cues, hence the project name BAT. These LiDAR systems have been used in various applications such as self-driving cars, with limited research on specifically being used to help the visually impaired. In a study where LiDAR was tested on natural environments, it proved to be effective as a mapping tool, demonstrating its navigational potential (Kane et al., 2010). Using information mapped out from the ToF sensors, vibration motors located on the torso of the vest will then vibrate in the direction of incoming obstacles,

Figure 2: Physical perception of a blind person equipped with BAT in a park. (Tian, 2021)

Figure 3: Side perspective of BAT. This figure depicts the locations of each component. (Tian, 2021)

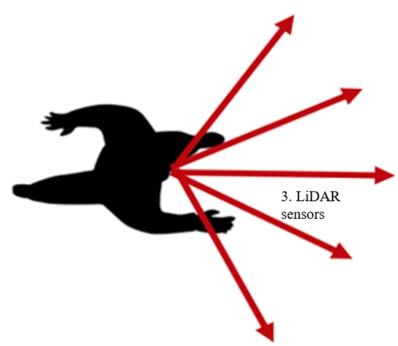

Figure 4: Above perspective of BAT. An array of LiDAR sensors can map out 155 degrees laterally. (Tian, 2021)

alerting users through haptic feedback. Through this method, I hope to create a technology-based method for navigation that can be updated over time with improvements in hardware accuracy and efficiency.

Specifically, the ToF sensors can be employed to locate the user's surroundings by being positioned horizontally next to each other. These sensors will be attached to motors that would spin the ToF sensors to give them the capability to scan in a 2D plane, allowing a semi-accurate attempt to carve out a flat depiction of obstacles in the user's vicinity and how far away they are located. To account for how this system only scans in a flat plane, I will also place various sensors on different locations on the torso to provide a more complete representation of elevation changes and depth. While these ToF sensors scan the surroundings by moving vertically to ensure complete coverage, haptic feedback motors can vibrate with increasing frequency in response to an increasingly close object. These motors would be located on the torso of the vest to provide coverage of angles where obstacles may appear from. To mimic the visible range for an able-bodied individual, I have decided to place five sensors on the user such that they cover a range of 155 degrees.

In addition, to ensure complete vertical coverage as well, I will place additional ToF sensors on the upper torso to account for blind spots as shown in Figure 3 on page 2. With the addition of these sensors, I can more accurately determine depth for key obstacles by measuring their distances for multiple sensors. This increased validation will potentially create a system that can allow users to navigate complex, elevated terrain such as stairs, as depicted in Figure 4 on page 2. To do this, I will be 3D printing an encasement for the sensors and motors. This would be mounted somewhere near the user's abdomen while the battery would be strapped to the interior of the vest or stored in a built-in pocket. I will work with sewing techniques to embed the electrical components into the vest, and then implement a printed circuit board to minimize wire clutter. As I approach a final product, I will work to make it more aesthetically pleasing through better electrical component integration.

LiDAR-based systems of visual notifications geared toward the blind have been tested with success, allowing users to navigate through hallways and avoid obstacles. Specifically, a team at the ETH Zurich's Soft Robotics Lab in Switzerland conducted a study with 162 trials across 12 clinically blind users, which not only determined that modern navigational solutions were at best incomplete, but also found 82% of users reported such a system as satisfactory (Katzschmann et al., 2018, pp. 583-593). Although these results are phenomenal, with innovation comes the constant demand for improvement. Realistically, sensor-based technologies for the blind can only safely be used in conjunction with a more conventional and safe form of navigation at the moment, such as a white cane or a guide dog. With this project, it would be ideal to work past that limitation and have technologically advanced aid systems outdate previous ones. By using interchangeable ToF sensors and sensitive vibration motors, this project can stay better up-to-date with improvements in hardware, as well as better versions of software that can be created to adapt to new hardware. The hope with this improvable technology is that over time, it can be rewritten to be increasingly accurate to meet the needs and feedback of those who directly use this device.

Using previous research, the technical project will build upon sensors mapping out a region (Lang & McCarty, 2009, pp. 12-13) and then providing feedback to the user through vibration motors. By using more concentrated ToF sensors that target specific areas, we can focus on incrementally increasing the accuracy of the system while finding the optimal location for haptic feedback. Not to mention, by integrating detection methods and computer vision techniques from vehicles, we can better protect users from possible dangers coming from their surroundings (Liu et al. 2014, p. 8). Over the course of two semesters under the guidance of Nada Basit of the Computer Science department at the University of Virginia, this independent research project can be expected to be fully-functional, with a conclusive scholarly article on the results, methods, and conclusions. There are three goals for the end result of this product: accuracy, inclusivity, and affordability. For accuracy, I hope for this device to be able to detect lateral obstacles from up to three meters away at 155 degrees, in addition to reporting elevation changes such as stairs or ledges. To foster inclusivity, this system is designed to not be burdensome or bulky to the user and not be detectable enough to ostracize them. Finally, I would like this product to be affordable at a price of no greater than $200. Given the potential of such a technology, my intentions are to reach as many users as possible.

THE INCREASING BLIND POPULATION

Currently, the rate of blindness has been increasing at a rate much faster than the general population (National Eye Institute, 2019). As shown in Figure 5, the number of cases of blindness has increased by 37.6% from 2000 to 2010. From 2030 to 2050, trends indicate that cases are expected to nearly double. This means that the National Eye Institute predicts cases of clinical blindness increasing fourfold from 2000 to 2050, while the population is not even expected to double (2019), making the reach of assistive technology on the rise in the foreseeable future.

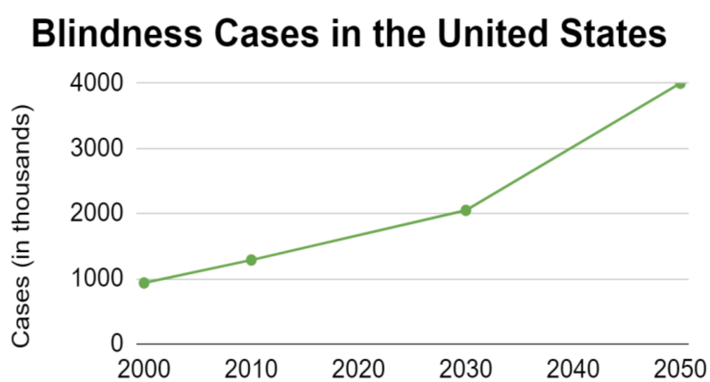

Figure 5: Projected cases of blindness over time in the United States. (Adapted by Erick Tian (2021) from National Eye Institute 2019).

Considering the wide reach intended, we must consider the actors and stakeholders who contribute to not just the technical, but also the social construction of navigational technology for the visually impaired. Using the Social Construction STS framework, we can analyze the relationships between assistive technology and individuals. As seen in Figure 6, many actors interact with the engineers who construct assistive technology.

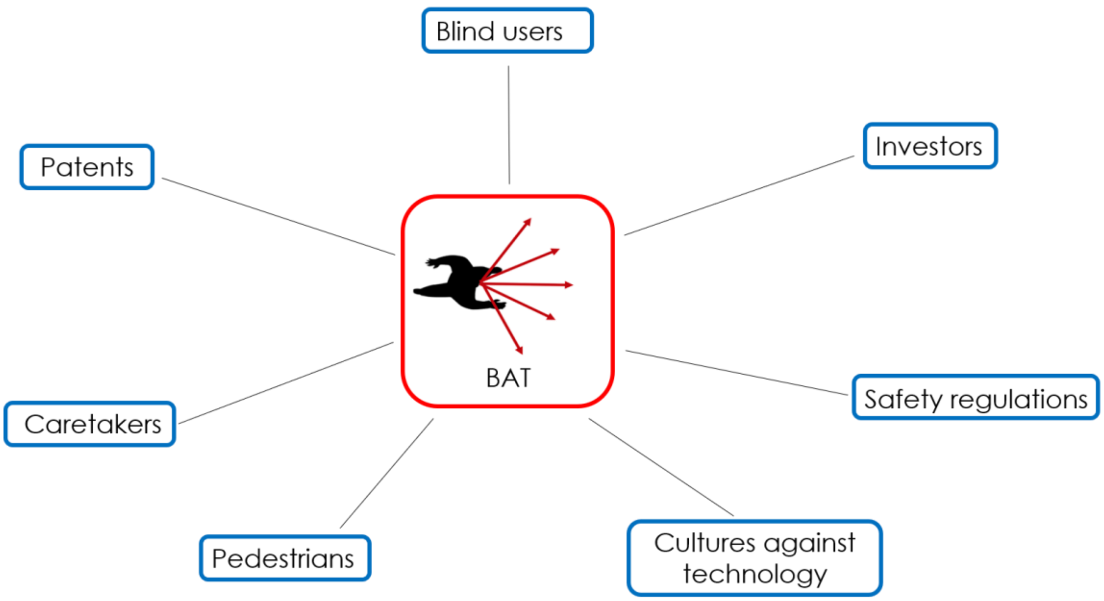

Figure 6: Social Construction of Technology framework for Blind-Assistive Technology. Engineers must account for their interactions with all primary actors. (Tian, 2021)

The users themselves, in addition to the caretakers of potential users, directly consider whether this product is viable for their needs. Furthermore, investors fund and believe in the concept, working with engineers to market the idea. Patent offices register the idea and check it against previous patents, while safety regulators ensure newly introduced practices and components will not be dangerous. As the two most commonly used navigational aids for the visually impaired are the white cane and guide dog, which both depend on a living being, BAT may pose safety concerns due to its reliance on technology. Moreover, culture plays an important role in the social aspect of the technology, as pedestrian reactions decide its acceptance, and certain groups may not be as familiar with technology, especially when used in this way. Particularly, individuals from less developed technical backgrounds, older generations, and those who want independence from technology may be hesitant to see BAT commonly used.

Using the Social Construction of Technology (SCOT), accessibility can be viewed from not only the lens of benefitting those who are disabled and directly affected, but also from the perspective of social good itself (Pinch & Bijker, 1987, pp. 410-411). As people generally wish to foster an inclusive society, those who lack access to certain resources will be compensated through other means or developments. Through this analysis of SCOT, this allows for a comprehensive method to analyze not only how perspectives of the visually impaired impact users of all backgrounds, but also the large role society plays in the creation and maintenance of science and technology.

ADDRESSING STRUCTURAL BIAS AND STIGMA

When considering these interactions, it is imperative to acknowledge how societal perception is inherently rooted in disability-focused technology, as traditionally marginalized groups must consider the existence of strong biases in all interactions. However, these biases can be reshaped. For the STS portion of my research, I hope to analyze how to best structurally reduce stigma to create an increasingly inclusive world. In a study done by Brian Stone and Deanna Brown (2021), college students' attitudes toward blindness became more positive after having taken a course on assistive technologies, disability advocacy, and accessible design relating to visual impairment. This implies that by focusing on how schools teach disability awareness, we can reduce stigma from an early age by influencing the culture of the next generation. A perfect way of representing how this relates to technology is through Pacey's Triangle, seen in Figure 7 on page 8.

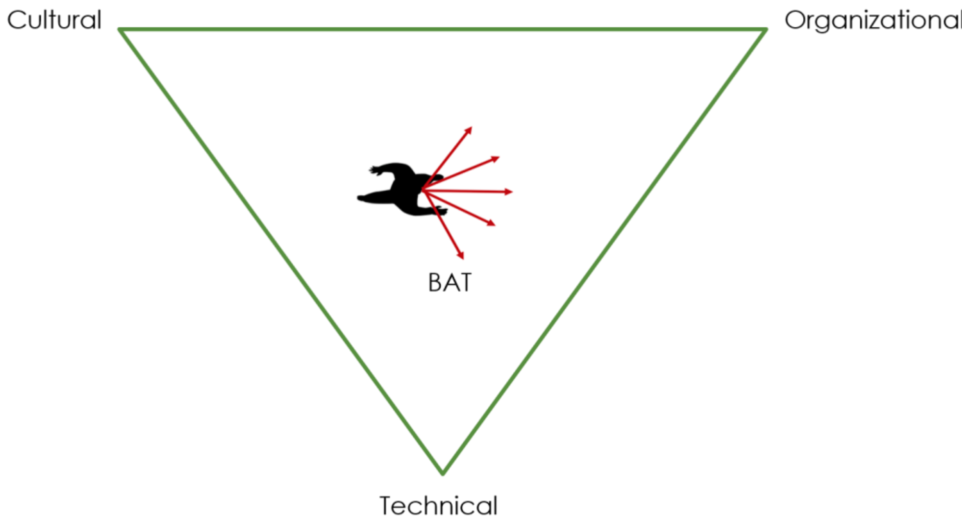

Figure 7: Blind-Assistive Technology and Pacey's Triangle. It is essential to not disregard the cultural, organizational, and technical aspects surrounding assistive technologies. (Tian, 2021)

As school is an organized institution, it represents how the organizational aspect of assistive technology affects the cultural aspect of it. To the same end, creating inclusive technology can lead to the normalization of disabilities culturally. That in turn can rewrite how organizational hierarchies design documentation and write legislation relating to accessibility, which can then further flag inappropriate design within infrastructure and technology.

Practical effectiveness only goes so far without proper integration into society, which may be difficult for users if the device they carry makes them stand out. As the focus of this research is on how to improve the lives of the disabled, social reaction must be considered when designing the system. As technology is evolving to provide use anywhere possible, the scope of this project may include a large portion of the blind population, which is why it is important to consider the ways pedestrians and society react to the visually impaired when thinking about systems that they may use on a daily basis (Silverman & Bell, 2020, p. 4). The best way to address it is by searching for what solutions have increased openness toward discussions centering around disabilities through a long-lasting and forward-thinking approach, that addresses these issues at their roots. The goal of this STS research project is to identify not only areas that cause stigma to increase, but also realize how stigma remains stagnant to better decrease barriers to access.

IMPLICATIONS OF BLIND-ASSISTIVE TECHNOLOGY IN DIGITAL SOCIETY

The Social Construction of Technology is inherently intertwined with Blind-Assistive Technology, as this creation aims to change daily interactions for its users. This means that the STS and technical portions of this prospectus are tightly coupled: Neither the technical nor the societal components of this research can exist alone without considering the other. The technology is responsible for creating accurate and working methods in order to enable its users, as well as serving a pivotal role in how disabilities are viewed in the first place. With this research adding to the literature on innovative robotics for increasing accessibility, this means future computer vision, image detection, and prediction algorithms can expand upon these ideas to create subtler and more efficient constructions. The STS portion of this research addresses preconceptions of the visually disabled that society must be cognizant of, despite it being currently overlooked. Combining these, this project hopes to advance our collective technological ability to empower users by increasing their range of senses while reshaping the narrative on ableist stigma.

REFERENCES

Kane, V. R., McGaughey, R. J., Bakker, J. D., Gersonde, R. F., Lutz, J. A., & Franklin, J. F. (2010). Comparisons between field- and LiDAR-based measures of stand structural complexity : Journal Canadien de la recherche forestière. *Canadian Journal of Forest Research*, 40(4), 32–36. http://dx.doi.org/10.1139/X10-024

Katzschmann, R. K., Araki, B., & Rus, D. (2018). Safe local navigation for visually impaired users with a time-of-flight and haptic feedback device. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 26(3), 583–593. https://doi.org/10.1109/TNSRE.2018.2800665

Lachenmayr, B., Berger, J., Buser, A., & Keller, O. (1998). Reduced visual capacity increases the risk of accidents in street traffic. *Der Ophthalmologe : Zeitschrift Der Deutschen Ophthalmologischen Gesellschaft*, 95(1), 44–50. https://doi.org/10.1007/s003470050234

Lang, M. W., & McCarty, G. W. (2009). LiDAR intensity for improved detection of inundation below the forest canopy. *The Journal of the Society of the Wetlands Scientists*, 29(4), 10–17. https://doi.org/http://handle.nal.usda.gov/10113/38821

Liu, S., Atia, M. M., Karamat, T. B., & Noureldin, A. (2014). A LiDAR-aided indoor navigation system for UGYs. *Journal of Navigation*, 68(2), 253–273. https://doi.org/10.1017/s037346331400054x

National Eye Institute. (2019, July 17). *Blindness Data and Statistics*. Retrieved from https://www.nei.nih.gov/learn-about-eye-health/outreach-campaigns-and-resources/eye-health-data-and-statistics/blindness-data-and-statistics

Pinch, Trevor J., and Wiebe E. Bijker. (1987). The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science*. 14(3), 399-441. https://doi.org/10.1177%2F030631284014003004

Silverman, A. M., & Bell, E. C. (2020). The association between mentoring and STEM engagement for blind adults. *Journal of Blindness Innovation & Research*, 10(2), 3–8. https://doi.org/10.5241/10-197

Simek, C., Sener, I. N., & Moran, M. (2020). An evaluation of the safety perceptions of transportation network companies as a mobility option for the visually impaired community. *Journal of Blindness Innovation & Research*, 10(2), 18–23. https://doi.org/10.5241/10-175

Stone, B. W., & Brown, D. (2021). Changing attitudes about visual impairment in the college classroom. *Journal of Blindness Innovation & Research*, 11(1), 31–45. https://doi.org/10.5241/11-200

Tian, E. (2021). *Above perspective of BAT. An array of LiDAR sensors can map out 155 degrees laterally.* [Figure 4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Blind-Assistive Technology and Pacey's Triangle. It is essential to not disregard the cultural, organizational, and technical aspects surrounding assistive technologies.* [Figure 7]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Physical perception of a blind person in a park.* [Figure 1]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Physical perception of a blind person equipped with BAT in a park.* [Figure 2]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Projected cases of blindness over time in the United States.* [Figure 5]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Side perspective of BAT. This figure depicts the locations of each component.* [Figure 3]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Tian, E. (2021). *Social Construction of Technology framework for Blind-Assistive Technology. Engineers must account for their interactions with all primary actors.* [Figure 6]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.