Personalized AR Navigation for Individuals with Motor Disabilities

1. Introduction

According to the most recent US Census study conducted in 2014, approximately 48.2 million adults have functional limitations, of which 17.6 percent of them are experiencing lower body functional limitations [12]. More specifically, about half of these adults require aids, including cane, crutches, walker, and wheelchair (5.5 million). Despite such a magnitude, many streets, sidewalks, and buildings are not accessible to these individuals [6]. To address this concern, researchers and organizations have been labeling accessibility issues that exist in outdoor and indoor spaces through crowdsourcing platforms [1,2,5,10]. This effort led to a proliferation of accessibility labels, making designing a map application that makes use of this data an apparent course of action. Additionally, the free-hands nature of augmented reality (AR) glasses make it a promising choice for navigation. By addressing this challenge, we aim to guide users with motor disabilities through paths they can reasonably travel through (e.g., a wheelchair user is not expected to go over high bumps).

The artifact we seek to create has three main components: 1) path preview, 2) path validation, and 3) path auditing. First, based on crowdsourced accessibility labels and the user's mobility level, our application will suggest several personalized routes from starting position A to destination B. Once the user selects a route, a glowing path displayed in AR will guide the user. The AR glasses will simultaneously validate whether the accessibility labels are correct or not using computer vision (CV), such that if the real-time accessibility condition of a path differs from prior perception, the user will be given a choice to be rerouted to a more accessible route. Finally, the user will also have the option to create and update accessibility labels in-situ to improve the navigation experience for future users.

For the scope of this course, we will be focusing on designing real-time detection of accessibility issues using AR and CV. Additionally, to account for the possible model training challenges, we will pilot the project on one street segment. The project will conclude with a pilot testing, with the goal of conducting future user studies to understand our target group's perceptions of AR navigation.

2. Related Work

2.1 Project Sidewalk

This project will be utilizing data from Project Sidewalk (https://projectsidewalk.org), an open-source crowdsourcing tool that enables online users to remotely label sidewalk conditions and identify accessibility problems using gamified missions and streetscape imagery — similar to a first-person video game. For each sidewalk label, Project Sidewalk collects a problem severity score, relevant tags, and optional open-ended descriptions [1,2,5,10]. However, because Project Sidewalk is based on Google Street View (GSV), the labeled data is limited to the time when GSV was captured, in some cases outdating the current situation by years [10]. Our contributions will extend Project Sidewalk by leveraging AR to incorporate real-time information that is more reflective of the current streets accessibility conditions.

2.2 Computer Vision Model for Accessibility

There are only a few datasets and CV models that are dedicated to detecting accessibility problems. One example is Mapillary, a dataset consisting of 1.8 billion images, many of which are labeled with accessibility issues, such as obstacles [8].

2.3 Existing AR Navigation Solutions

AR navigation is a vast space with a sea of literature. For example, Kim et al. designed a marker-based indoor navigation solution, which displays turns and current location on a 2D UI [4]. Mulloni et al. designed an AR navigation solution that projects arrows onto the real world [7]. Höllerer et al. explored providing more information beyond directions, such as names of surrounding buildings [3]. Finally, Zhao et al. designed graphical overlays on top of stairs to improve saliency for low vision individuals [11]. We will be designing our navigation system based on the insights discussed in prior literature.

3. Goals and Timeline

3.1 Literature Review

This stage is twofold; we will be gathering literature on CV models for outdoor accessibility and prior approaches on visualizing CV results in AR. We expect this to take 1 week.

3.2 CV Model and Algorithm

We will first attempt to train a CV model using the Mapillary dataset. If this attempt fails, we will use a pre-trained model (e.g., YOLO [9]) or manually label one street segment. Combined with a user's individual mobility condition and needs, we will assign an accessibility score to each path segment. We expect this to take 3 weeks.

3.3 Prototype

Based on the results from our CV model and algorithm, we will visualize which path is better for the user using the Microsoft Hololens 1. We expect this step to take 1 week to complete.

3.4 Pilot Testing

We will validate our prototype on a street segment, with a goal of conducting future user studies to understand how to design an AR application for individuals with motor disabilities. We expect this step to take 1 week to complete.

References

[1] Kotaro Hara. 2016. Scalable Methods to Collect and Visualize Sidewalk Accessibility Data for People with Mobility Impairments. (2016). DOI:https://doi.org/10.13016/M2RZ4N

[2] Kotaro Hara, Jin Sun, Robert Moore, David Jacobs, and Jon Froehlich. 2014. Tohme: detecting curb ramps in google street view using crowdsourcing, computer vision, and machine learning. In *Proceedings of the 27th annual ACM symposium on User interface software and technology*, 189–204.

[3] Tobias Höllerer and Steve Feiner. 2004. Mobile augmented reality. *Telegeoinformatics Locat.-Based Comput. Serv.* 21, (2004).

[4] Jongbae Kim and Heesung Jun. 2008. Vision-based location positioning using augmented reality for indoor navigation. *IEEE Trans. Consum. Electron.* 54, 3 (2008), 954–962.

[5] Anthony Li, Manaswi Saha, Anupam Gupta, and Jon E. Froehlich. 2018. Interactively modeling And visualizing neighborhood accessibility at scale: An initial study of Washington DC. In *Proceedings of the 20th international acm sigaccess conference on computers and accessibility*, 444–446.

[6] Hugh Matthews, Linda Beale, Phil Picton, and David Briggs. 2003. Modelling Access with GIS in Urban Systems (MAGUS): capturing the experiences of wheelchair users. *Area* 35, 1 (2003), 34–45.

[7] Alessandro Mulloni, Hartmut Seichter, and Dieter Schmalstieg. 2011. Handheld augmented reality indoor navigation with activity-based instructions. In *Proceedings of the 13th international conference on human computer interaction with mobile devices and services*, 211–220.

[8] Gerhard Neuhold, Tobias Ollmann, Samuel Rota Bulo, and Peter Kontschieder. 2017. The Mapillary Vistas Dataset for Semantic Understanding of Street Scenes. In *2017 IEEE International Conference on Computer Vision (ICCV)*, IEEE, Venice, 5000–5009. DOI:https://doi.org/10.1109/ICCV.2017.534

[9] Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi. 2016. You only look once: Unified, real-time object detection. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, 779–788.

[10] Manaswi Saha, Michael Saugstad, Hanuma Teja Maddali, Aileen Zeng, Ryan Holland, Steven Bower, Aditya Dash, Sage Chen, Anthony Li, and Kotaro Hara. 2019. Project sidewalk: A web-based crowdsourcing tool for collecting sidewalk accessibility data at scale. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–14.

[11] Yuhang Zhao, Elizabeth Kupferstein, Brenda Veronica Castro, Steven Feiner, and Shiri Azenkot. 2019. Designing AR visualizations to facilitate stair navigation for people with low vision. In *Proceedings of the 32nd annual ACM symposium on user interface software and technology*, 387–402.

[12] Americans With Disabilities: 2014. 32.