Safe and Efficient E-Wayfinding (SeeWay)
Assistive Navigation for the Visually Impaired

Technology Transfer Activities

by

Bing Li, Clemson University
Johnell Brooks, Clemson University
Gurcan Comert, Benedict College
Aries Arditi, Visibility Metrics LLC

Contact information:
Bing Li, Ph.D.
Department of Automotive Engineering, Clemson University
4 Research Dr., Greenville, SC 29607
Email: bli4@clemson.edu, (864)365-0649

October 2022

Center for Connected Multimodal Mobility (C^2M^2)

CLEMSON UNIVERSITY

Benedict College | The Citadel, The Military College of South Carolina | SC State University | University of South Carolina

200 Lowry Hall, Clemson University
Clemson, SC 29634

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, by the Center for Connected Multimodal Mobility (C^2M^2) (Tier 1 University Transportation Center) Grant, which is headquartered at Clemson University, Clemson, South Carolina, USA, from the U.S. Department of Transportation's University Transportation Centers Program. However, the U.S. Government assumes no liability for the contents or use thereof.

ACKNOWLEDGMENT

The project is funded by the Center for Connected Multimodal Mobility (C²M²) (Tier 1 University Transportation Center) Grant, from the U.S. Department of Transportation's University Transportation Centers Program and administered by the Transportation Program of Clemson University, University of South Carolina, and Benedict College.

Table of Contents

DISCLAIMER ii
ACKNOWLEDGMENT iii
Technology Transfer Activities 1
1 Summary of Research Study and Findings 1
2 Outputs 2
2 Outcomes 3
3 Impacts 3

TECHNOLOGY TRANSFER ACTIVITIES

1 Summary of Research Study and Findings

In this study, we first conducted transportation preferences study on challenges and opportunities for visually impaired users, and models of AI-enabled visual language navigation are created and validated. Further, mobility assistance solution using autonomous robotics technologies has been explored for people with mobility impairment, wheelchair users and senior citizens. The highlight of the research study and findings are as following,

- To increase understanding of vehicle-related challenges, including access, in-vehicle considerations, comfort, and acceptance of ride-sharing and transportation options for the visually impaired, we conducted user interviews for their preference study.
- Ten visually impaired participants, with an average age of 57.5 years, completed a semi-structured interview. Interviews were conducted via Zoom or phone, and focused on their transportation preferences and challenges, as well as how they want their transportation to look in the future.
- All participants typically ask family and friends to use local transport, while only two use carpooling services. Half of the participants described the most common challenge when getting into a car as hitting their own head. All participants used their sense of touch to locate seat belts, and most used both touch and hearing to locate the vehicle and door they were entering. When asked what they want in the future, examples include talking canes, electronic guide dogs or earbuds that can provide directions.
- Throughout the interviews, participants expressed the importance of transportation to them. This study increases understanding of the challenges faced when moving from walking in an indoor environment to getting into a vehicle. Understanding how visually impaired people currently board and exit vehicles may help engineers, new technology developers, and providers create more processes and/or training to help increase transportation options for visually impaired people.
- We propose a new visual-language model-based navigation method for the blind or visually impaired (BVI). It consists of a scene graph map building block, a navigation path generation block for global path reasoning via visual-linguistic navigation (VLN), and an obstacle-avoidance navigation block for real-time local navigation.
- Field tests have shown the effectiveness of VLN global path finding and local path re-planning. Experimental and quantitative results show that heuristic instructions outperform guided/detailed instructions in terms of VLN success rate (SR), and that SR decreases with increasing navigation length.
- We propose an AI framework embodied in a hands-free human-machine interface (HMI) for electric wheelchair users, but the same concepts apply to more general users. HMI research focuses on hands-free user input for machines, hands-free user output for automated navigation, and hands-free user output for manipulation.
- We also upgraded a Permobil C400 powered wheelchair with multi-sensor data fusion technology to enrich its terrain recognition, rollover stability and comfort prediction. The experimental results show that the IMU sensor data located on the human chest is in good agreement with the simulation analysis data, and is suitable for a variety of complex real terrain conditions, which verifies the accuracy of the wheelchair-human system dynamics model and the feasibility of the method.
- For better visual perception, we proposed a novel multi-modality depth prediction model for monocular depth prediction. Our model achieved the state-of-the-art for depth prediction and object detection downstream task.

2 Outputs

We well accomplished the research goals, and further extended it to more general assistive mobility and navigation scenarios with autonomous wheelchairs. Blow is the list of published papers for the research dissemination of this project, as well as pending or future output.

2.1 Accomplished Outputs

Peer-Reviewed Journal Article

- H. Luo, Z. Yang, P. Yin, J. Brooks and **B. Li**. "Modeling and Prediction of User Stability and Comfortability on Autonomous Wheelchairs with 3D Mapping." *IEEE Transactions on Human-Machine Systems*, 2022.
- P. Yin, L. Xu, Z. Feng, A. Egorov and **B. Li**. "PSE-Match: A Viewpoint-Free Place Recognition Method with Parallel Semantic Embedding." *IEEE Transactions on Intelligent Transportation Systems*, 2021.

Peer-Reviewed Conference Articles

- Z. Yang, L. Yang, L. Kong, A. Wei, L. Leaman, J. Brooks and **B. Li**. "SeeWay: Vision-Language Assistive Navigation for the Visually Impaired." IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2022. *Best Paper Finalists*.
- J. Leaman, Z. Yang, Y. N. Elglaly, H. La and **B. Li**. "Embodied-AI Wheelchair Framework with Hands- free Interface and Manipulation." IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2022.
- Z. Feng, L. Jing, P. Yin, Y. Tian and **B. Li**. "Advancing Self-supervised Monocular Depth Learning with Sparse LiDAR.", Conference on Robot Learning (CoRL), 2021.

Seminar and Presentation

- **B. Li**, "ISANA: Intelligent Situation Awareness and Navigation Aid", As-We-See-It visually-impaired group, *Greenville Baha'i Center*, 2020.
- **B. Li**, "Assistive Navigation for Disabled Travelers in the Transportation Chains", C^2M^2 Distinguished Speaker Series, 2020.
- **B. Li**, "Visual Computing for Assistive Navigation", *Intel*, 2021.
- **B. Li**, "Computer Vision and AI-Based Wayfinding for Blind or Visually Impaired Travelers", C^2M^2 Distinguished Speaker Series, 2021.

2.2 Future Output

Peer-Reviewed Journal Article

- J. Brooks, **B. Li**, C. Jenkins, L. Dylgjeri, Sarathkrishna, A. Ajayan, M. Ghodekar, S. Nikhal, A. Rana and Z. Yang. "Transportation Preferences, Challenges and Opportunities for Visually Impaired Users." *British Journal of Visual Impairment*, 2022.

Dissertation

- Amogh Venkataramana Reddy. Master Thesis on the topic of Assistive Mobility and Navigation Assistance for At-Risk Population, Advisor: Dr. Bing Li, Department of Automotive Engineering, status: ongoing, expected by Spring 2023.

2 Outcomes

The research has produced the following critical outcomes:

- Data of transportation preferences study on challenges and opportunities for visually impaired users.
- AI-models of visual-language navigation for visually impaired users.
- Technological frameworks of assistive mobility and navigation solutions.

3 Impacts

We hope this research will increase knowledge in the transport community and the general public about assisted mobility and navigation for the visually impaired, and we expect this research will have a very positive impact on the efficiency of building economic and wider technology solutions to assist at-risk populations.

- *Transportation agencies, enforcement agencies, and public officials*: Transportation agencies will have better knowledge about the assistive navigation needs for the visually impaired population. Americans with Disabilities Act (ADA) policy makers might possibly use these database results in developing new standards for assistive mobility and navigation technology configurations.
- *Transportation and technology professionals*: Understanding how visually impaired people currently get on and off vehicles may help engineers, new technology developers and providers create more processes and/or training to help increase transportation options for visually impaired people. The proposed framework and vision for intelligent wheelchair technologies can guide the future design of assistive mobility solutions for the transportation chains, especially for the transition between indoor and outdoor, and the first-or-last mile transportation needs.