Wheelshare: Smart Surface Classification for Accessible Routing through Built Environments

Ce Zhang, Junwei Li, Mingyuan Zhuang, Zheng Cao, Valeria Mokrenko, Md Osman Gani, Vaskar Raychoudhury

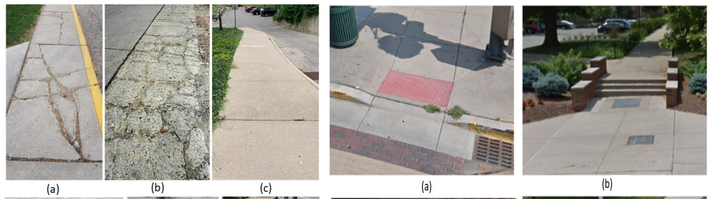
SMART Research Lab, Department of Computer Science and Software Engineering, Miami University, Ohio

Introduction

- Mobility assistance for differently-abled individuals is an important basic need.
- We proposed the first machine learning enabled accessible routing system which classifies surfaces based on their vibration patterns.
- The system generates multiple routes based on a personalized profile on the type of wheelchair and the information about the environment collected from crowdsourcing
- Data analysis and training of the model uses accelerometer and gyroscope data contributed from 22 participants using a manual wheelchair.

Motivation

- Travelling can be challenging for wheelchair users due to unknown obstacles.
- Not all routes to a destination are friendly to a user who relies on "barrier-free access".
- Emergency situations can impede an individuals ability to travel, even more so when accessibility is required.



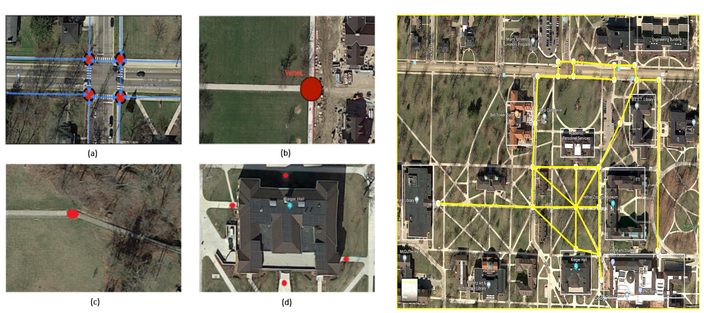
(a) Broken Sidewalk in Oxford, OH
(b) Narrow and Broken Side-road (for pedestrians) in Yu Yao, Zhejiang, China
(c) High Slope (9-12°) in Oxford, OH
(d) Uneven Sidewalk in Dresden, Germany
(e) Cobblestone Squares in Mannheim, Germany
(f) Curb without Access Ramp in Yu Yao, Zhejiang, China

Main objectives

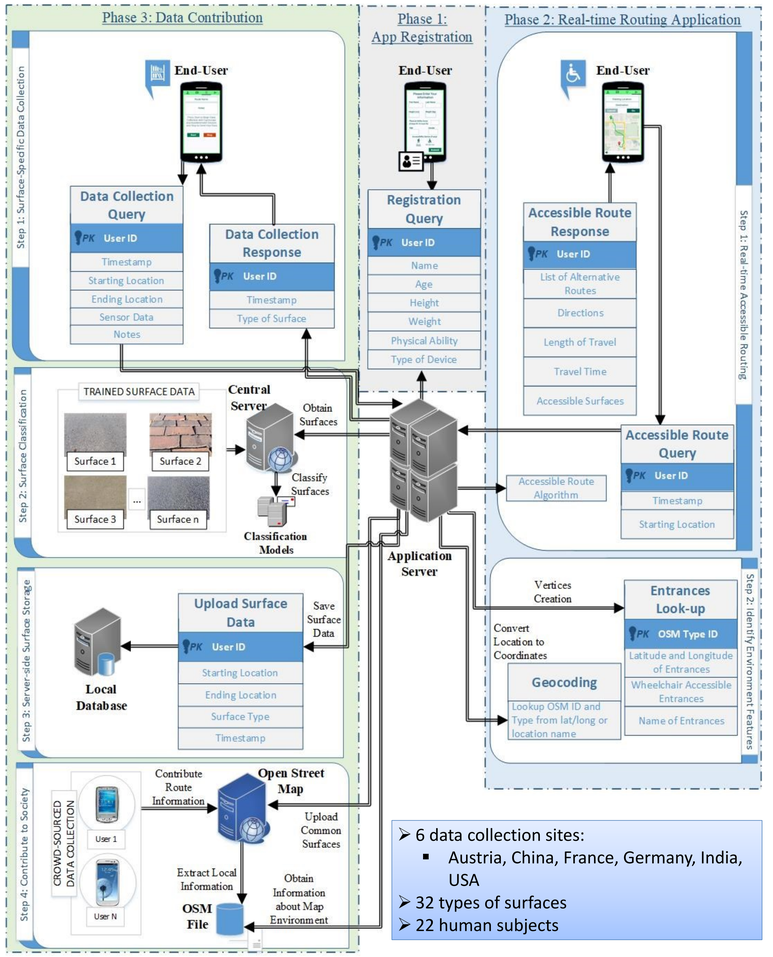
- Generate personalized, accessible routes that allow the user to easily traverse from one place to another.
- Identify multiple routes between two locations based on the built environment of the user
- Build user profile based on the type of wheelchair and preferences
- Use sensor data to identify surface accessibility with 100% accuracy
- Automate surface recognition to identify current surface at real-time.
- Contribute knowledge about the current environment to Open Street Map

Our Approach

- We first generate an overlay graph on the map of the environment.
- We set vertices on change in surface type (c), sidewalk junctions and T-intersections (a, b) and if starting from a building, locations of entrances (d)
- Separate scores are assigned depending on type and nature (broken or uneven) of surfaces, steepness of slopes, presence of stairs, height of curbs and presence of crosswalks (with and without pedestrian crossing signals)



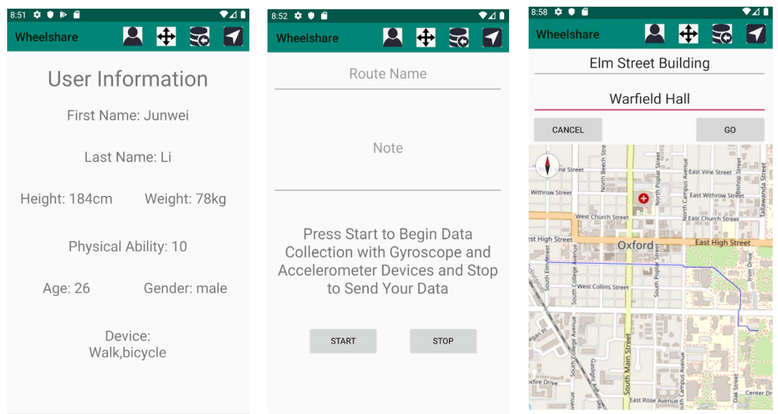
Methodology



- 6 data collection sites:
  - Austria, China, France, Germany, India, USA
- 32 types of surfaces
- 22 human subjects

App User Interface

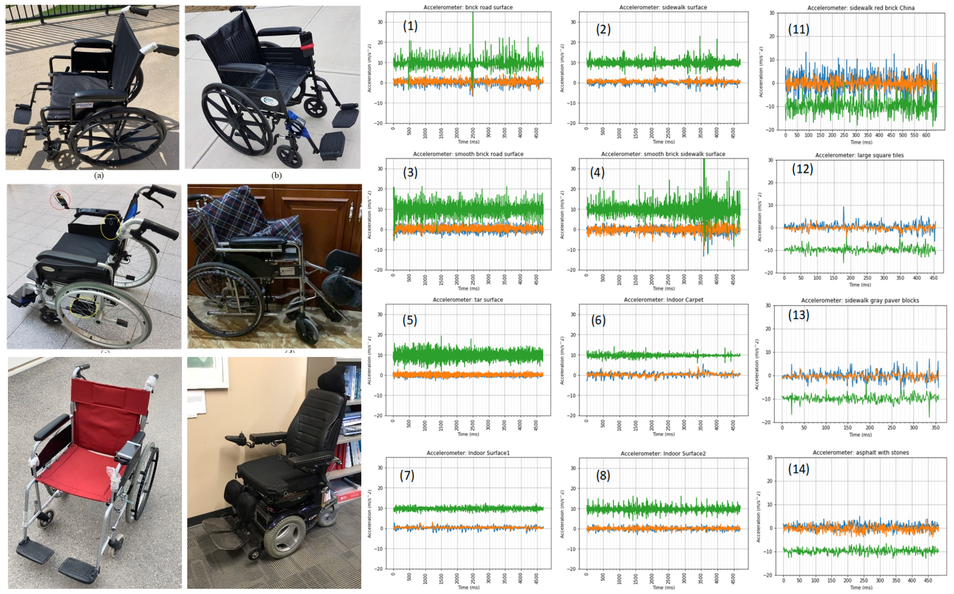
- Collect data for open street map.
- Provide safe routes for wheelchair user.
- Personalized accessible routing.



Data

Surfaces Considered in USA: (a) High St. Rough Brick, (b) High St. Brick, (c) High St. Sidewalk, (d) High St. Smooth Brick 1 (with rough edges), (e) High St. Smooth Brick 2, (f) Chestnut St. Parking Asphalt, (g) Chestnut Jogging Track Soft Asphalt-like Surface, (h) Benton ***Indoor*** Carpet, (i) Benton ***Indoor*** Mat Surface (indoor surface 1), (j) Benton ***Indoor*** Tiles (indoor surface 2), (k)-(o) Various Curbs
Surfaces Considered in Europe: (p) Very Smooth ***Indoor*** (tiled) Floor, (q) Smooth Asphalt, (r) Rough Tiled Sidewalk, (s) Trimmed (2 inch) Grassland, (t) Very Rough Irregular Cobble Stones Outdoor (with large and deep gaps), (u) Rough Irregular Cobble Stones (Bike Paths), (v) Smooth Tiled Sidewalk, (w) Rough Regular (square) Granite Cobble Stones [small but deep gaps in between], (x) Very Smooth Grey Stone Tiled Sidewalk, (y) Rough Regular (Rectangular) Granite Cobble Stones [with small and shallow gaps], (z) Deep (2-3 inch) Gravel (8-20 mm)
Surfaces Considered in China: (aa) Brick Sidewalk Blocks, (ab) Smooth Paver Blocks (with gaps in between), (ac) Large Smooth Square Tiled, (ad) Rough Concrete with Embedded Stones, (ae) Striped Concrete Texture
Surfaces Considered in India: Very smooth ***Indoor*** mosaic floor

Experiment



Conclusion

- We developed the first-ever sensor-based surface classification approach using machine learning.
- We developed an accessible path routing for wheelchair users.
- Our approach is scalable and personalized.
- We will be able to dynamically re-route users where needed.
- Large scale data collection about surfaces is planned using crowd-sourcing. Collected data will be contributed to the research community using Open Street Map project.

Acknowledgements

This work is partially supported by the UG Summer Scholarship and the Faculty Research Grant from Miami University, OH, USA.

Publication

Md Osman Gani, Vaskar Raychoudhury, Janick Edinger, Valeria Mokrenko, Zheng Cao, Ce Zhang, "Smart Surface Classification for Accessible Routing through Built Environment - A Crowd-sourced Approach," Accepted for publication in the 6th ACM International Conference on Systems for Energy-Efficient Built Environments, Cities, and Transportation (BuildSys'19), Nov. 13-14, 2019, Columbia University, NY, USA. [CORE Rank: A]