Automated Identification of Wheelchair Accessible Outdoor Pathways

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Introduction

Motivation

- Wheelchair users and other mobility-impaired individuals often face barriers when navigating outdoors (Beale et al. 2006)
- Many maps and wayfinding applications do not provide sufficiently **useful** or **reliable** accessibility information (Prescott 2016)

Case Study: Carnegie Mellon University

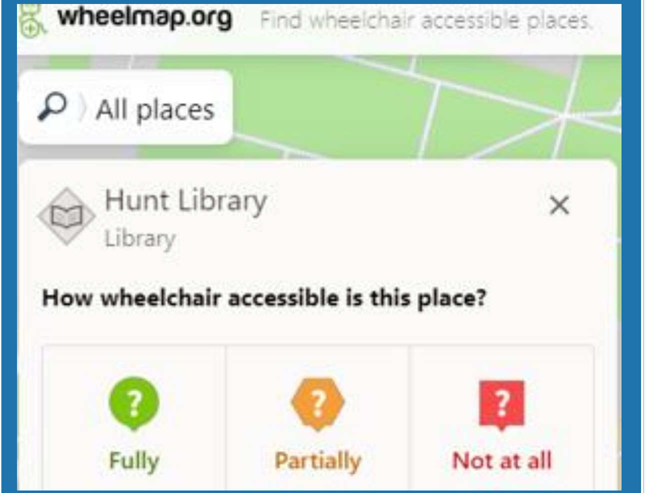
- Current campus maps do not include information about wheelchair accessible paths, building entrances, or parking
- The campus wheelchair accessibility map was **last updated in 2013** (according to CMU's Office of Marketing and Communication)

1. https://wheelmap.org/
2. https://www.accessable.co.uk/
3. https://www.accessmap.io/
4. https://www.mapillary.com/

Related Work

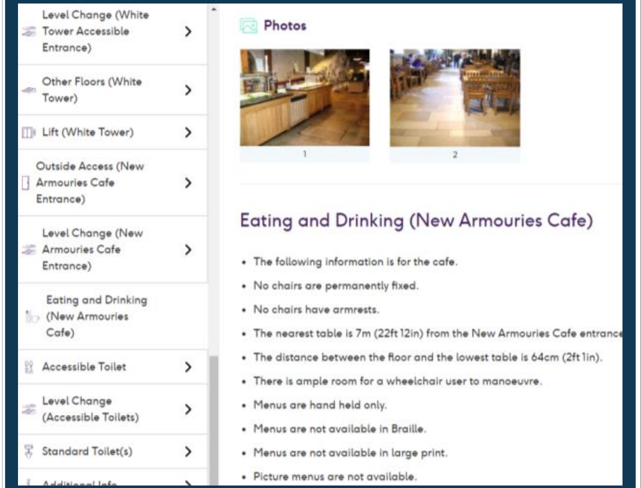
Wheelmap[1]

- Wheelchair accessibility labels (i.e., fully, partially, or not accessible)
- Crowdsourced data
- 98.4% of locations in the UK were marked as "unknown" 3 years after launch (Ding 2017)
- Available worldwide



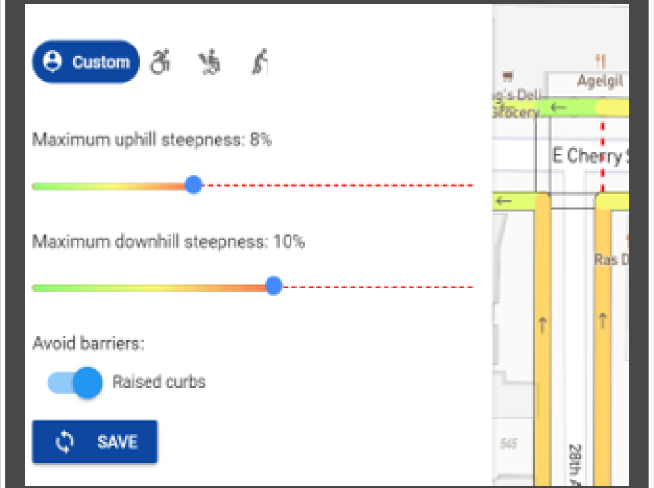
AccessAble[2]

- Accessibility information for various needs
- Provides detailed access guides with images
- Uses 33 accessibility symbols
- Data collected by surveyors
- UK and Ireland only



Access Map[3]

- Customized routing (e.g., set maximum uphill/downhill steepness)
- Data from city Department of Transportation
- Not easily translatable to other cities (Caspi 2017)
- Seattle area only



Mapillary[4]

- Uses computer vision to recognize over 40 object types (e.g., crosswalk, traffic signs)
- Crowdsourced street-level images as input data
- No navigation

Objectives

Use a combination of existing methods in aerial photogrammetry, artificial intelligence, and geographic information system (GIS) analysis to automate the identification of wheelchair accessible outdoor paths.

Target problems:

- **Scalability**: collect complete data in a repeatable and time efficient manner
- **Usefulness**: provide specific information about location and type of barrier
- **Reliability**: provide accurate information that can be updated easily when changes occur

Scope:

Classify **outdoor** paths as wheelchair accessible using 2010 Americans with Disabilities Act (ADA) standards for **ramp slopes** (Section 405.2) and **walking surface widths** (Section 403.5.1).

Identification of Road Surfaces and Slopes

Data Collection and Processing:

- **Capture aerial images** using a small unmanned aircraft system
- **Process aerial images** using Pix4DMapper software to obtain digital terrain model and orthomosaic
- **Identify road surfaces** using a trained Gradient Boosted Trees model (Becker et al. 2018)
- **Classify road surface slopes** as flat (incline less than 5%), ADA accessible ramps (incline between 5% and 8.33%), or inaccessible (incline greater than 8.33%) using the digital terrain model

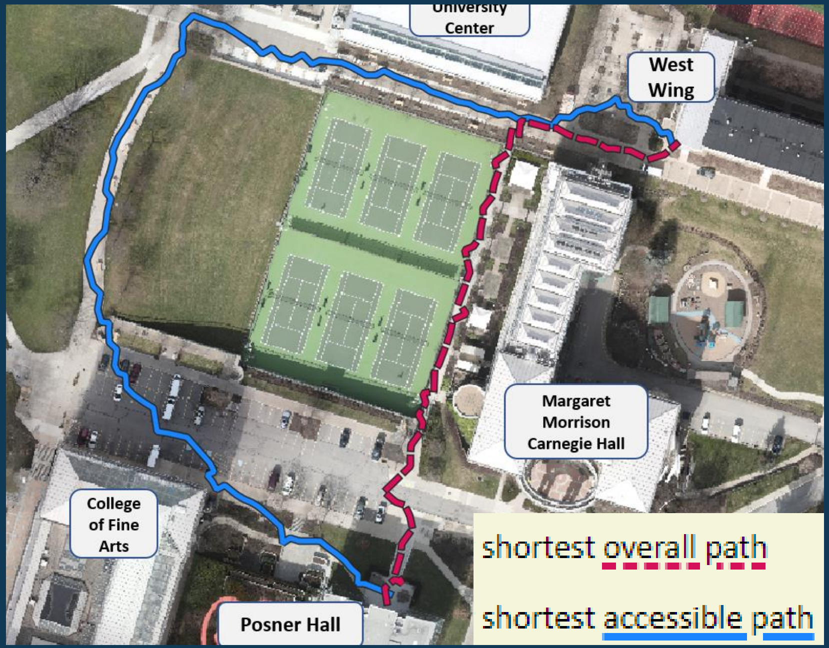
Wheelchair Accessible Navigation

Use the path detection and slope data to identify the shortest wheelchair accessible path between buildings:

- **Manually label building entrances** (locations and accessibility)
- **Incorporate path width standards** by calculating the maximum slope in each 36in x 36in region
- **Convert path raster to a network graph**
- **Implement Dijkstra's algorithm** to find the shortest wheelchair accessible path between buildings

A portion of the shortest overall path and shortest wheelchair accessible path between two buildings (as identified by this algorithm).

The accessible path navigates to a ramp to avoid multiple sets of stairs.



The shortest overall path and shortest wheelchair accessible path between West Wing and Posner Hall (as identified by this algorithm).

The current algorithm does not consider the location of curb cuts when crossing the parking lot.

Results

Case Study: Carnegie Mellon University

This approach was applied to a case study of 62 acres of Carnegie Mellon University's campus in Pittsburgh, PA.

A user interface* was developed to provide accessible navigation information for wheelchair users in the Carnegie Mellon community and allow CMU administration to identify areas which could be changed to improve wheelchair accessibility on campus.

* https://amylopata.github.io/

This approach identified wheelchair accessible outdoor paths for **254 of the 300** building pairs considered in this case study.

On average, the shortest wheelchair accessible path between two buildings was **1.5 times longer** (in distance) than the shortest overall path between those same buildings.

The bike ramps along the Mall (between Doherty Hall and Baker/Porter Hall) are too steep to be wheelchair accessible. Without these barriers, there would be wheelchair accessible outdoor paths for an **additional 22 building pairs** and the **average distance disparity would be reduced**.

Evaluation of Approach

Data Completeness

- In the case study of CMU's campus, the Gradient Boosted Trees model identified 89% of the outdoor pathways
- Of the 11% of paths that were manually identified, 32% were under building overhangs

Time Efficiency

- Data collection for 62 acres of CMU's campus required approximately 30 minutes of aerial video
- Total computer processing time was approximately 5 hours

Accuracy

A field test of 15 random building pairs identified only 2 barriers which were not identified by the algorithm:

- A fence around a construction zone (most likely because the fence was thin and similar in color to the sidewalk)
- Location of curb cuts when crossing parking lot (out of scope for this project)

Limitations

- GBT road surface classification model cannot distinguish between sidewalks and roads
- Requires manual identification of building entrances and pathways under building overhangs
- May be less accurate in areas with more trees

Future Work

Recommendations for future work include:

- **Replicate results** in other outdoor spaces (e.g., public parks, university campuses, outdoor shopping centers)
- Incorporate **crowd-sourced validation** of road surface identification and accessibility classification
- Consider **additional ADA standards**
- Include wheelchair accessible **indoor navigation** routes

Questions?

References

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