Project Sidewalk: Mapping the Accessibility of the Physical World **at Scale** using Interactive Computational Tools

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Google Tech Talk

Jan 22, 2020

MAKEABILITY LAB

DESIGN USE BUILD

PAUL G. ALLEN SCHOOL OF COMPUTER SCIENCE & ENGINEERING

UNIVERSITY of WASHINGTON

UNIVERSITY OF MARYLAND 1856

30.6

million U.S. adults have a mobility impairment

Source: US Census, 2010


15.2
million use an assistive aid
Source: US Census, 2010


144 Spring St
New York
Google
Street View
CHANEL
CHANEL
CHANEL
CHANEL
WOOSTER ST
ONE WAY
CHANEL
DIESEL
Spring St
Broadway-Lafayette
Station B, D, F, M
Tap
Prince St
SOHO
Google


144 Spring St
New York
Google
Street View
NO CURB RAMPS
WOOSTER ST
ONE WAY
CHANEL
DIESEL
Spring St
Broadway-Lafayette Station B, D, F, M
Prince St
Tap
SOHO
Google


PHYSICAL OBSTACLES


SURFACE PROBLEMS


INCOMPLETE SIDEWALKS
FedEx
Marckres
Norder &

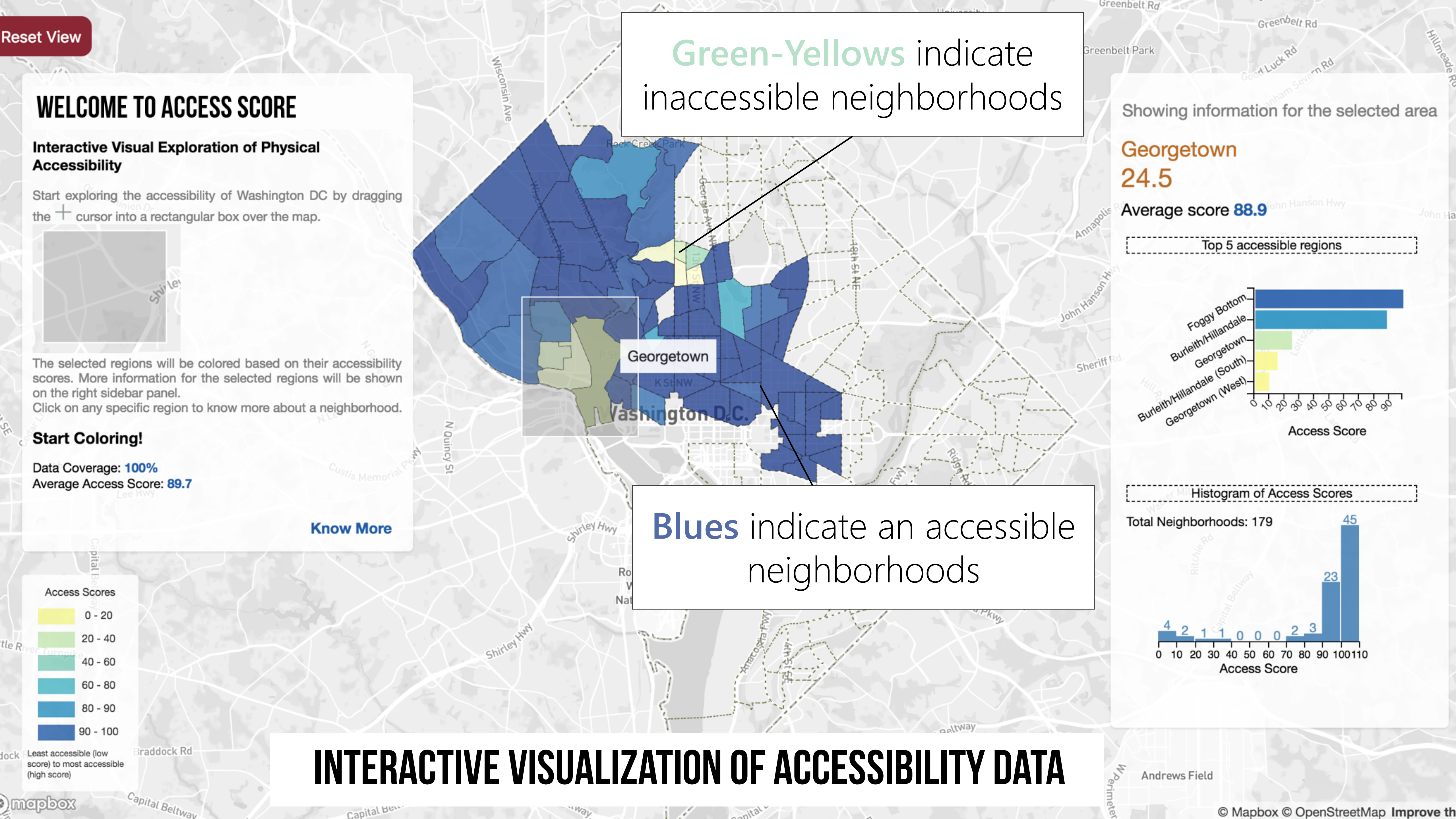

PHYSICAL OBSTACLES
NO CURB RAMP
SURFACE DEGRADATION


Accessible infrastructure has a significant impact on the independence and mobility of citizens
[Thapar *et al.*, 2004 ; Nuernberger, 2008]

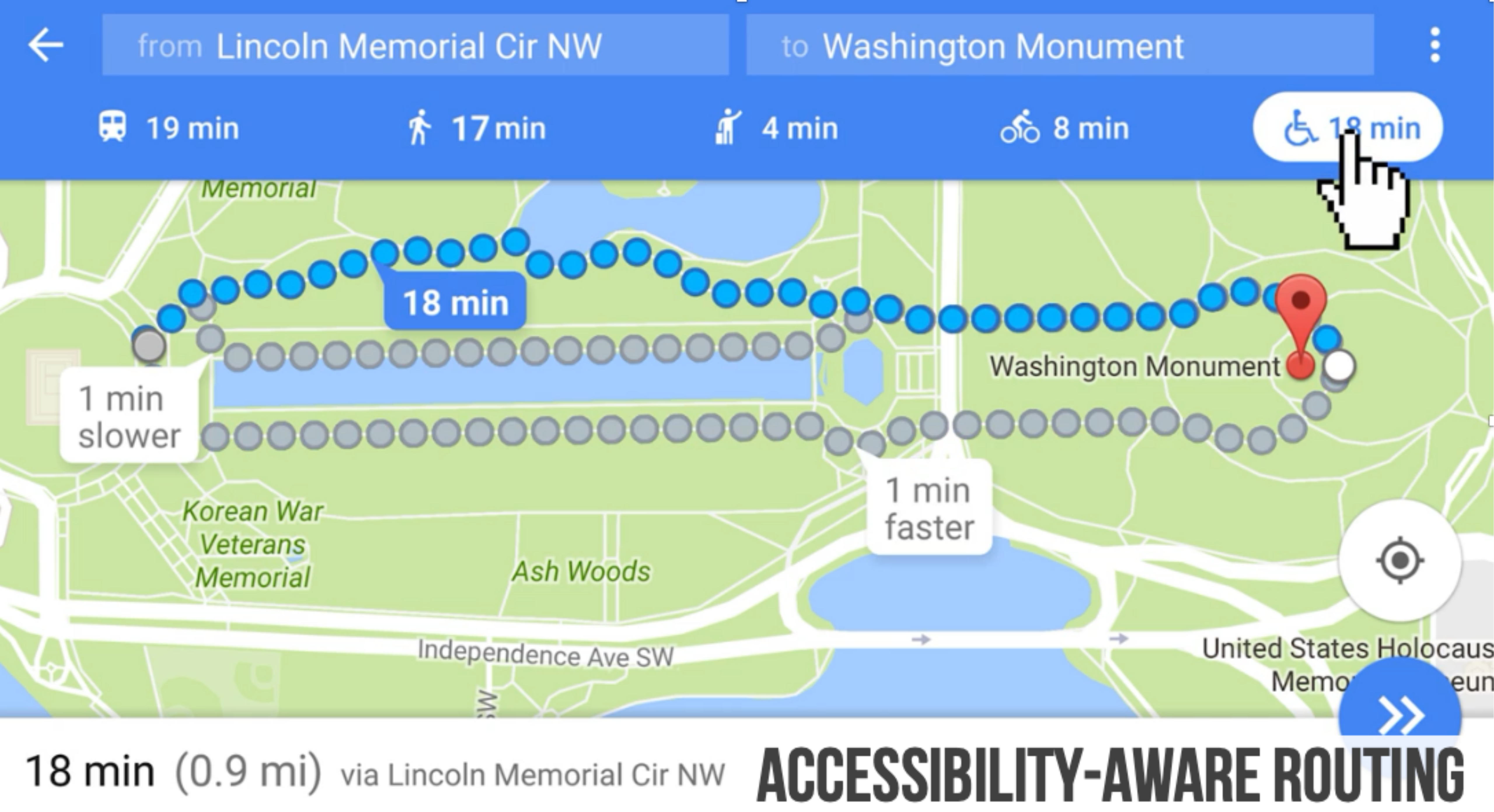
The National Council on Disability noted that there is **no comprehensive information** on "the degree to which sidewalks are accessible" in cities.

National Council on Disability, 2007
The impact of the Americans with Disabilities Act: Assessing the progress toward achieving the goals of the ADA


OUR VISION
Design systems that transform the way urban accessibility information is **collected** and **utilized**.

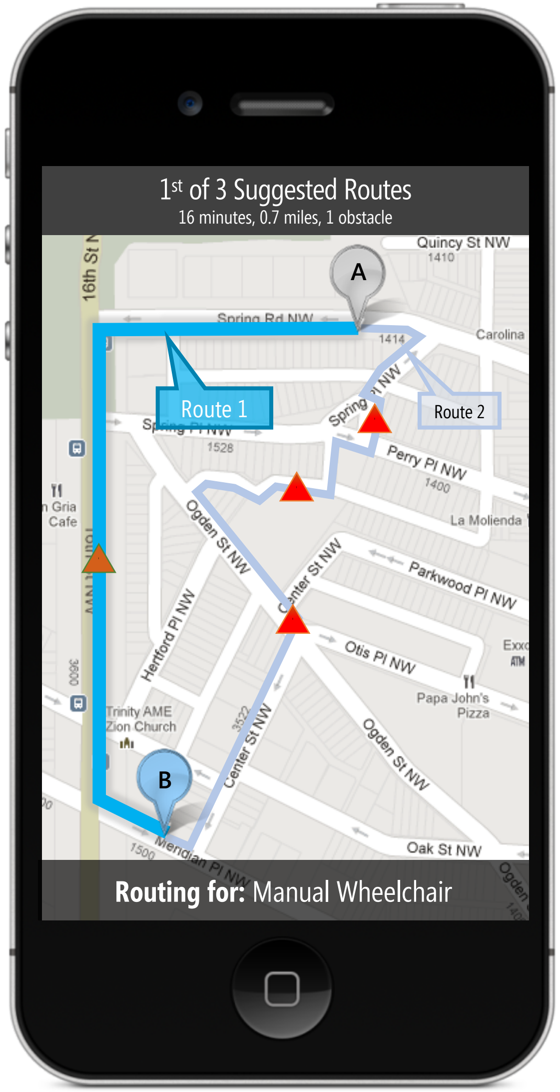


INTERACTIVE VISUALIZATION OF ACCESSIBILITY DATA



ACCESSIBILITY-AWARE ROUTING

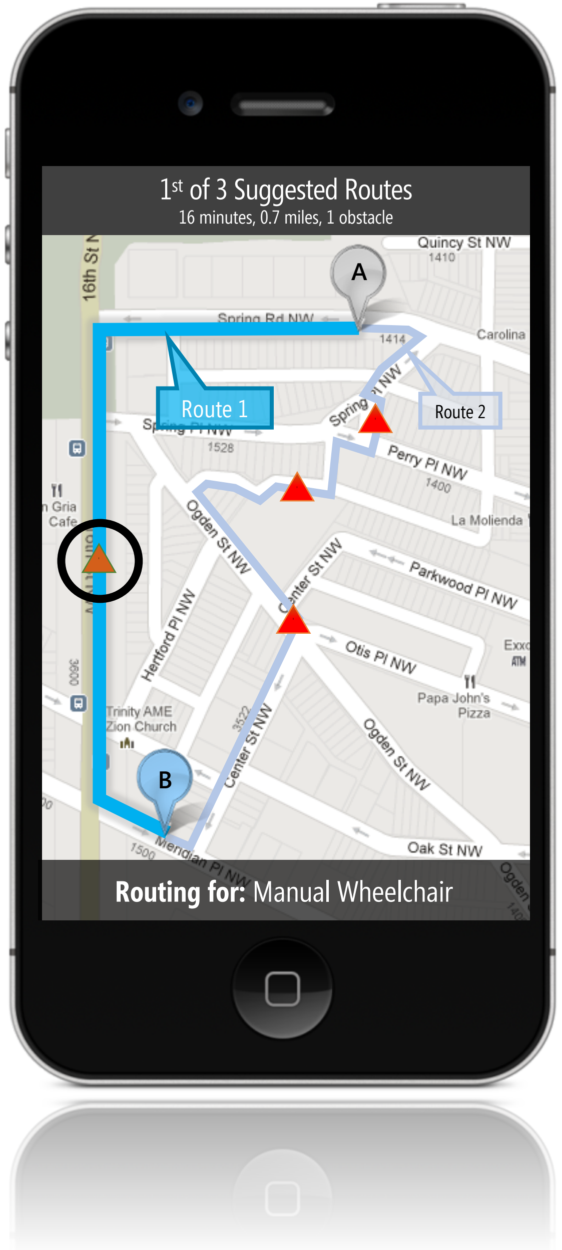
ACCESSIBILITY-AWARE ROUTING



Showing alternate routes tailored to a person

MOTIVATION

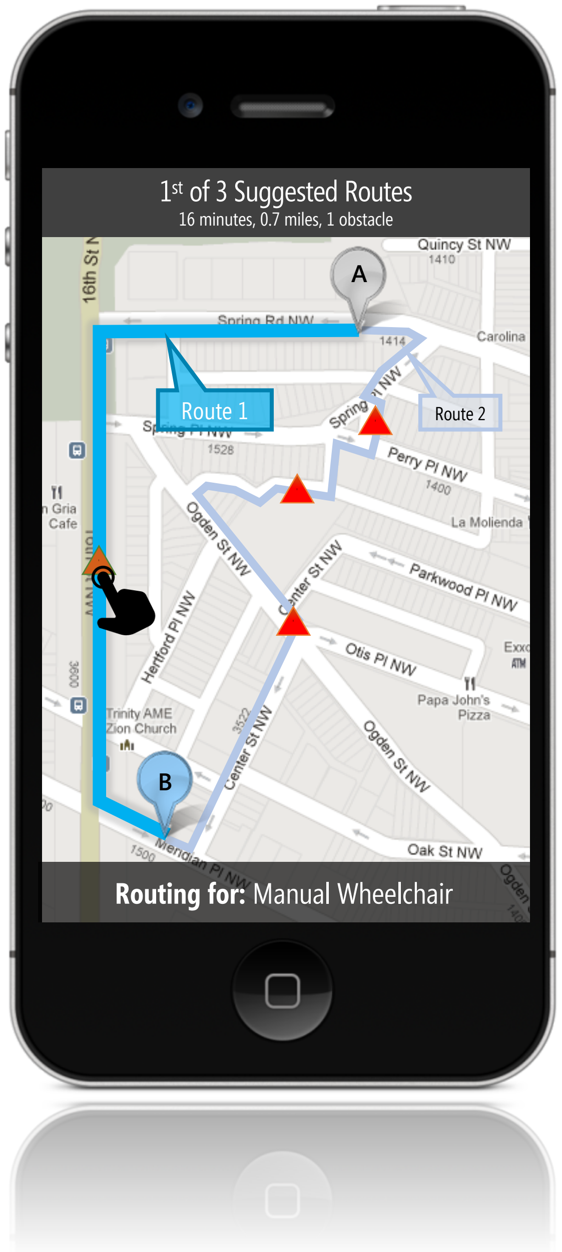
ACCESSIBILITY-AWARE ROUTING



Investigating mobility barriers along the route

MOTIVATION

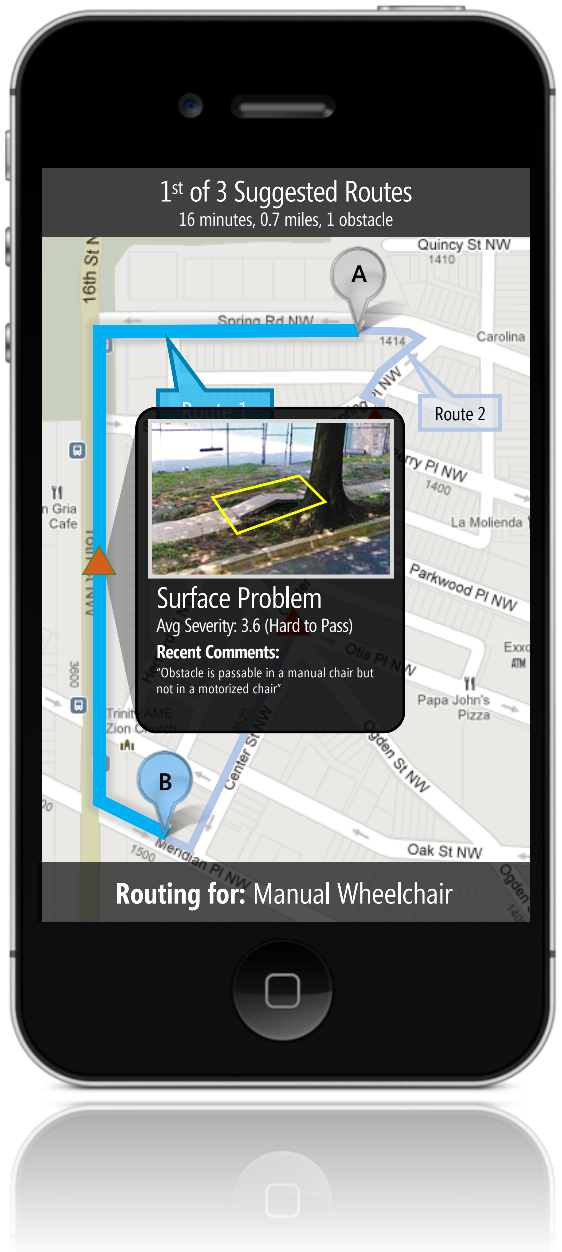
ACCESSIBILITY-AWARE ROUTING



Investigating mobility barriers along the route

MOTIVATION

ACCESSIBILITY-AWARE ROUTING



Investigating mobility barriers along the route

THESE APPLICATIONS HAVE

HUGE DATA

REQUIREMENTS

THESE APPLICATIONS HAVE

HUGE DATA

REQUIREMENTS

How do we get this data?

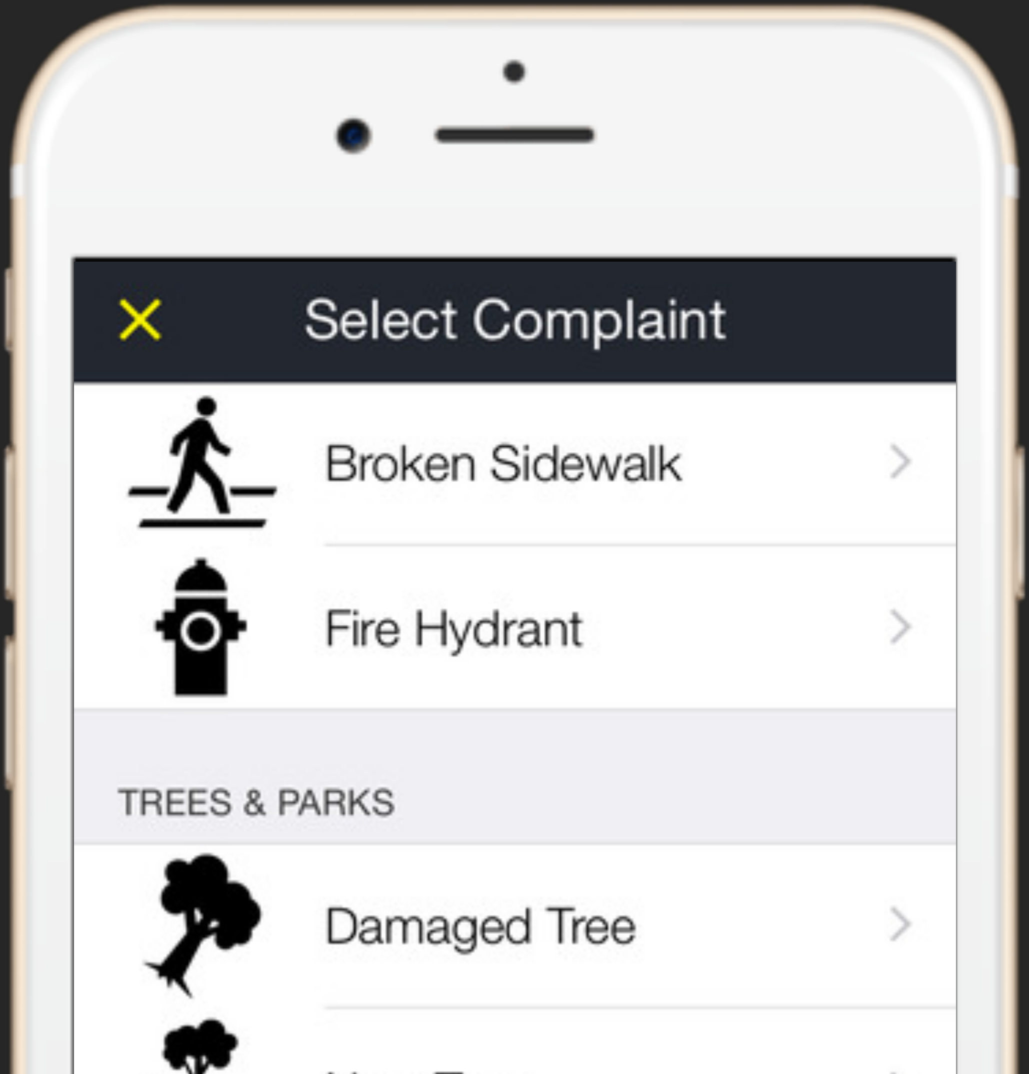
Traditional Physical Audits

Walkability Audit
Wake County, North Carolina

Walkability Audit
Wake County, North Carolina

Safe Routes to School Walkability Audit
Rock Hill, South Carolina

Mobile Reporting Solutions



http://www1.nyc.gov/311/index.page

MOTIVATION

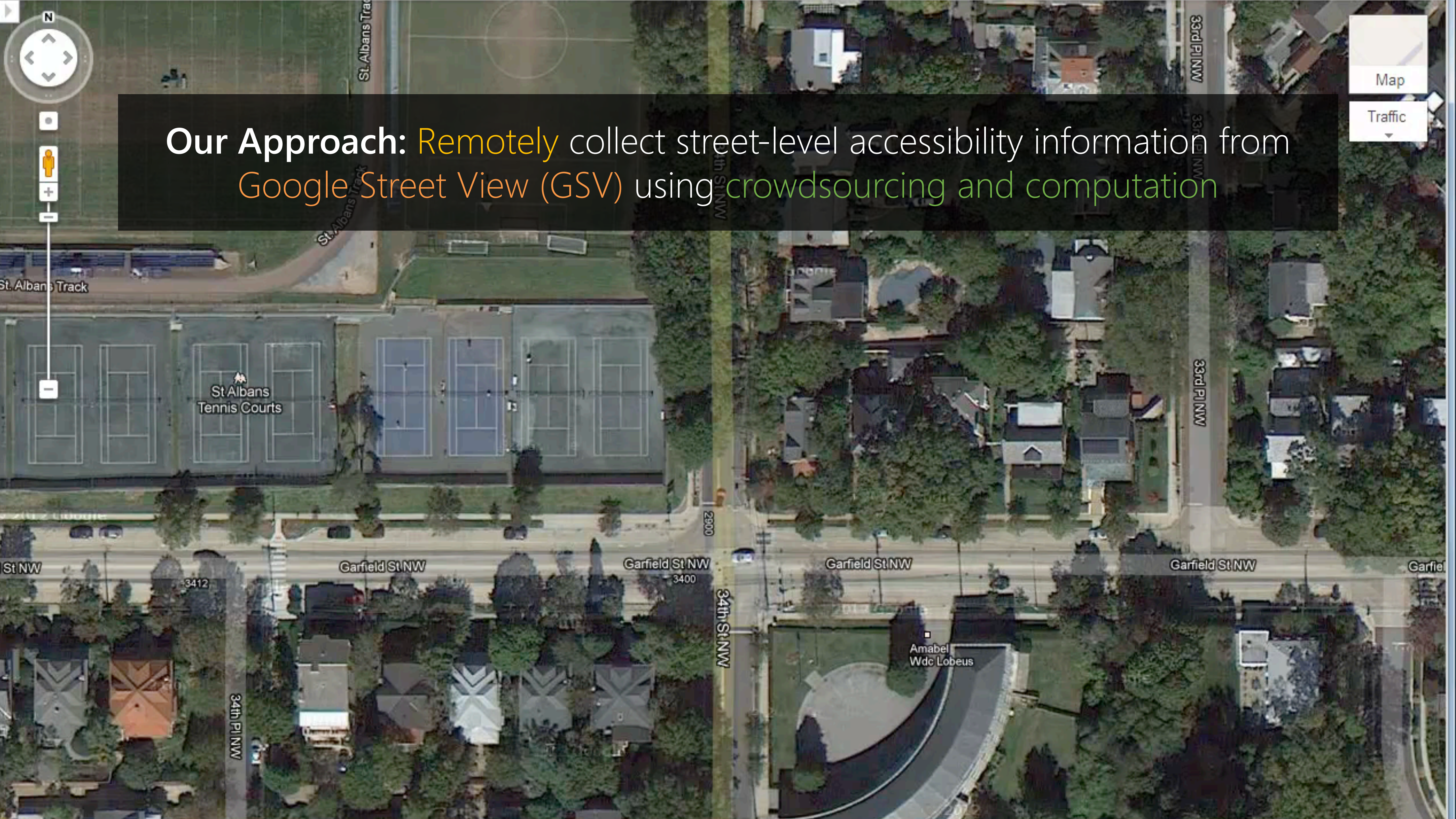
CHALLENGES OF TRADITIONAL DATA COLLECTION APPROACHES?

Slow, Manual, and Laborious

Huge Cost

Localized

Our Approach: Remotely collect street-level accessibility information from Google Street View (GSV) using crowdsourcing and computation



TALK OUTLINE

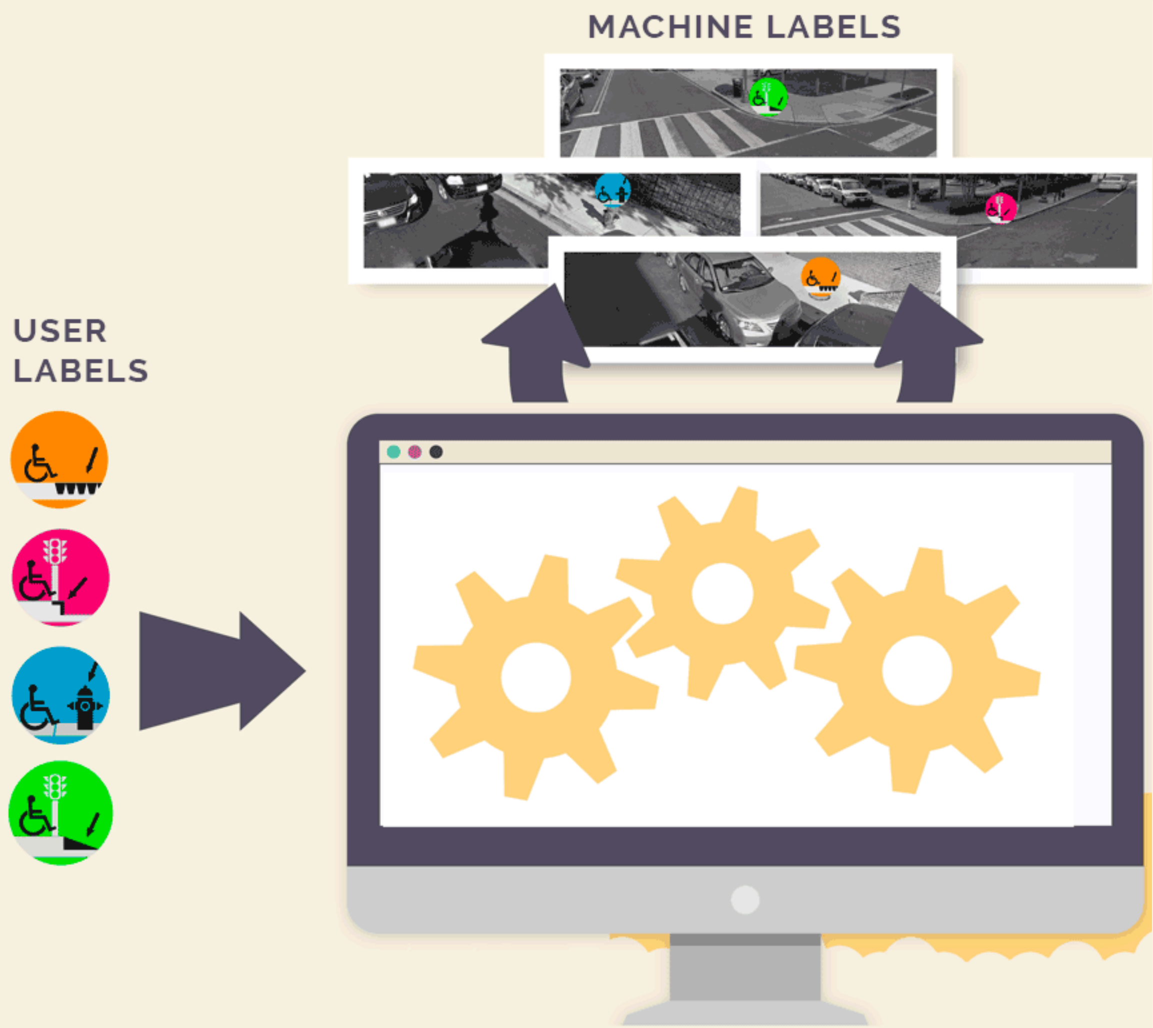
TALK OUTLINE

USER LABELS

DATA

Crowdsourced
Data Collection

TALK OUTLINE



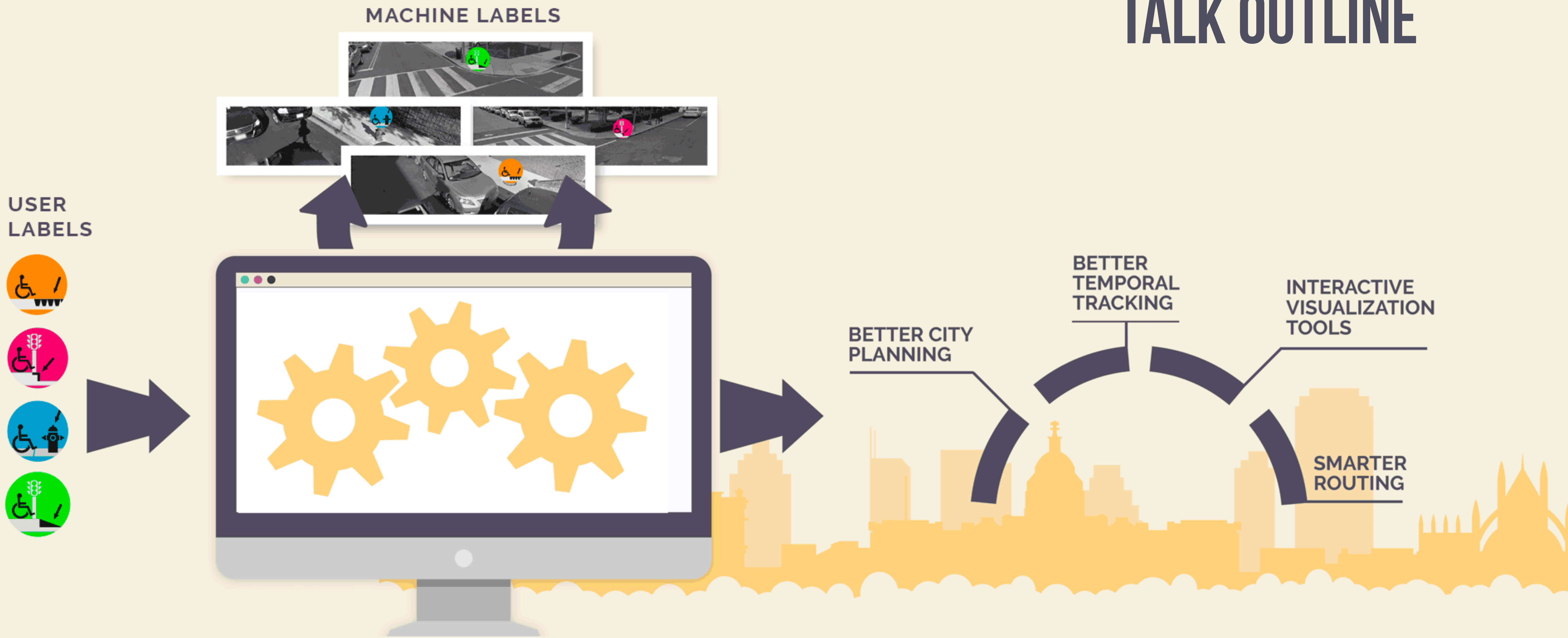
DATA

Crowdsourced Data Collection

COMPUTER VISION + MACHINE LEARNING

(Semi) Automatic Data Collection

TALK OUTLINE



DATA
Crowdsourced Data Collection

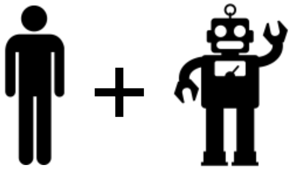
COMPUTER VISION + MACHINE LEARNING
(Semi) Automatic Data Collection

INTERACTIVE APPLICATIONS
Accessibility-ware Application Design

THIS TALK WILL BE…

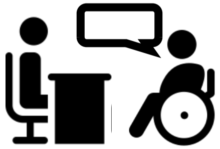
Crowdsourced
Data Collection

50%



(semi) Automated
Data Collection

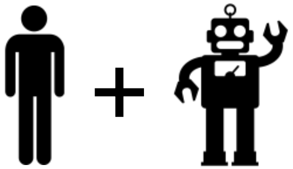
20%



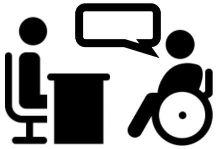
Accessibility-aware
Application Design

30%

Crowdsourced
Data Collection



(semi) Automated
Data Collection



Accessibility-aware
Application Design

Crowdsourced
Data Collection

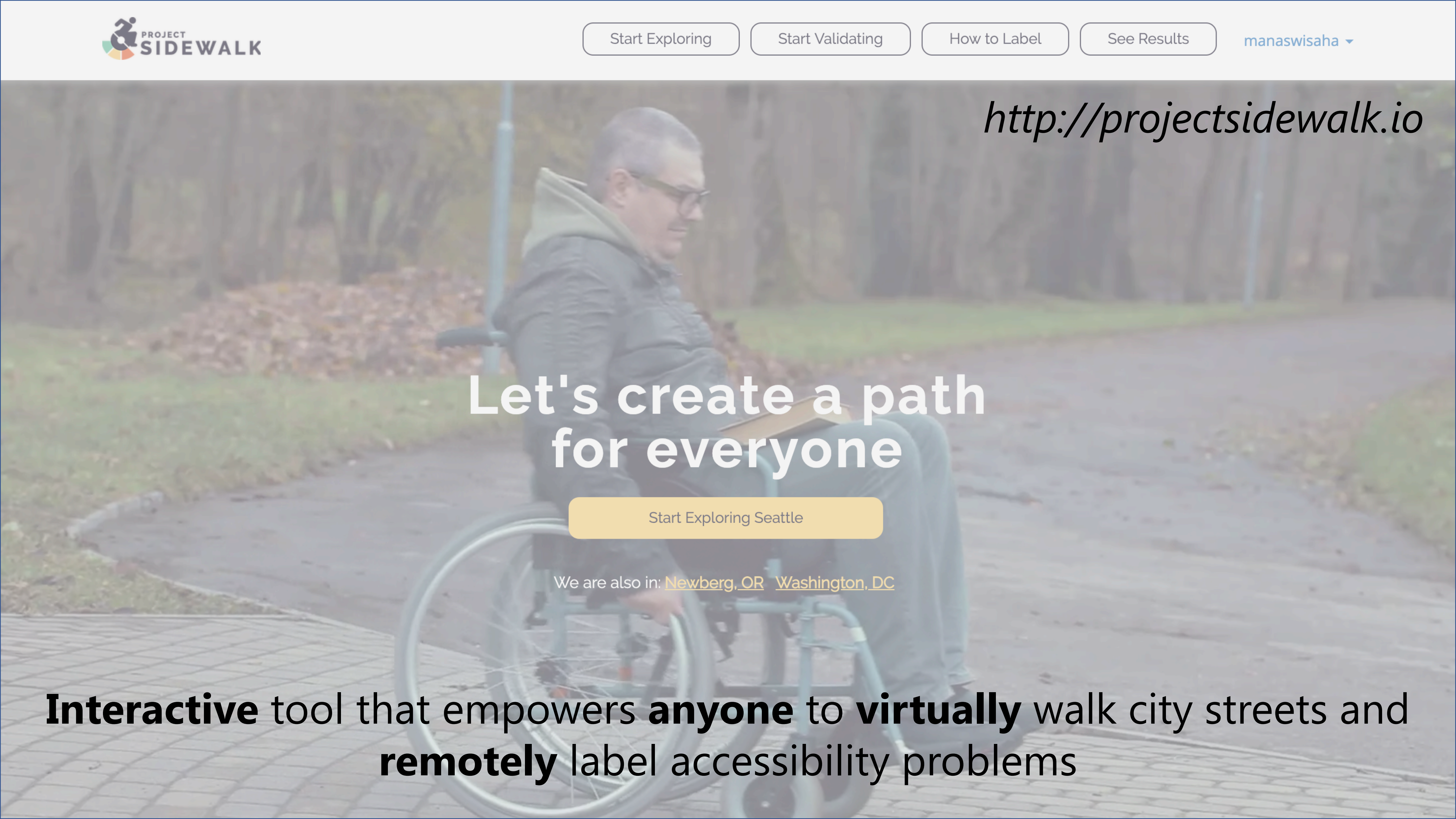
(semi) Automated
Data Collection

Accessibility-aware
Application Design

1. How can we design a crowdsourcing system to collect street-level accessibility data from Google Street View?
2. How to quickly train crowd workers to accurately label accessibility features in Google Street View imagery?

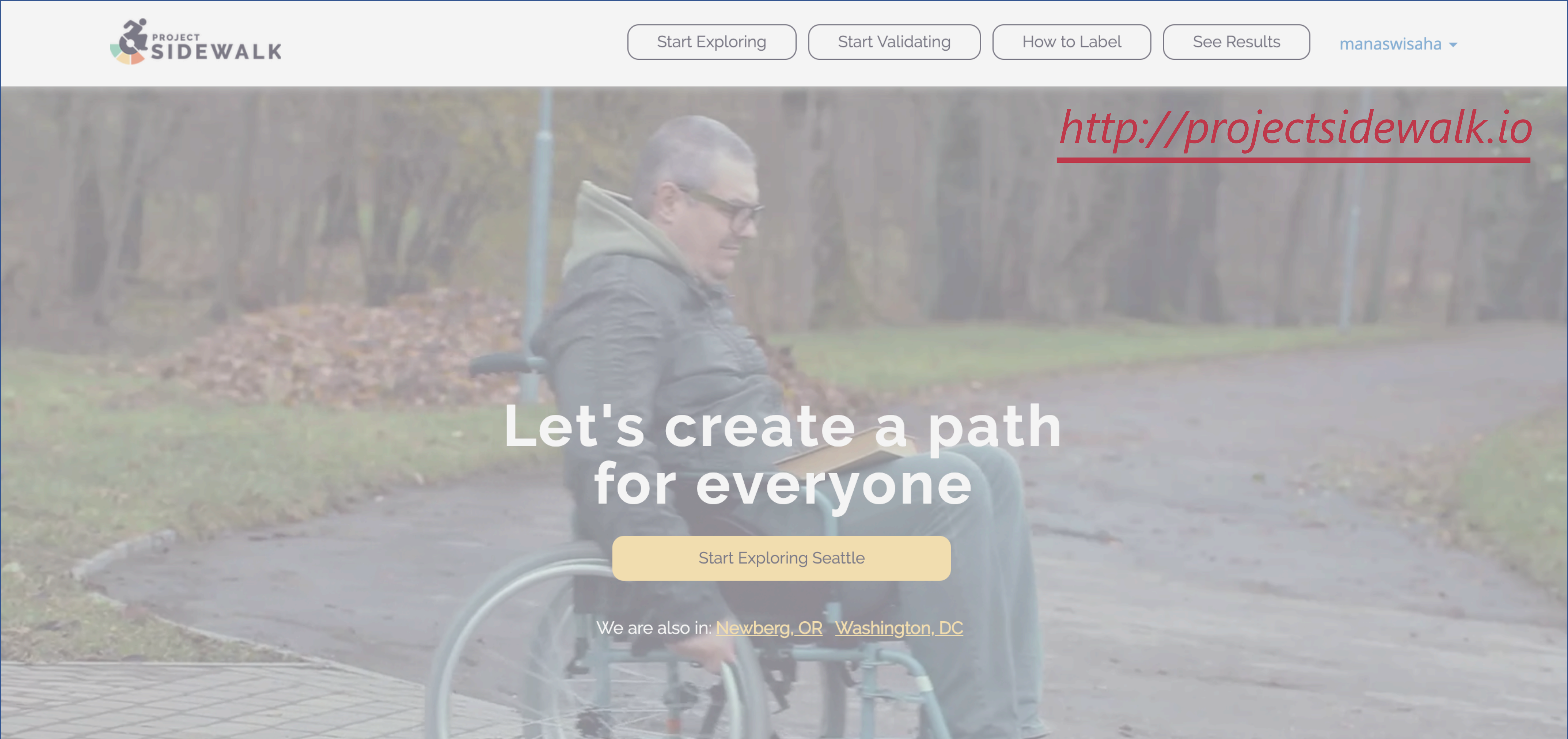
PROJECT SIDEWALK

HTTP://PROJECTSIDEWALK.IO



http://projectsidewalk.io

Interactive tool that empowers **anyone** to **virtually** walk city streets and **remotely** label accessibility problems



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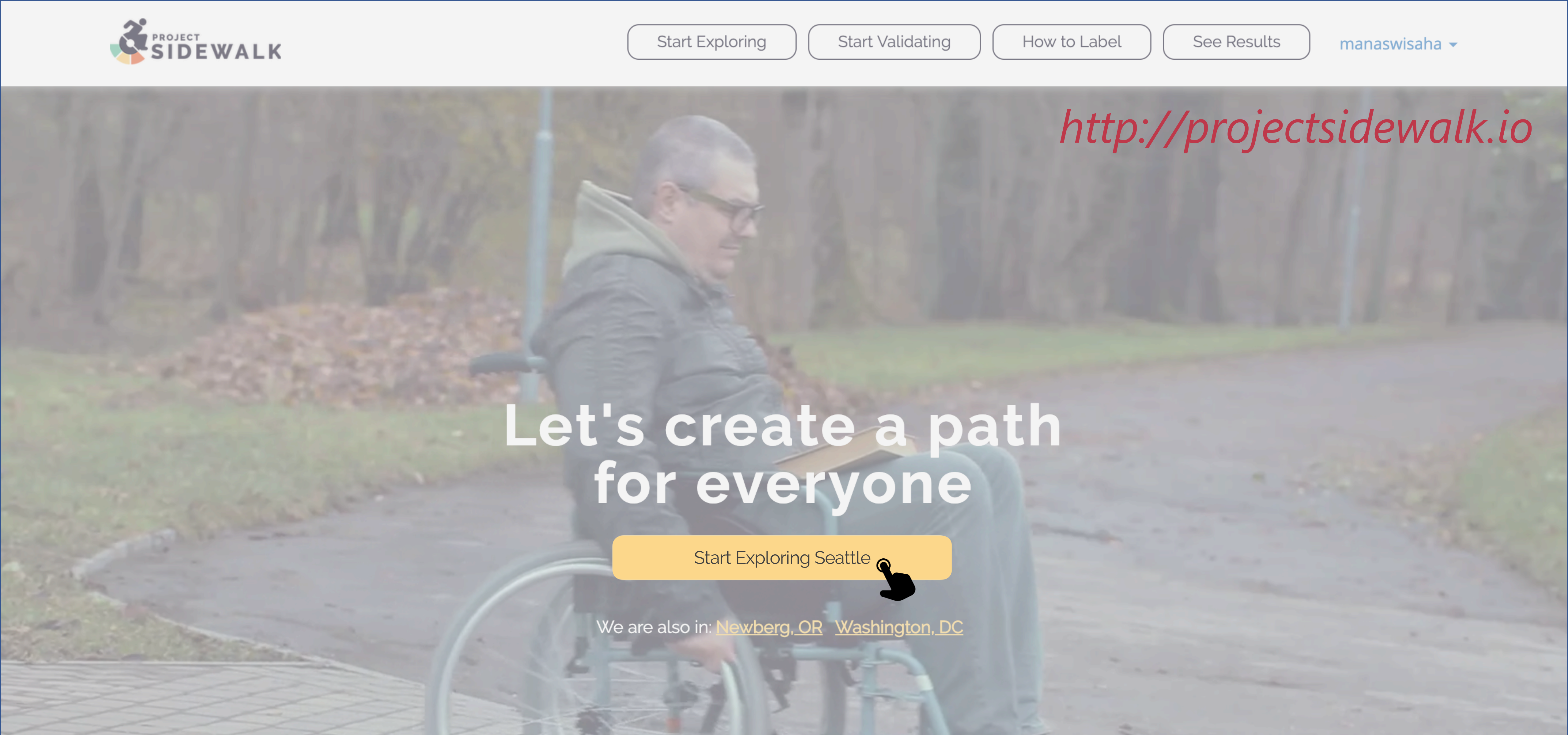
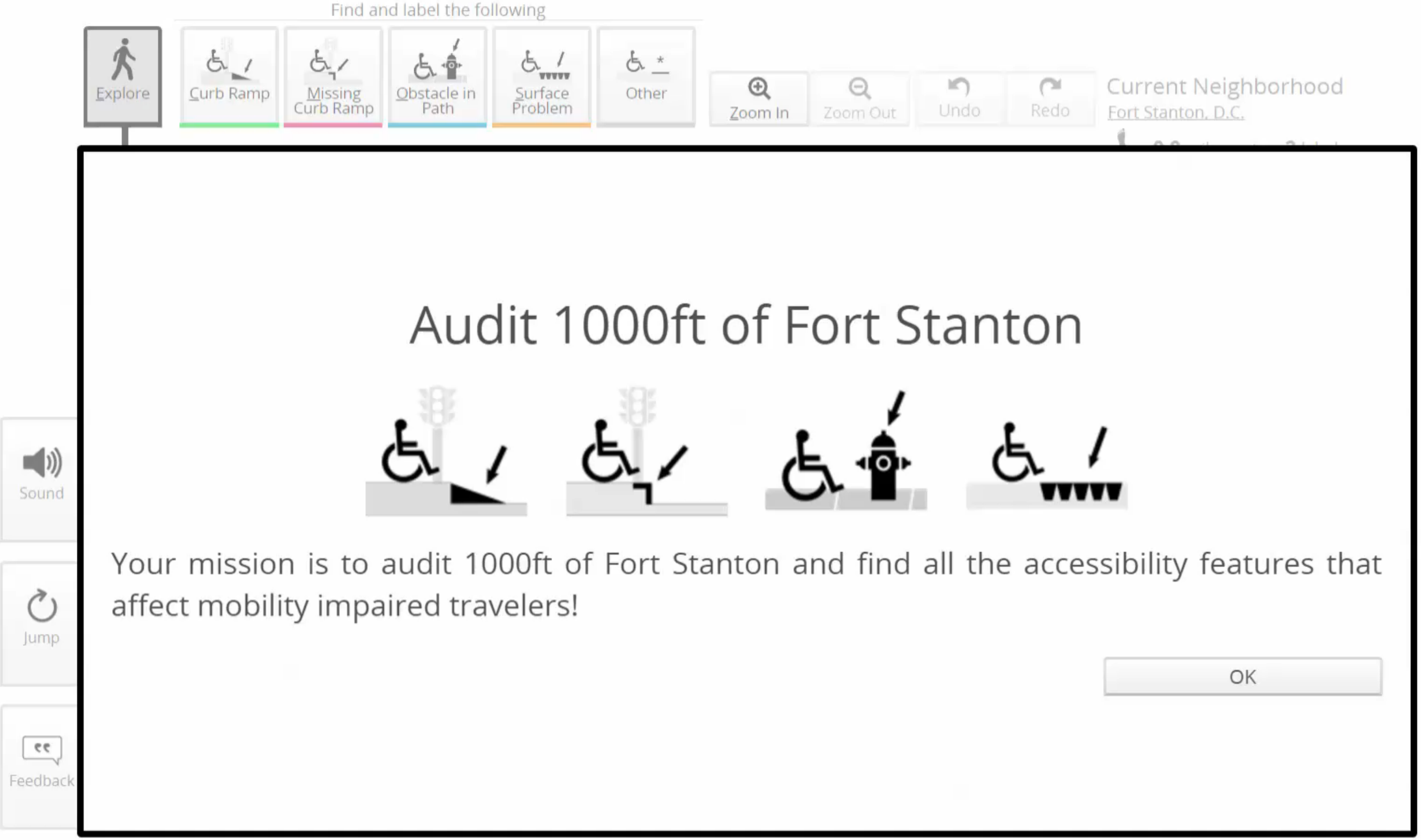
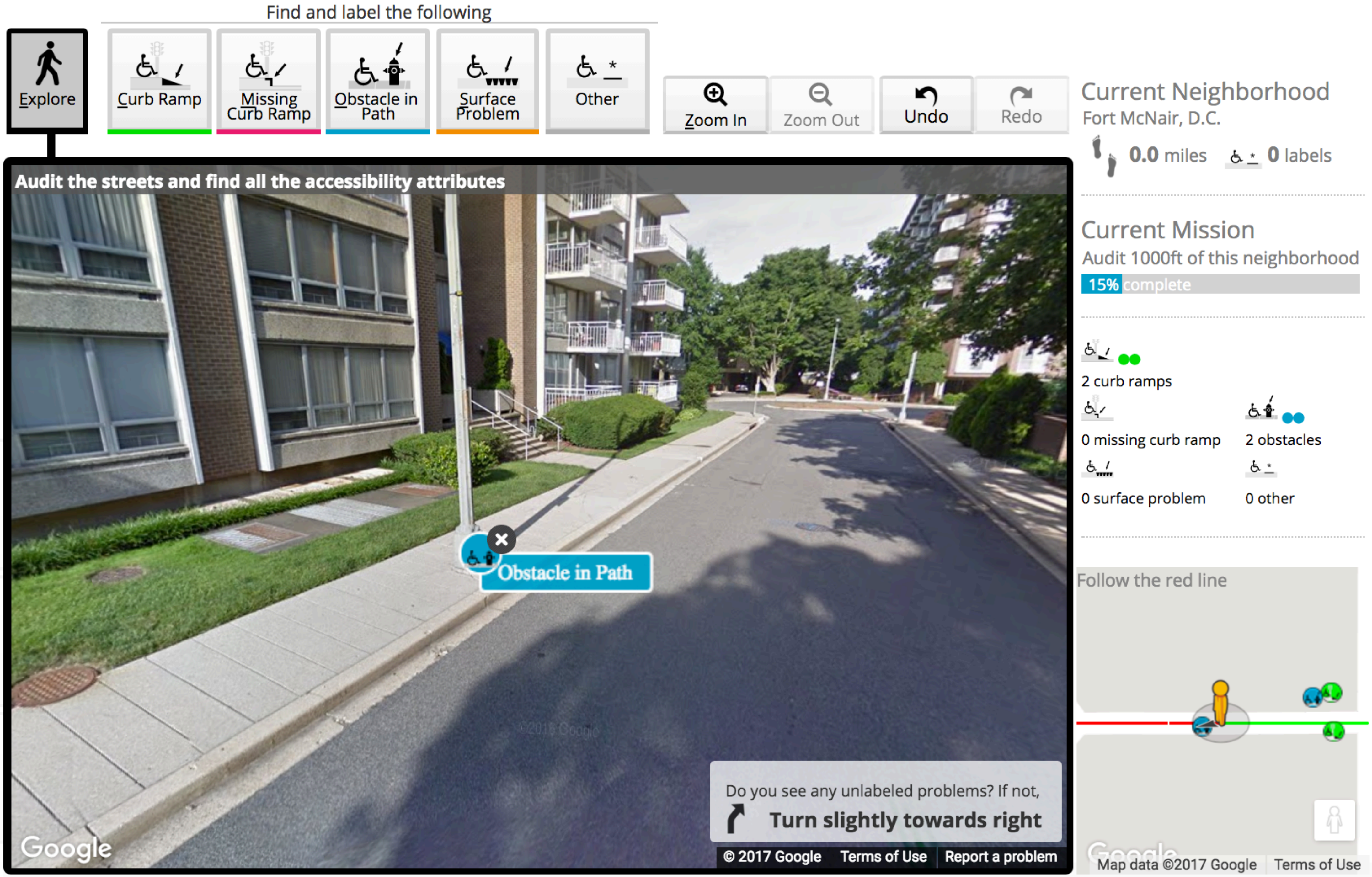


Interactive tool that empowers **anyone** to **virtually** walk city streets and **remotely** label accessibility problems

TOOL WALKTHROUGH



TOOL WALKTHROUGH



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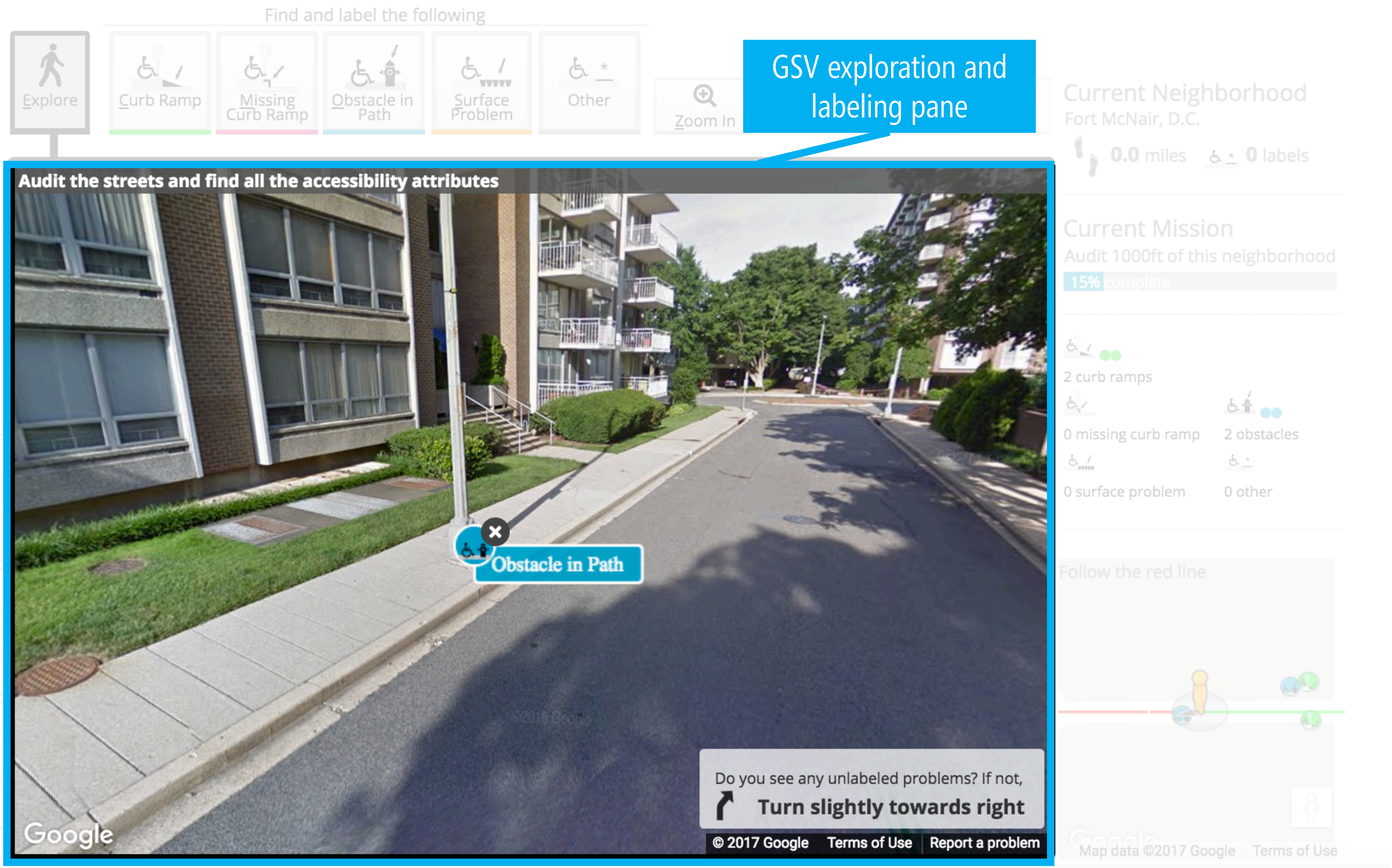

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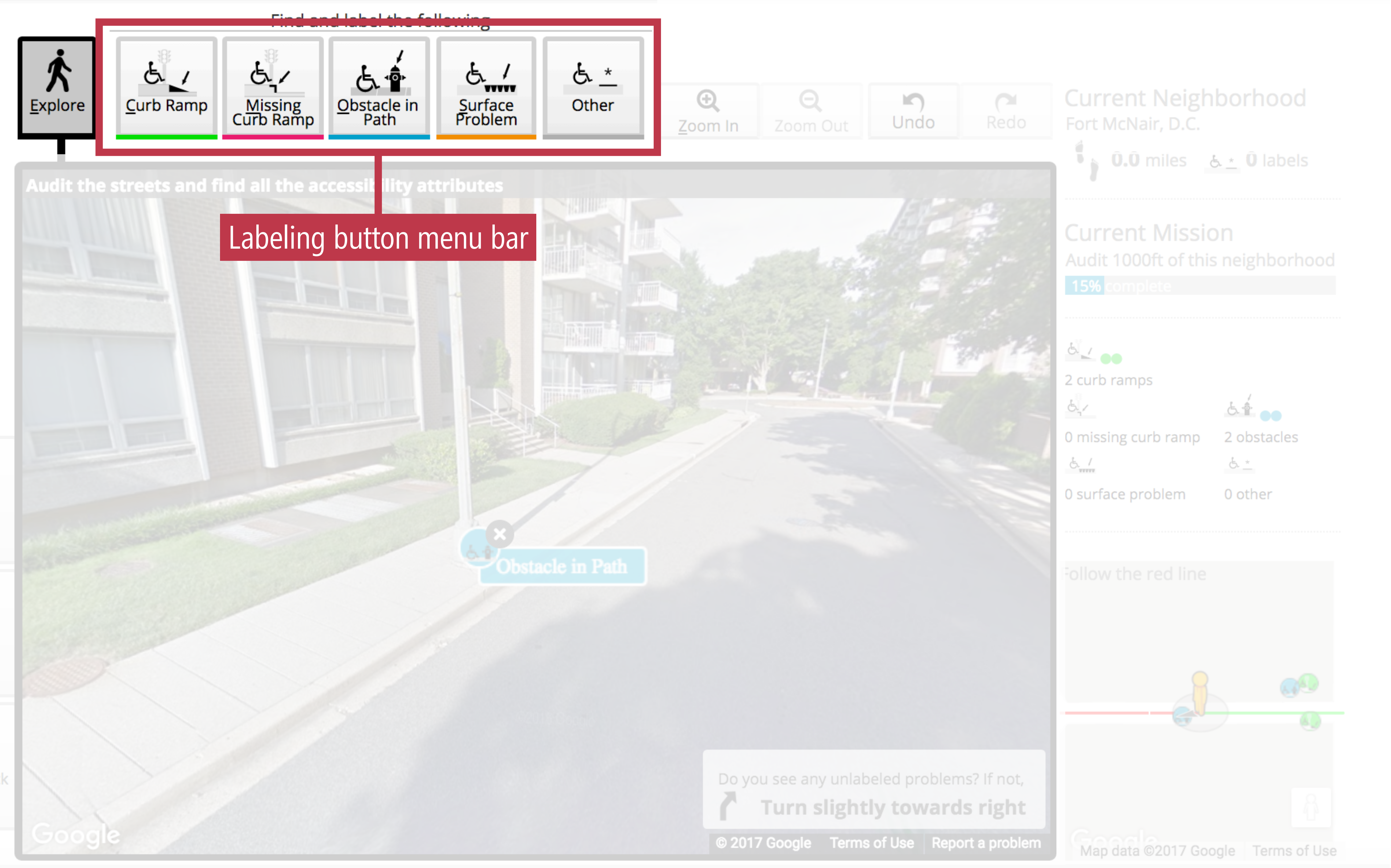

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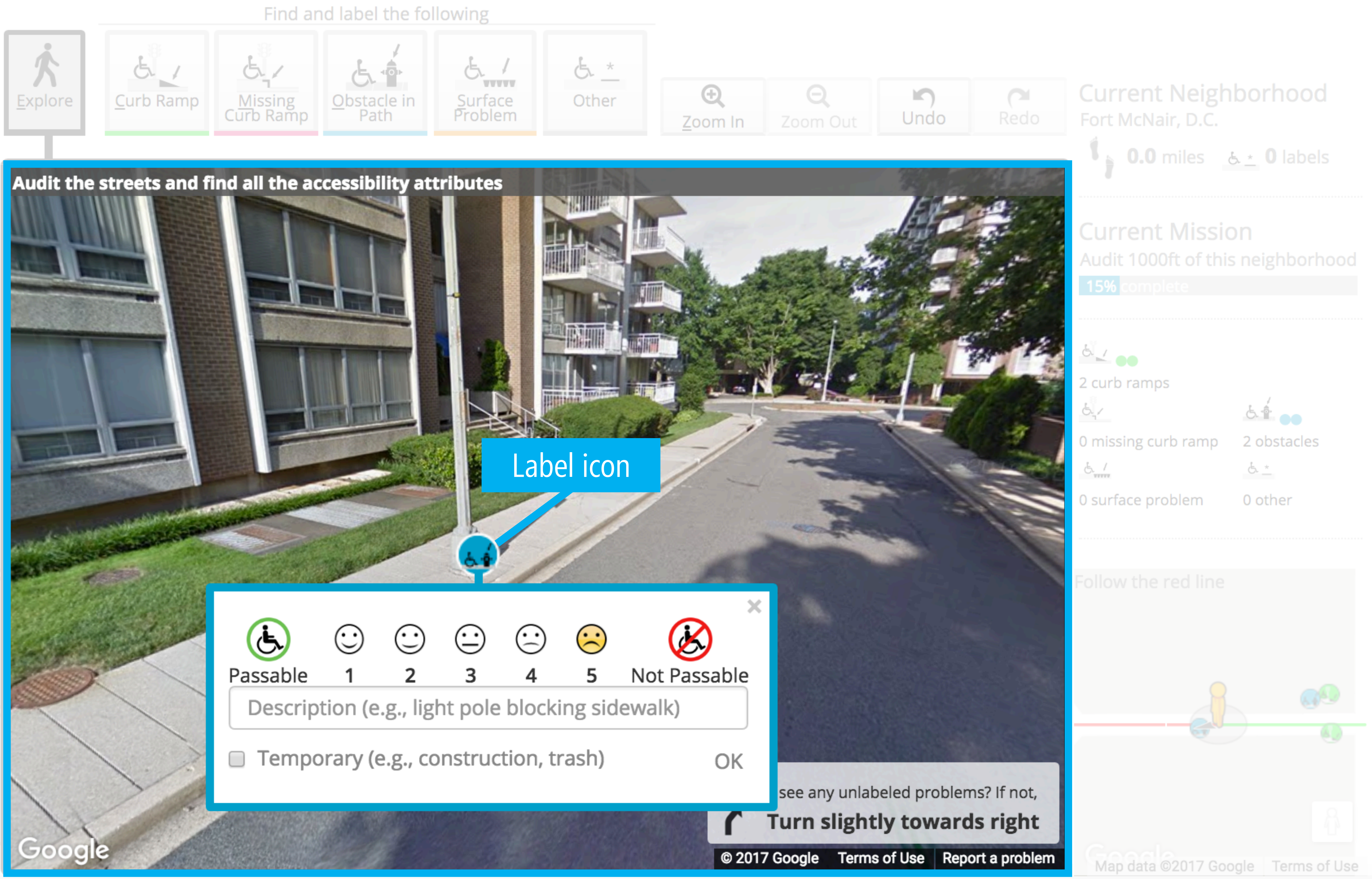

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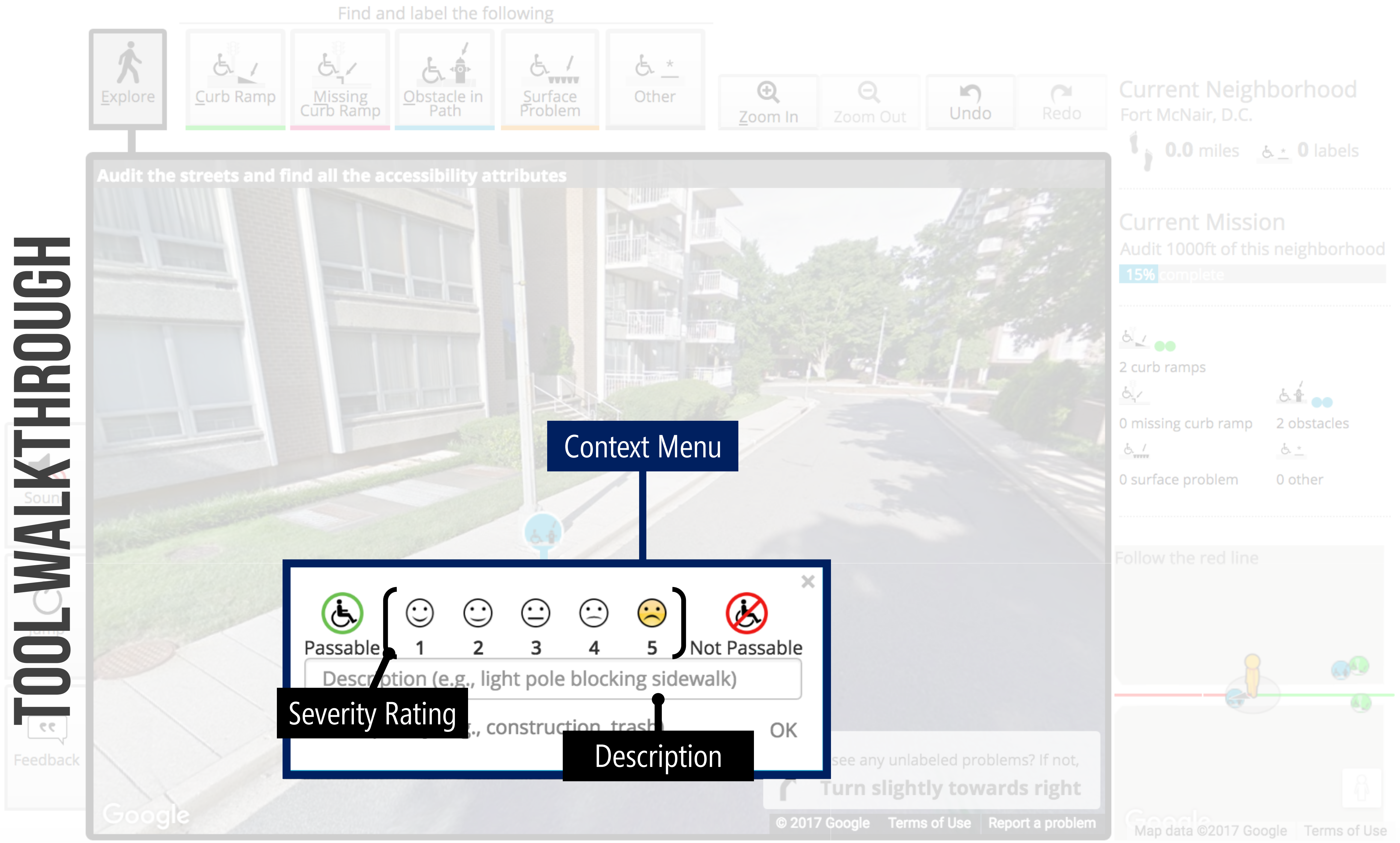

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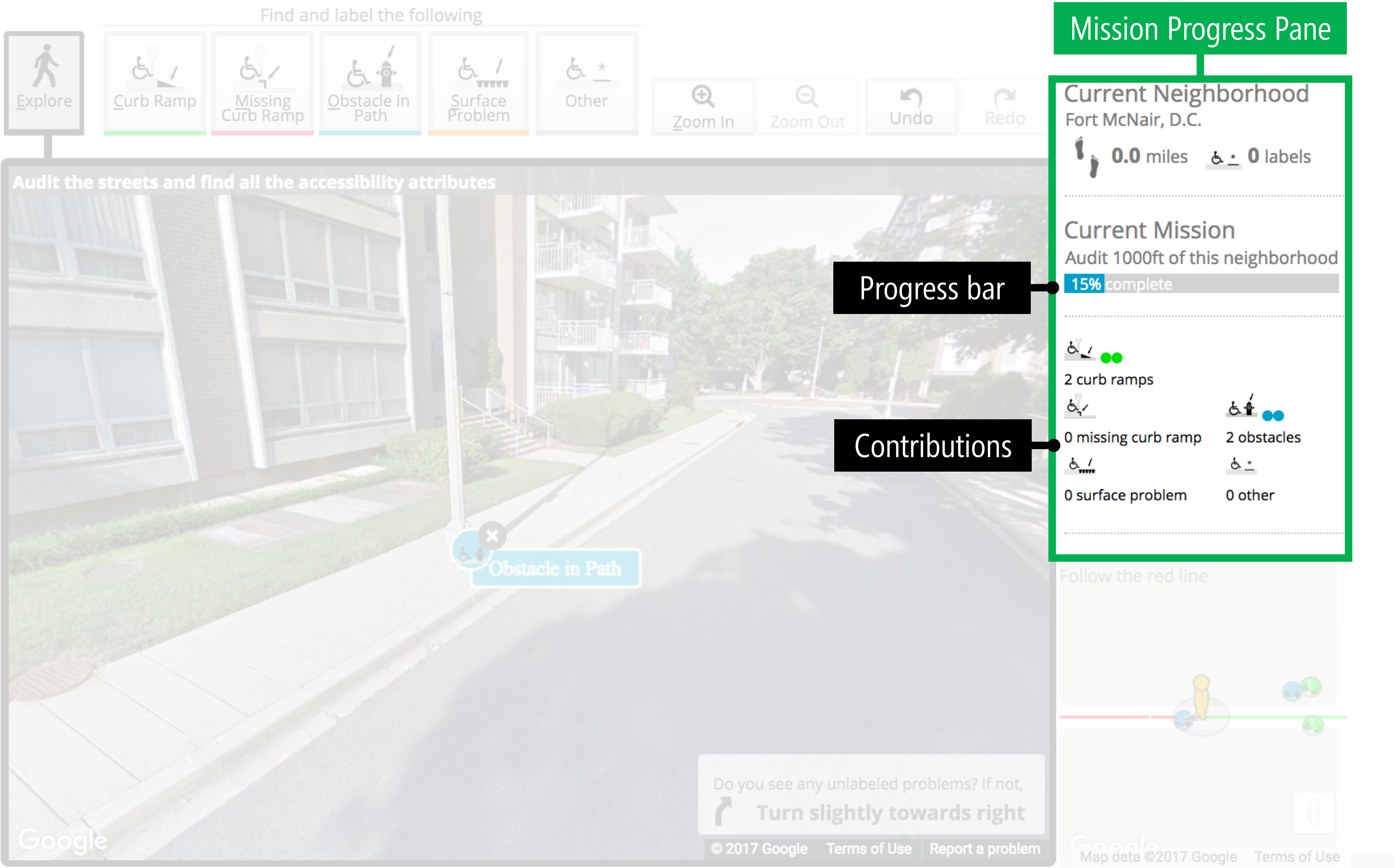

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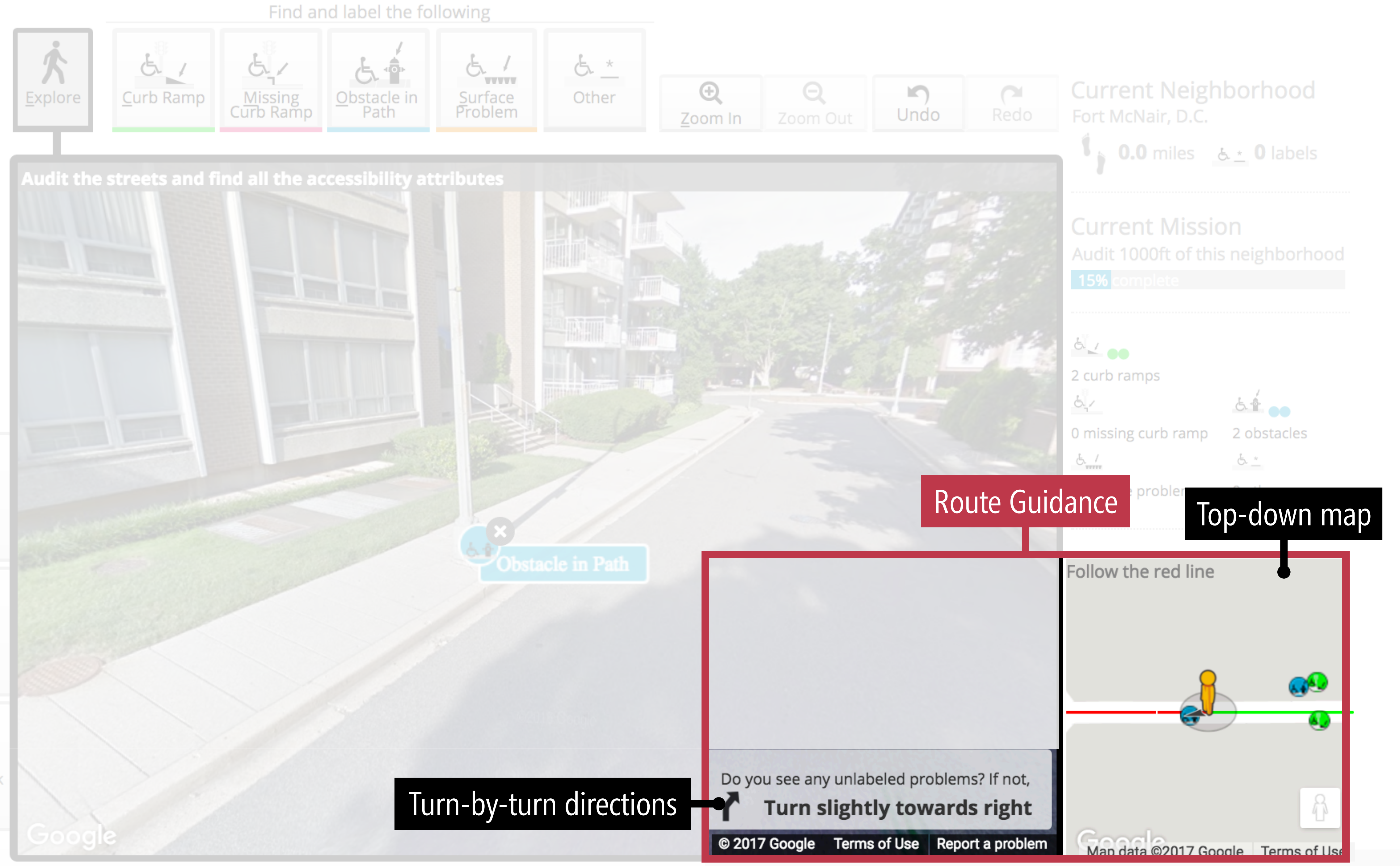
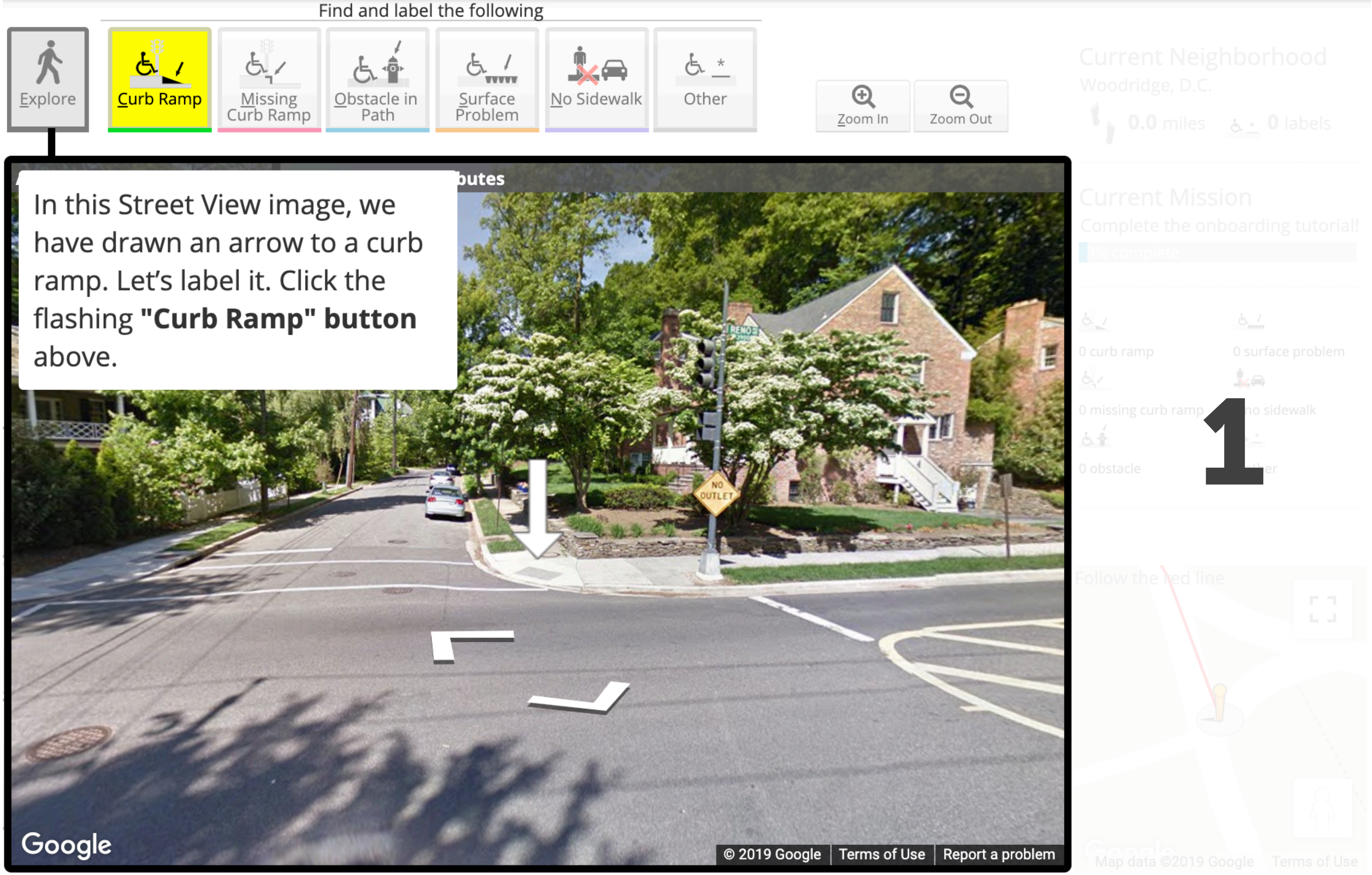


PROJECT SIDEWALK SYSTEM

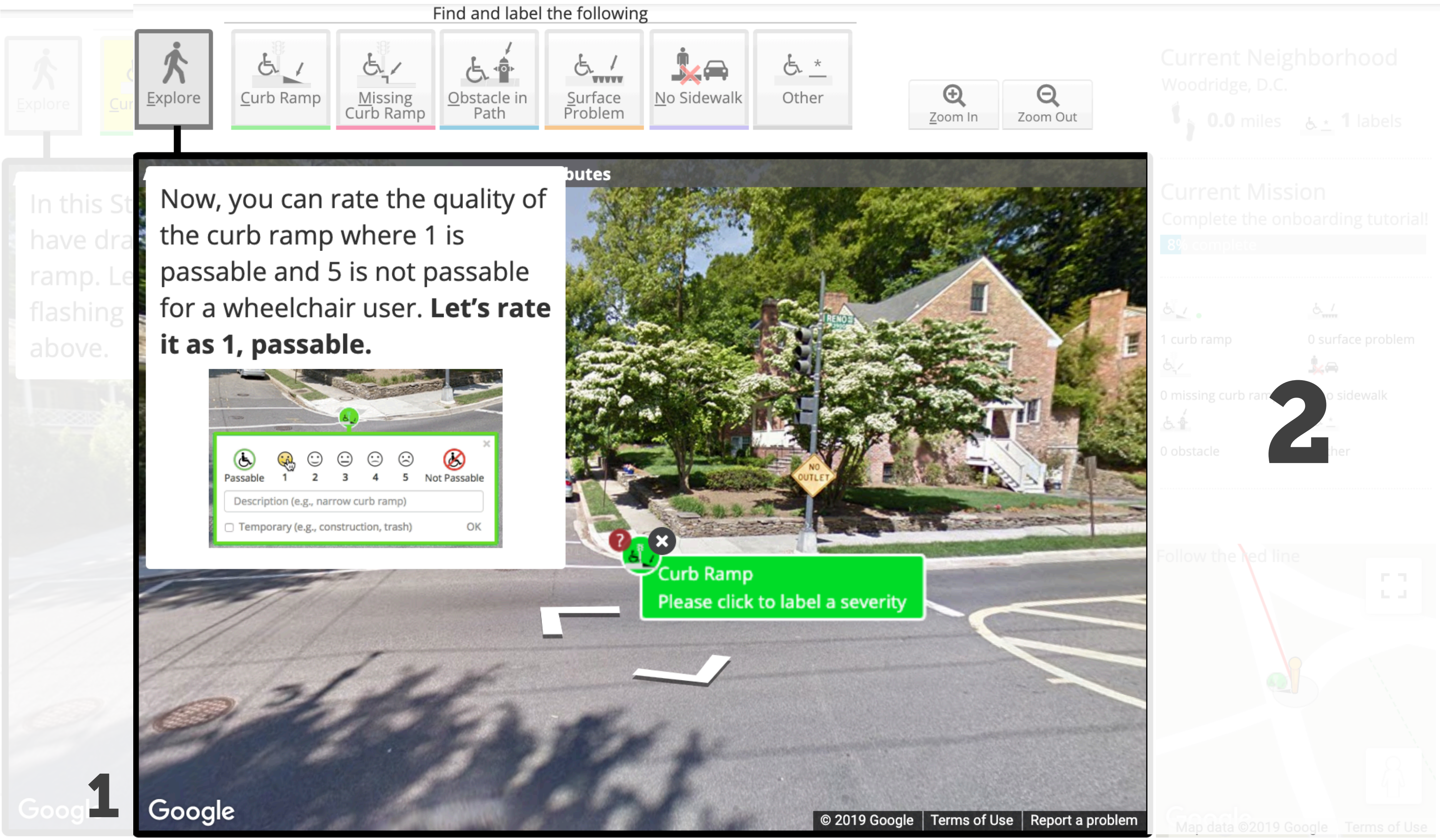
INTERACTIVE TUTORIAL



1

PROJECT SIDEWALK SYSTEM

INTERACTIVE TUTORIAL



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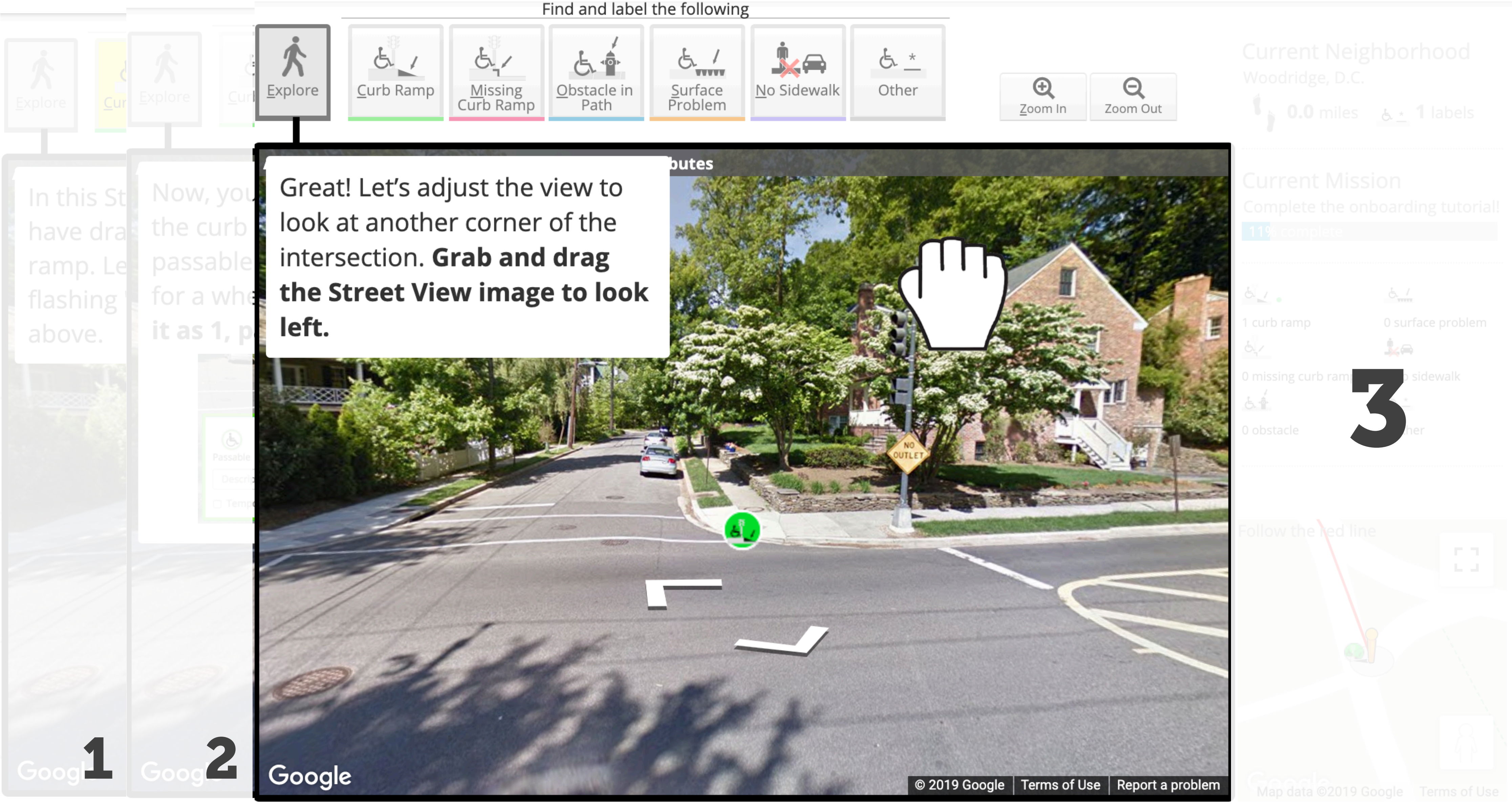

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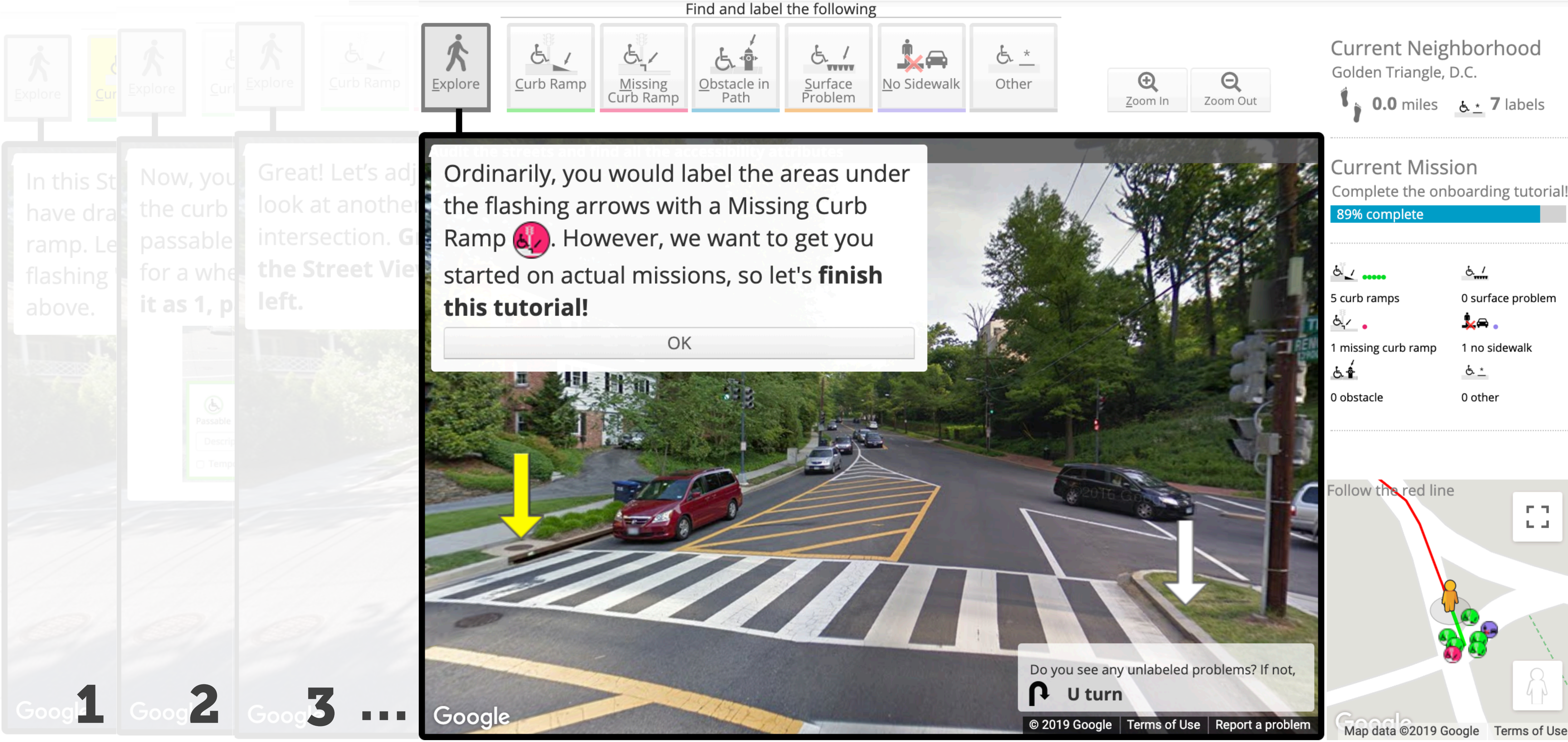
INTERACTIVE TUTORIAL

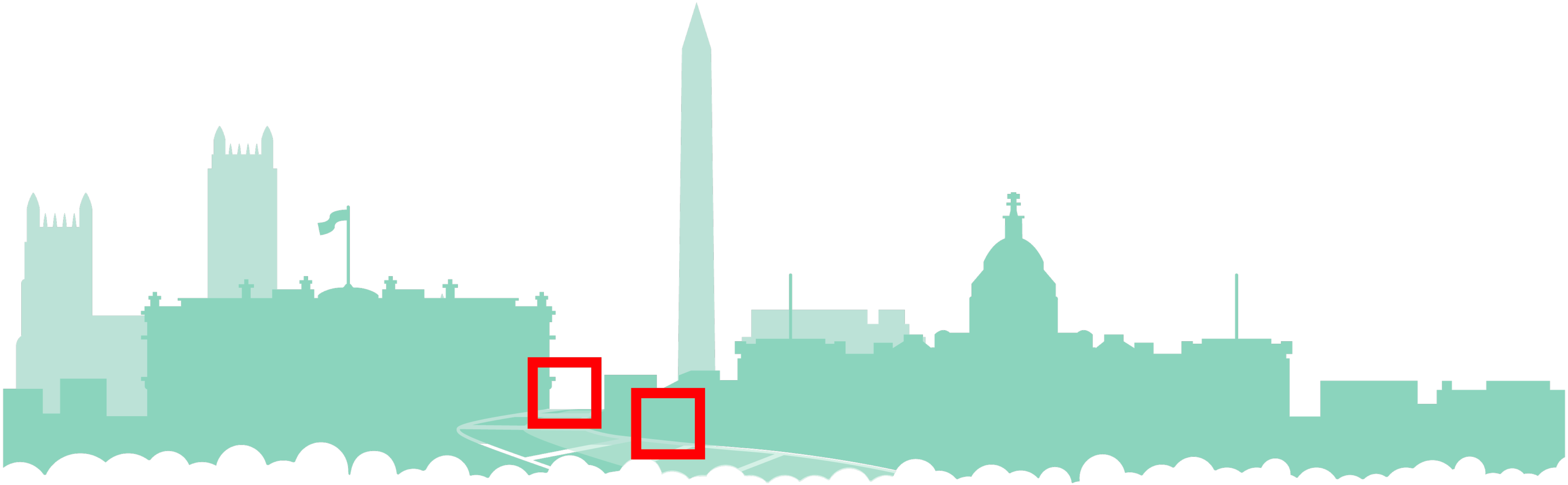


PROJECT SIDEWALK SYSTEM

DEPLOYMENT

CHI 2019, BEST PAPER

Washington DC



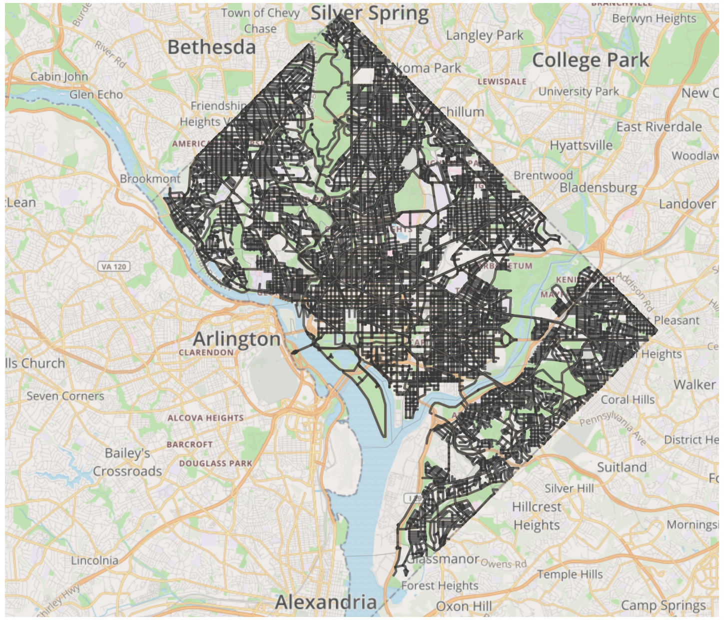
18-month deployment ~ Fall **2016** - Spring **2018**

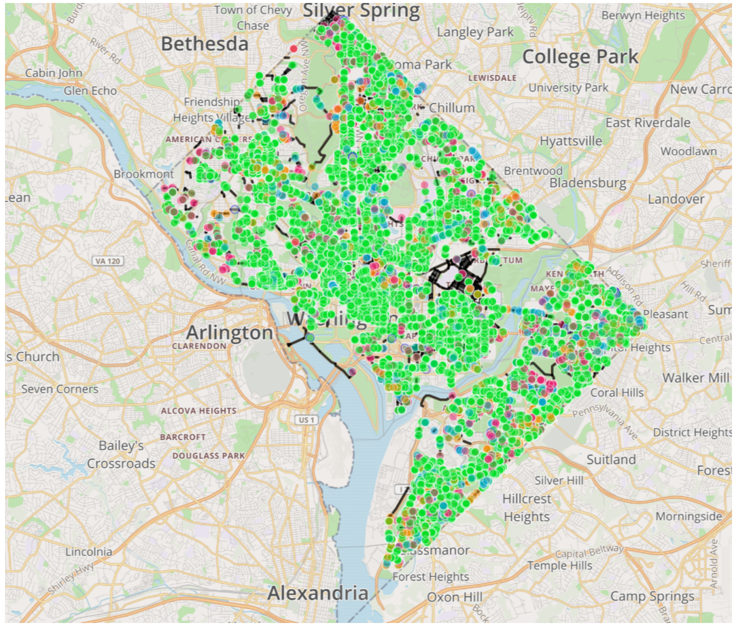
PROJECT SIDEWALK SYSTEM: DC DEPLOYMENT

DATA COLLECTED

CHI 2019, BEST PAPER

PROJECT SIDEWALK
HTTP://PROJECTSIDEWALK.IO





~800

USERS

Volunteers Turkers

~3000

MILES

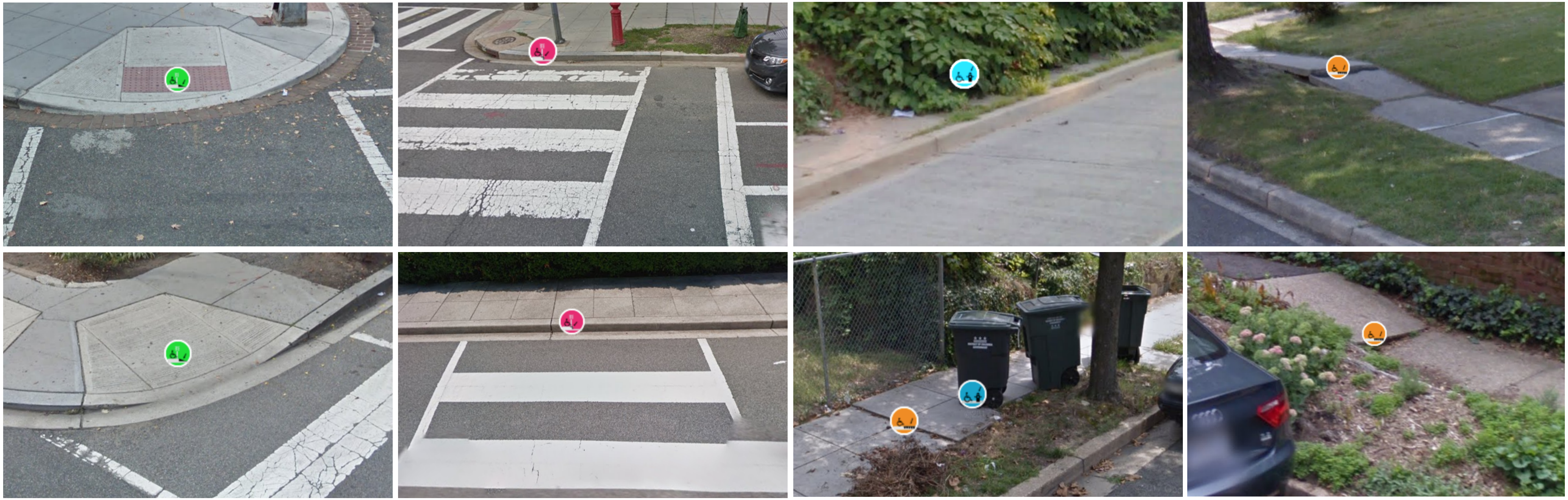
250,000+

LABELS

PROJECT SIDEWALK SYSTEM: DC DEPLOYMENT

LABEL EXAMPLES

CHI 2019, BEST PAPER



142,835 Curb Ramps	**18,719** Missing Curb Ramps	**21,736** Obstacles	**8309** Surface Problems

PROJECT SIDEWALK SYSTEM: DEPLOYMENTS

MORE CITIES!

Newberg, OR

100%
Newberg mapped

107
miles covered

16,930
labels

MORE CITIES!

Seattle, WA

47%
Seattle mapped

880
miles covered

89,000+
labels

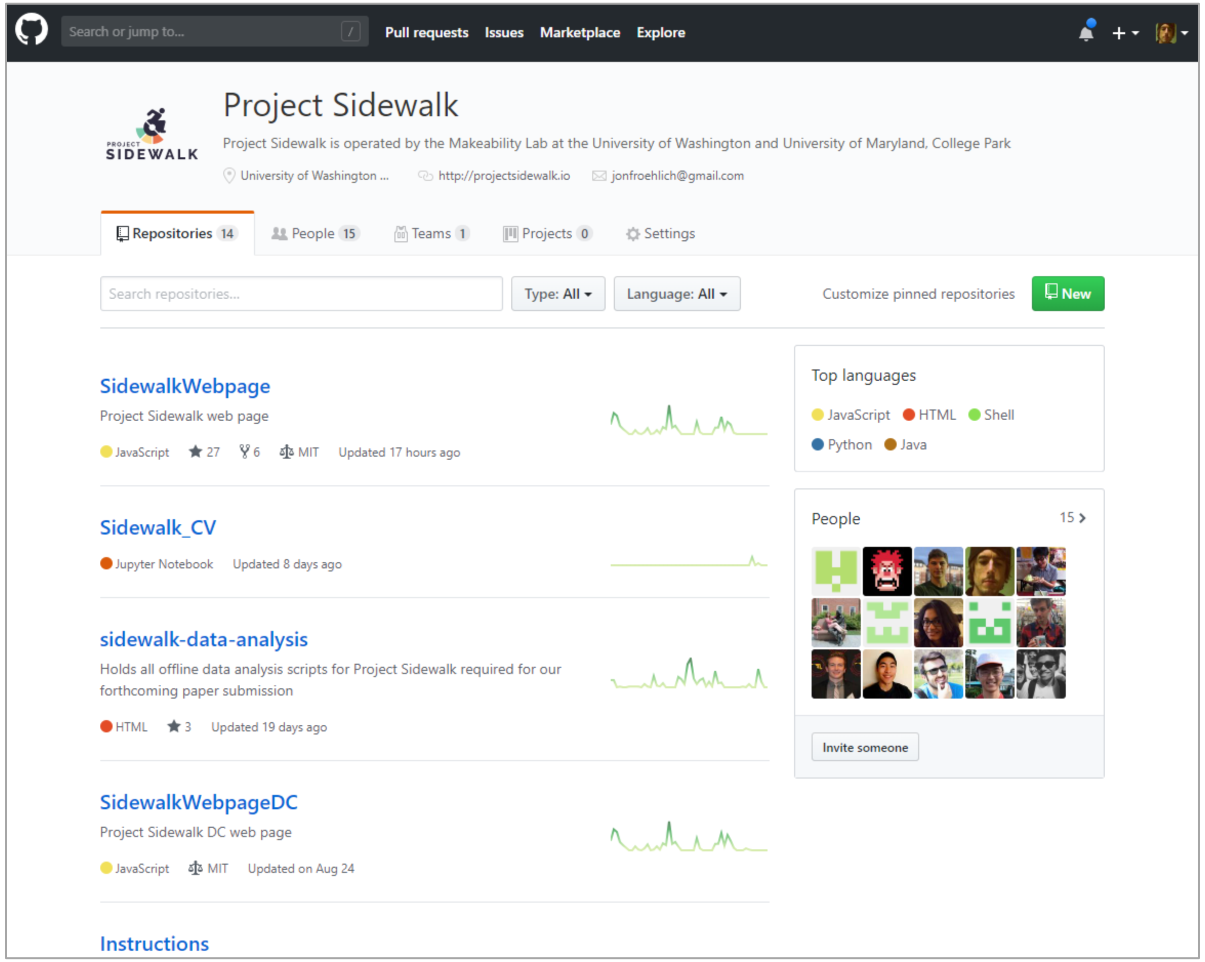
PROJECT SIDEWALK SYSTEM: DEPLOYMENTS

MORE CITIES!

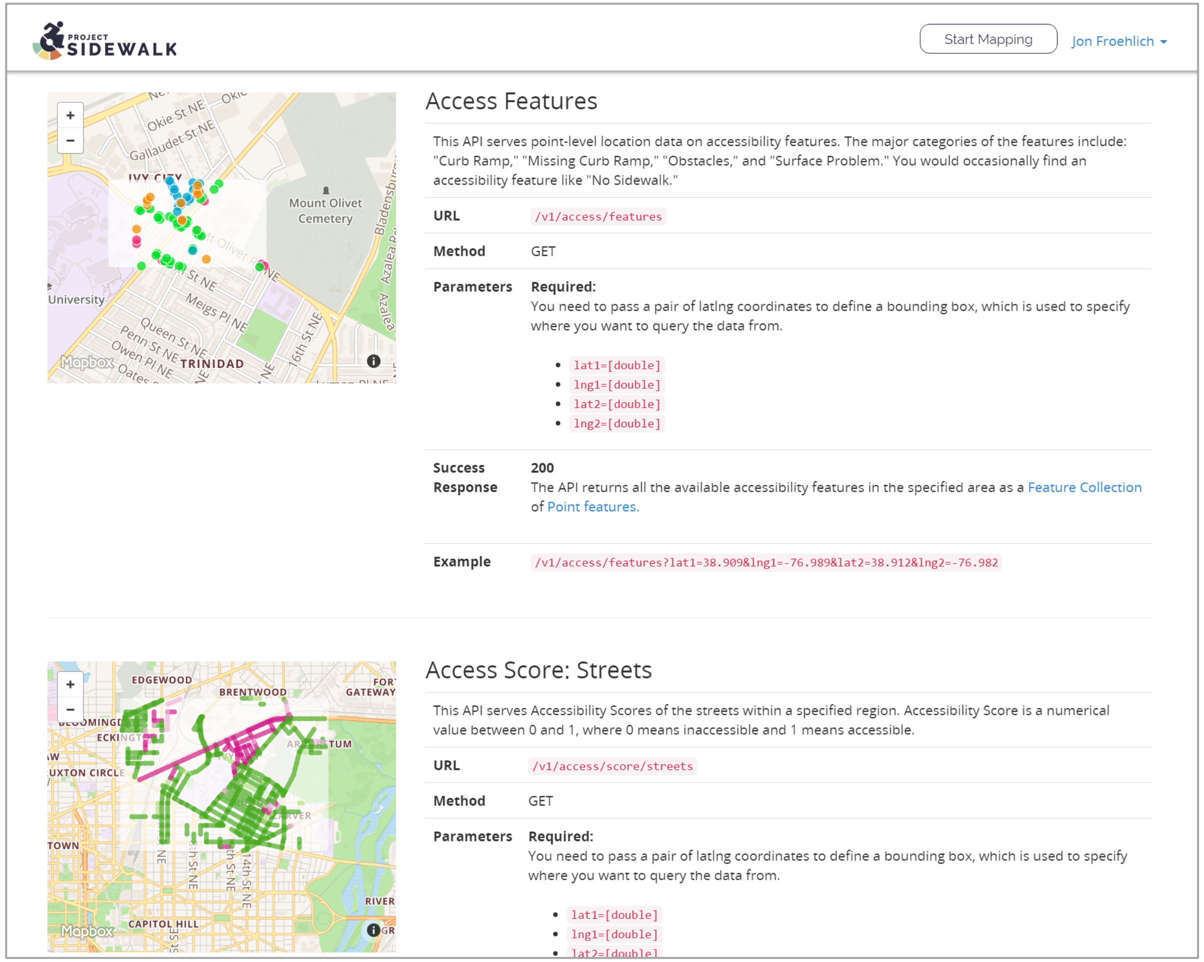
Downtown

PROJECT SIDEWALK SYSTEM

OPEN SOURCE & OPEN DATA



https://github.com/ProjectSidewalk



http://projectsidewalk.io/api

KEY STAKEHOLDERS

People with Mobility Impairments

Accessibility Advocates

Government Officials

Elected Officials
and other policymakers

DOTs

Caregivers

KEY STAKEHOLDERS

People with Mobility Impairments

Caregivers

People affected by inaccessible infrastructure

Elected Officials
and other policymakers

DOTs

KEY STAKEHOLDERS

People who can bring change i.e., improve accessibility

Accessibility Advocates

Government Officials

Elected Officials
and other policymakers

DOTs

KEY STAKEHOLDERS

People with Mobility Impairments

Caregivers

Accessibility Advocates

Government Officials

Elected Officials
and other policymakers

DOTs

Project Sidewalk System

Stakeholder Perceptions and Concerns

Perceived Value

Concerns

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Perceived Value

Enabled rapid data collection

Gathered diverse perspectives about accessibility

Helped engage citizens in thinking about urban design

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Perceived Value

"*It's really good for a starting point. This is a first observation, and when you send somebody out in the field, they can see those observations and pick up more information. It's just neat!*

-G4"

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concerns

Data age i.e., outdated GSV imagery or labels

Data reliability

Diverse and conflicting perspectives

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concern: Data Reliability

“*I would have more confidence if different people did it, did the same street.*”

-G4

Multi-user routing

Data validations

WHAT ARE THE STAKEHOLDERS' P… AND CONCERNS?

Concern: Data Reliability

"I would have more con… …nt people did it, did the sa…"

Multi-user routing

Data validations

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concern: Diverse and Conflicting Perspectives

"*My concern as a user [is that] someone said this was accessible and I got there and it wasn't accessible, because everyone has different opinions on accessibility.*"

-MI1

Visual Evidence via Labeled GSV images

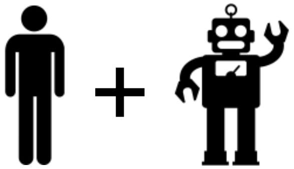
Parameterizable accessibility models

Crowdsourced
Data Collection

(semi) Automated
Data Collection

Accessibility-aware
Application Design

Crowdsourced
Data Collection

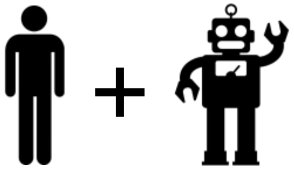


(semi) Automated
Data Collection

Accessibility-aware
Application Design

1. How can we use computer vision to automatically and accurately detect accessibility attributes?
2. How can we combine crowdsourcing and computer vision to increase the data collection efficiency?

Crowdsourced
Data Collection



(semi) Automated
Data Collection

Accessibility-aware
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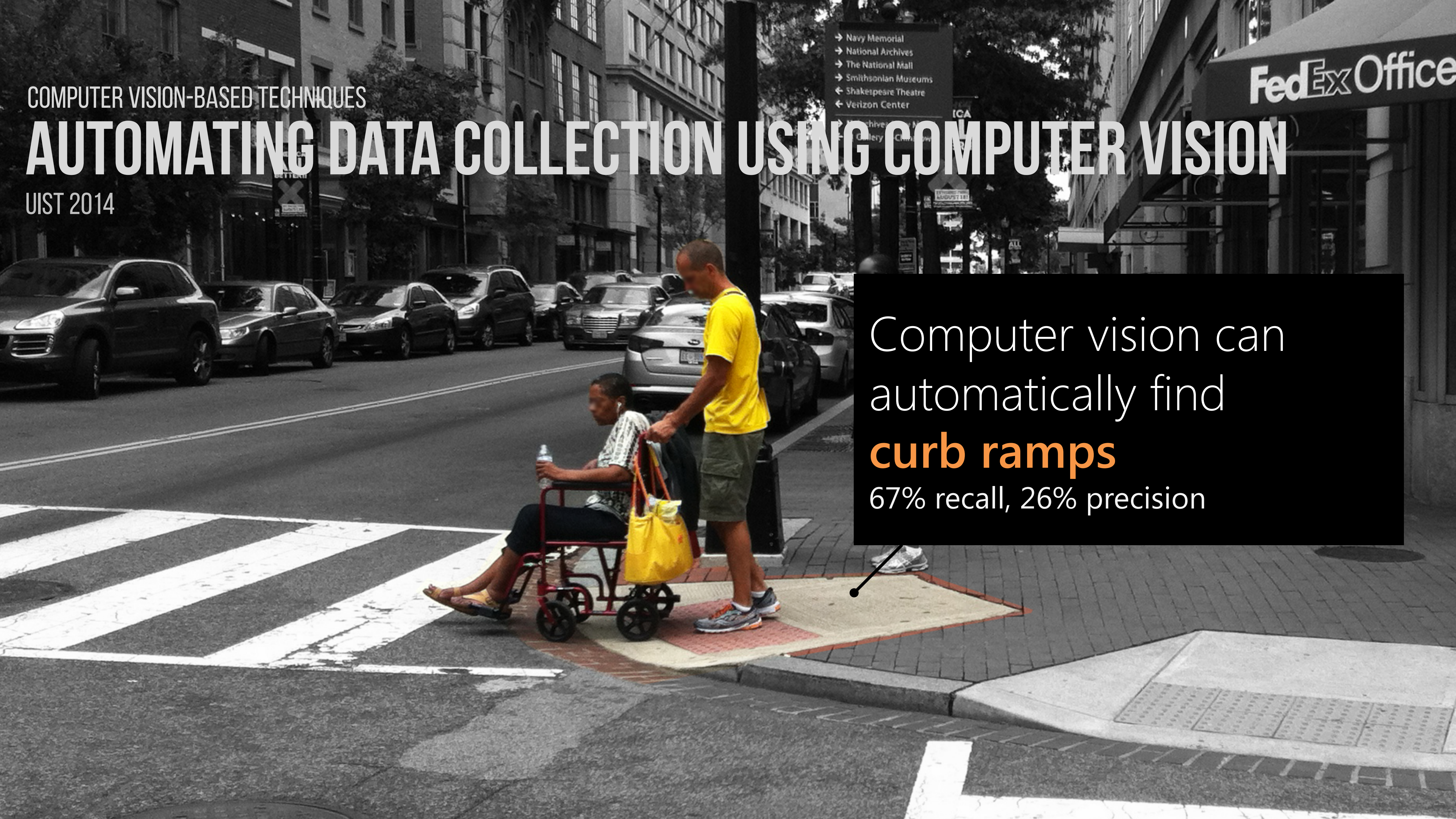
Automating Data Collection using Computer Vision

COMPUTER VISION-BASED TECHNIQUES

AUTOMATING DATA COLLECTION USING COMPUTER VISION

UIST 2014



Computer vision can automatically find **curb ramps**

67% recall, 26% precision

AUTOMATING DATA COLLECTION USING COMPUTER VISION

CVPR 2017

COMPUTER VISION-BASED TECHNIQUES

AUTOMATING DATA COLLECTION USING COMPUTER VISION

ASSETS 2019

Curb Ramp

Obstacles

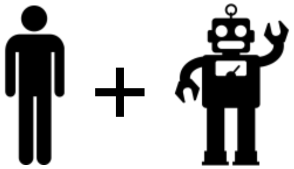
+17% recall

+117% recall

Missing Curb Ramp

Surface Problem

Crowdsourced
Data Collection

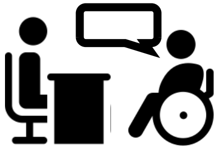


(semi) Automated
Data Collection

Accessibility-aware
Application Design

Crowdsourced
Data Collection

Automated
Data Collection

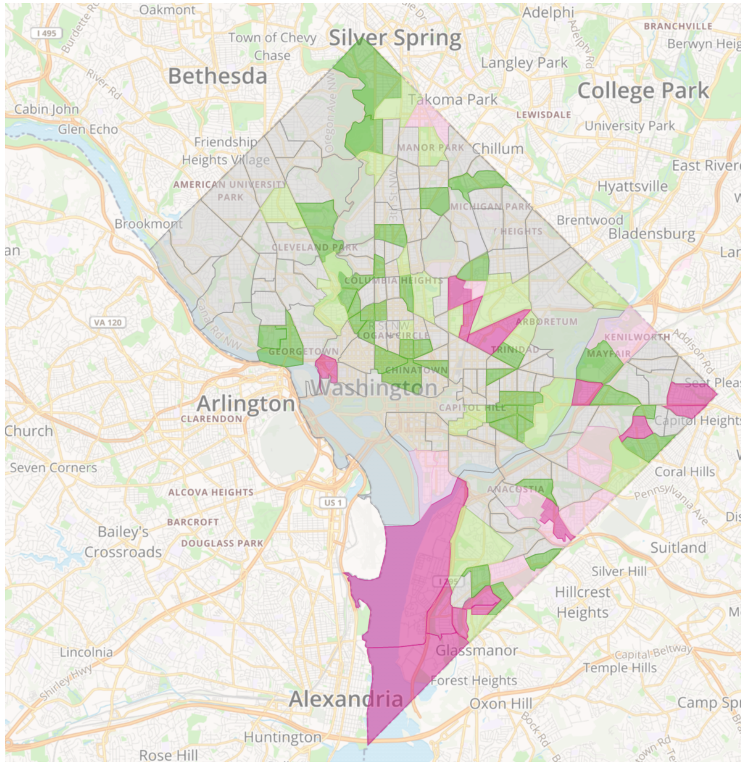


Accessibility-aware
Application Design

1. What location-based applications should we design with the collected accessibility data?
2. How do we design these interactive mapping tools?

ACCESSIBILITY-AWARE APPLICATIONS

Smart routing for people with mobility impairments



City accessibility visualizations

DC

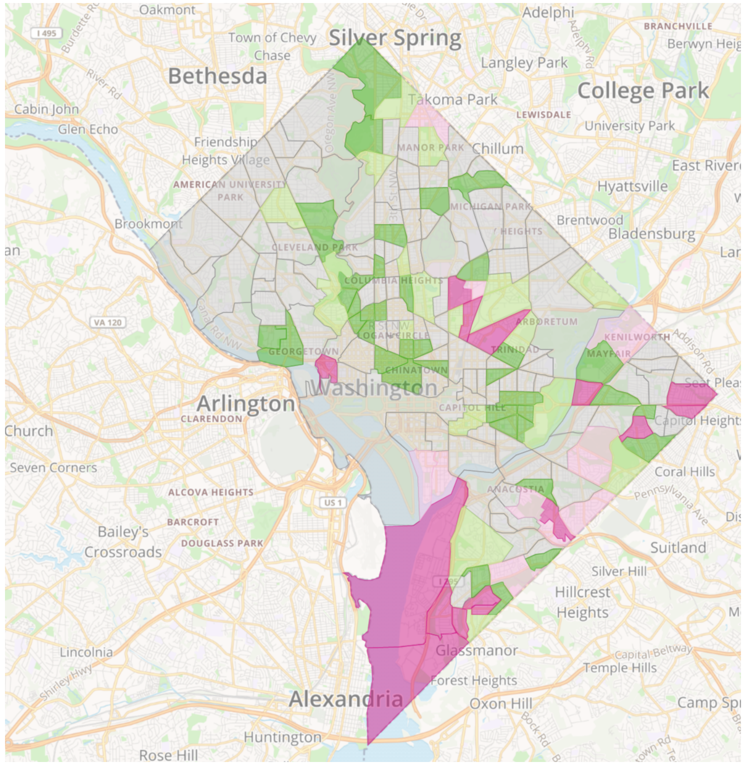
vs

Seattle

Cross-city comparison tools

ACCESSIBILITY-AWARE APPLICATIONS

Smart routing for people with mobility impairments

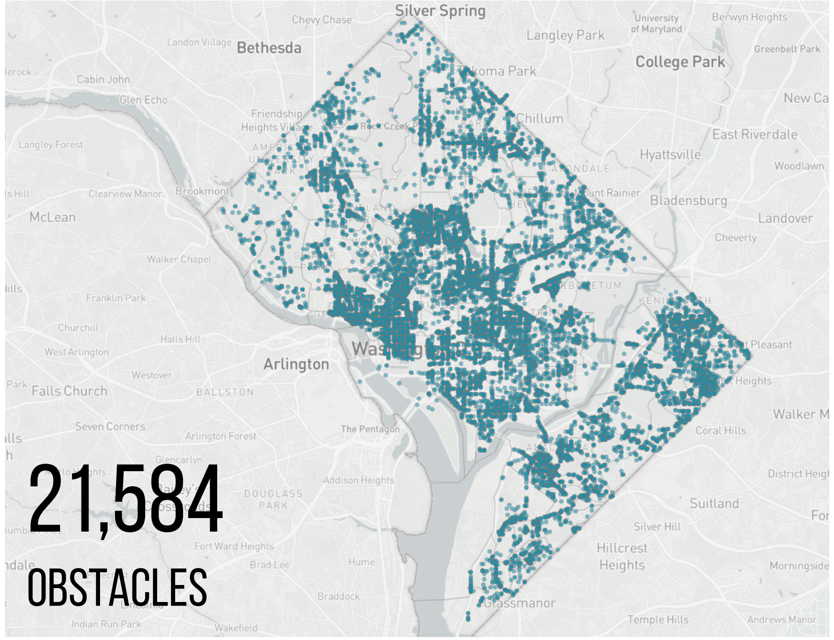


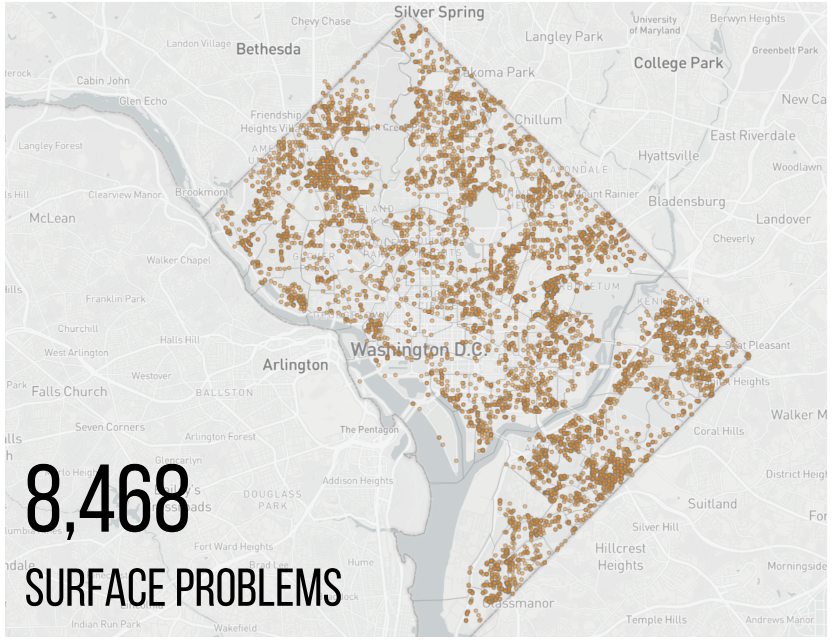
City accessibility visualizations

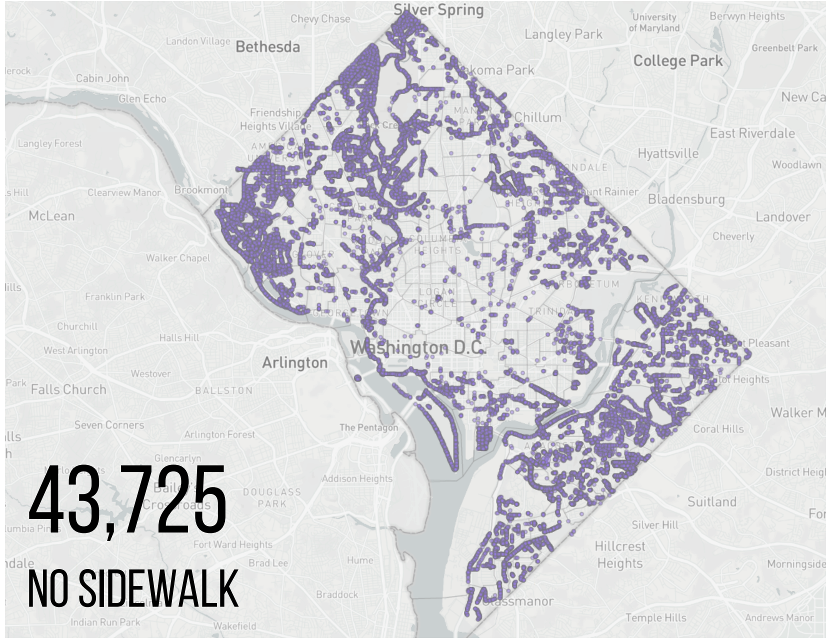
Cross-city comparison tools

APPLICATIONS: INTERACTIVE TOOLS

VISUALIZING ACCESSIBILITY







What are the (in)accessible areas of the city?

Why are they (in)accessible?

Where are the areas with highest repair needs?

KEY STAKEHOLDERS

What are the (in)accessible areas of the city?

People with Mobility Impairments

Accessibility Advocates

Government Officials

Elected Officials
and other policymakers

DOTs

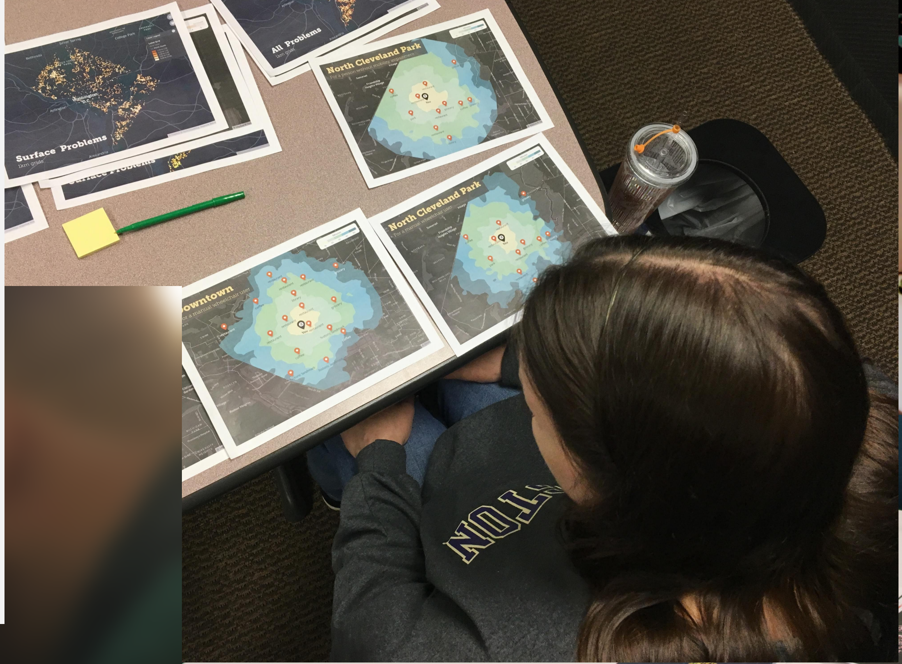
Caregivers

Where are the areas with highest repair needs?

DESIGN INTERVIEWS

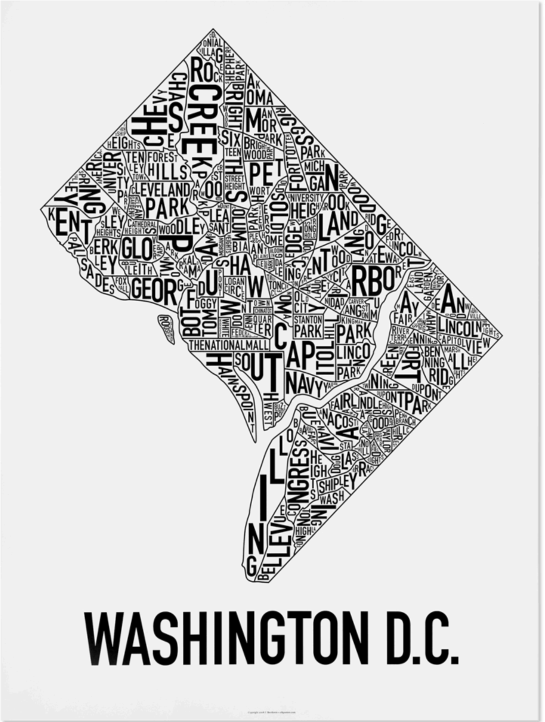
N=25

TRANSPORTATION DEPARTMENT OFFICIALS
CITY ELECTED OFFICIALS
ACCESSIBILITY ADVOCATES
PEOPLE WITH MOBILITY DISABILITIES
CAREGIVERS



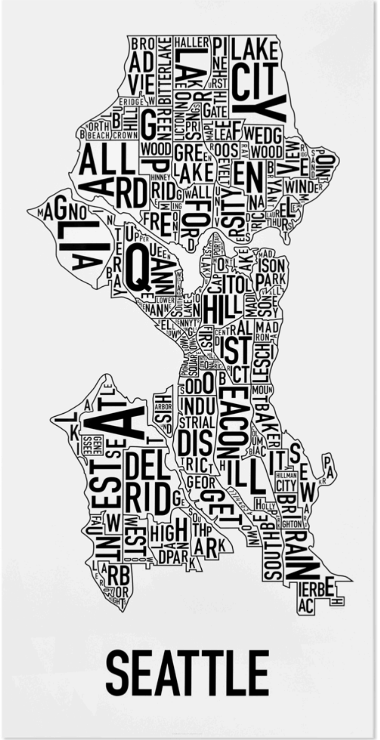
WORK IN PROGRESS...

MODELING ACCESSIBILITY



vs

vs

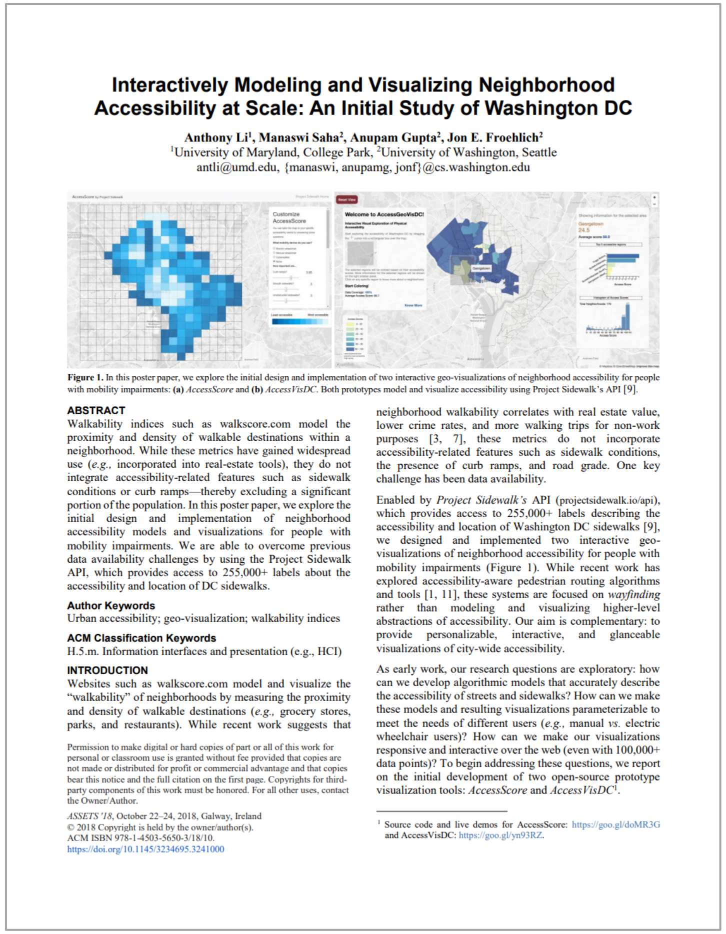


What are the correlates to accessibility?

How do we compare accessibility across cities?

APPLICATIONS: INTERACTIVE GIS TOOLS

ACCESS SCORE: PERSONALIZING ACCESSIBILITY MODELS



Interactively Modeling and Visualizing Neighborhood Accessibility at Scale: An Initial Study of Washington DC

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Figure 1. In this poster paper, we explore the initial design and implementation of two interactive geo-visualizations of neighborhood accessibility for people with mobility impairments: **(a)** *AccessScore* and **(b)** *AccessVisDC*. Both prototypes model and visualize accessibility using Project Sidewalk's API [9].

ABSTRACT
Walkability indices such as walkscore.com model the proximity and density of walkable destinations within a neighborhood. While these metrics have gained widespread use (*e.g.,* incorporated into real-estate tools), they do not integrate accessibility-related features such as sidewalk conditions or curb ramps—thereby excluding a significant portion of the population. In this poster paper, we explore the initial design and implementation of neighborhood accessibility models and visualizations for people with mobility impairments. We are able to overcome previous data availability challenges by using the Project Sidewalk API, which provides access to 255,000+ labels about the accessibility and location of DC sidewalks.

Author Keywords
Urban accessibility; geo-visualization; walkability indices

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION
Websites such as walkscore.com model and visualize the "walkability" of neighborhoods by measuring the proximity and density of walkable destinations (*e.g.,* grocery stores, parks, and restaurants). While recent work suggests that neighborhood walkability correlates with real estate value, lower crime rates, and more walking trips for non-work purposes [3, 7], these metrics do not incorporate accessibility-related features such as sidewalk conditions, the presence of curb ramps, and road grade. One key challenge has been data availability.

Enabled by *Project Sidewalk's* API (projectsidewalk.io/api), which provides access to 255,000+ labels describing the accessibility and location of Washington DC sidewalks [9], we designed and implemented two interactive geo-visualizations of neighborhood accessibility for people with mobility impairments (Figure 1). While recent work has explored accessibility-aware pedestrian routing algorithms and tools [1, 11], these systems are focused on *wayfinding* rather than modeling and visualizing higher-level abstractions of accessibility. Our aim is complementary: to provide personalizable, interactive, and glanceable visualizations of city-wide accessibility.

As early work, our research questions are exploratory: how can we develop algorithmic models that accurately describe the accessibility of streets and sidewalks? How can we make these models and resulting visualizations parameterizable to meet the needs of different users (*e.g.,* manual *vs.* electric wheelchair users)? How can we make our visualizations responsive and interactive over the web (even with 100,000+ data points)? To begin addressing these questions, we report on the initial development of two open-source prototype visualization tools: *AccessScore* and *AccessVisDC*[1].

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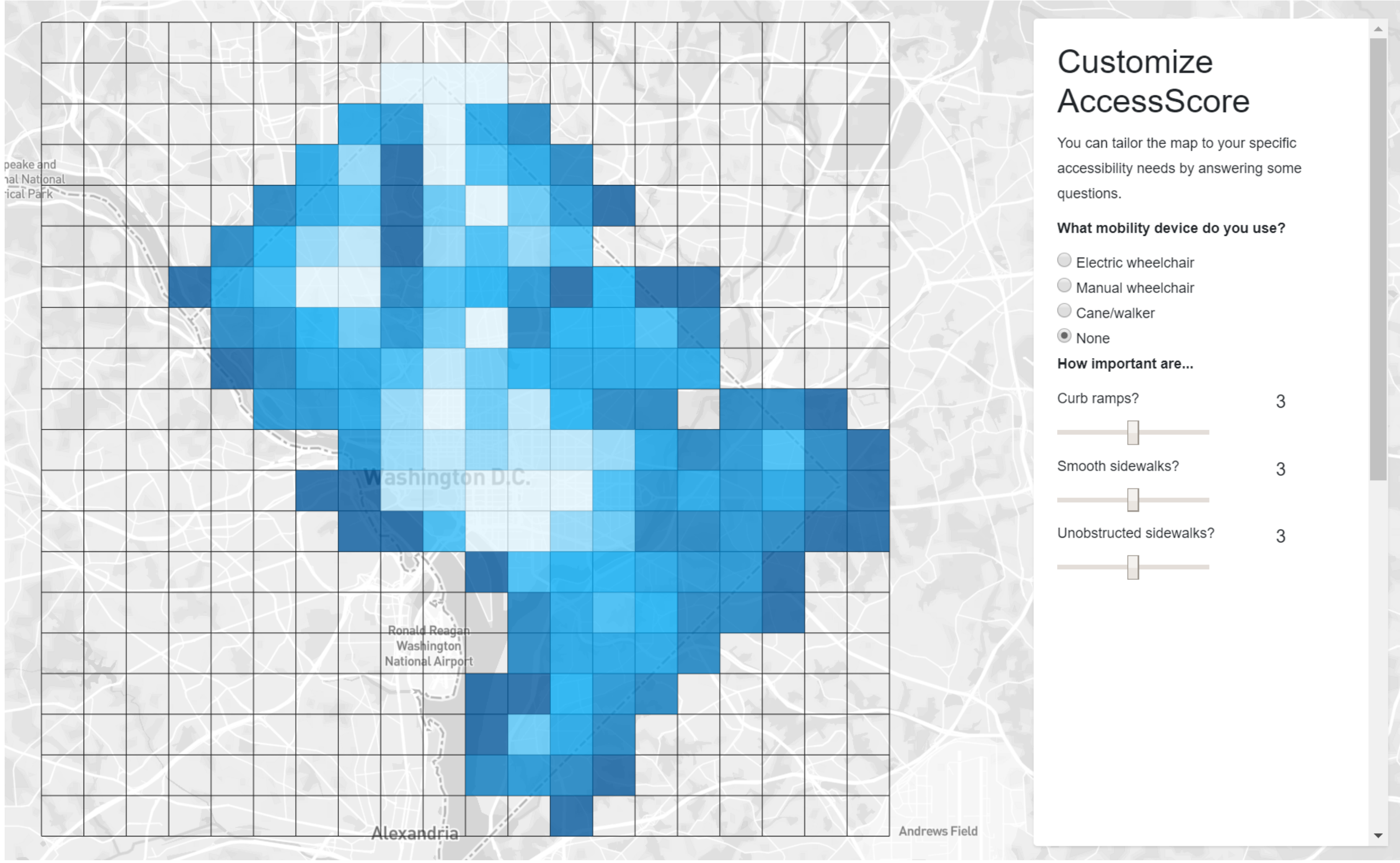
[1] Source code and live demos for AccessScore: https://goo.gl/doMR3G and AccessVisDC: https://goo.gl/yn93RZ.



[ASSETS'18 Poster]

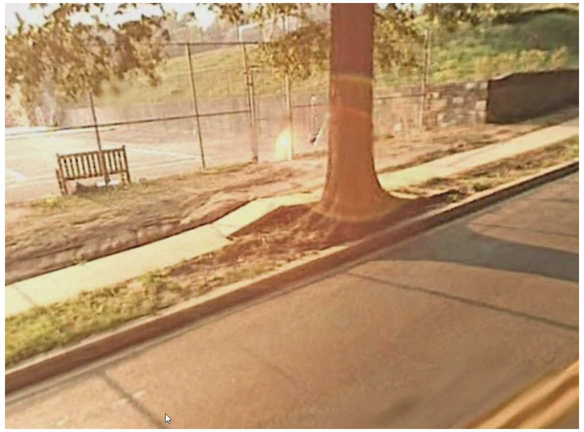
Urban Evolution

How does accessibility change over time?

Temporal Tracking: Tools for tracking sidewalk infrastructure over time using computer vision

APPLICATIONS: TEMPORAL TRACKING

TRACKING ACCESSIBILITY INFRASTRUCTURE OVER TIME



Sept 2007

Jul 2009

May 2011

June 2011

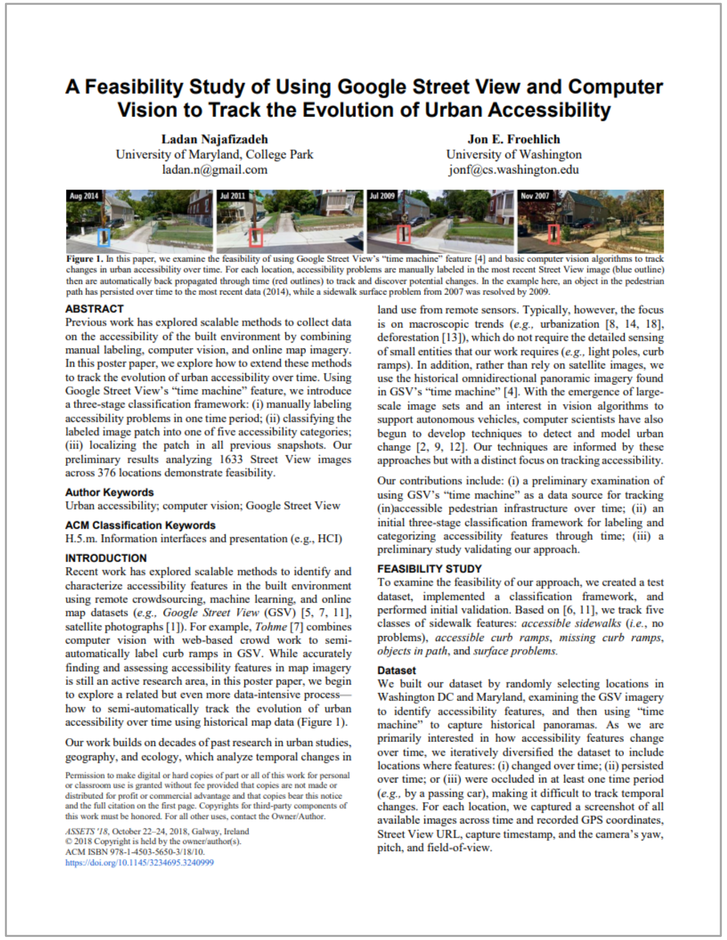
May 2014

Aug 2014

Nov 2016

TRACKING ACCESSIBILITY INFRASTRUCTURE OVER TIME

ASSETS 2018



A Feasibility Study of Using Google Street View and Computer Vision to Track the Evolution of Urban Accessibility

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Figure 1. In this paper, we examine the feasibility of using Google Street View's "time machine" feature [4] and basic computer vision algorithms to track changes in urban accessibility over time. For each location, accessibility problems are manually labeled in the most recent Street View image (blue outline) then are automatically back propagated through time (red outlines) to track and discover potential changes. In the example here, an object in the pedestrian path has persisted over time to the most recent data (2014), while a sidewalk surface problem from 2007 was resolved by 2009.

ABSTRACT
Previous work has explored scalable methods to collect data on the accessibility of the built environment by combining manual labeling, computer vision, and online map imagery. In this poster paper, we explore how to extend these methods to track the evolution of urban accessibility over time. Using Google Street View's "time machine" feature, we introduce a three-stage classification framework: (i) manually labeling accessibility problems in one time period; (ii) classifying the labeled image patch into one of five accessibility categories; (iii) localizing the patch in all previous snapshots. Our preliminary results analyzing 1633 Street View images across 376 locations demonstrate feasibility.

Author Keywords
Urban accessibility; computer vision; Google Street View

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION
Recent work has explored scalable methods to identify and characterize accessibility features in the built environment using remote crowdsourcing, machine learning, and online map datasets (*e.g., Google Street View* (GSV) [5, 7, 11], satellite photographs [1]). For example, *Tohme* [7] combines computer vision with web-based crowd work to semi-automatically label curb ramps in GSV. While accurately finding and assessing accessibility features in map imagery is still an active research area, in this poster paper, we begin to explore a related but even more data-intensive process—how to semi-automatically track the evolution of urban accessibility over time using historical map data (Figure 1).

Our work builds on decades of past research in urban studies, geography, and ecology, which analyze temporal changes in land use from remote sensors. Typically, however, the focus is on macroscopic trends (*e.g.,* urbanization [8, 14, 18], deforestation [13]), which do not require the detailed sensing of small entities that our work requires (*e.g.,* light poles, curb ramps). In addition, rather than rely on satellite images, we use the historical omnidirectional panoramic imagery found in GSV's "time machine" [4]. With the emergence of large-scale image sets and an interest in vision algorithms to support autonomous vehicles, computer scientists have also begun to develop techniques to detect and model urban change [2, 9, 12]. Our techniques are informed by these approaches but with a distinct focus on tracking accessibility.

Our contributions include: (i) a preliminary examination of using GSV's "time machine" as a data source for tracking (in)accessible pedestrian infrastructure over time; (ii) an initial three-stage classification framework for labeling and categorizing accessibility features through time; (iii) a preliminary study validating our approach.

FEASIBILITY STUDY
To examine the feasibility of our approach, we created a test dataset, implemented a classification framework, and performed initial validation. Based on [6, 11], we track five classes of sidewalk features: *accessible sidewalks* (*i.e.*, no problems), *accessible curb ramps*, *missing curb ramps*, *objects in path*, and *surface problems.*

Dataset
We built our dataset by randomly selecting locations in Washington DC and Maryland, examining the GSV imagery to identify accessibility features, and then using "time machine" to capture historical panoramas. As we are primarily interested in how accessibility features change over time, we iteratively diversified the dataset to include locations where features: (i) changed over time; (ii) persisted over time; or (iii) were occluded in at least one time period (*e.g.,* by a passing car), making it difficult to track temporal changes. For each location, we captured a screenshot of all available images across time and recorded GPS coordinates, Street View URL, capture timestamp, and the camera's yaw, pitch, and field-of-view.

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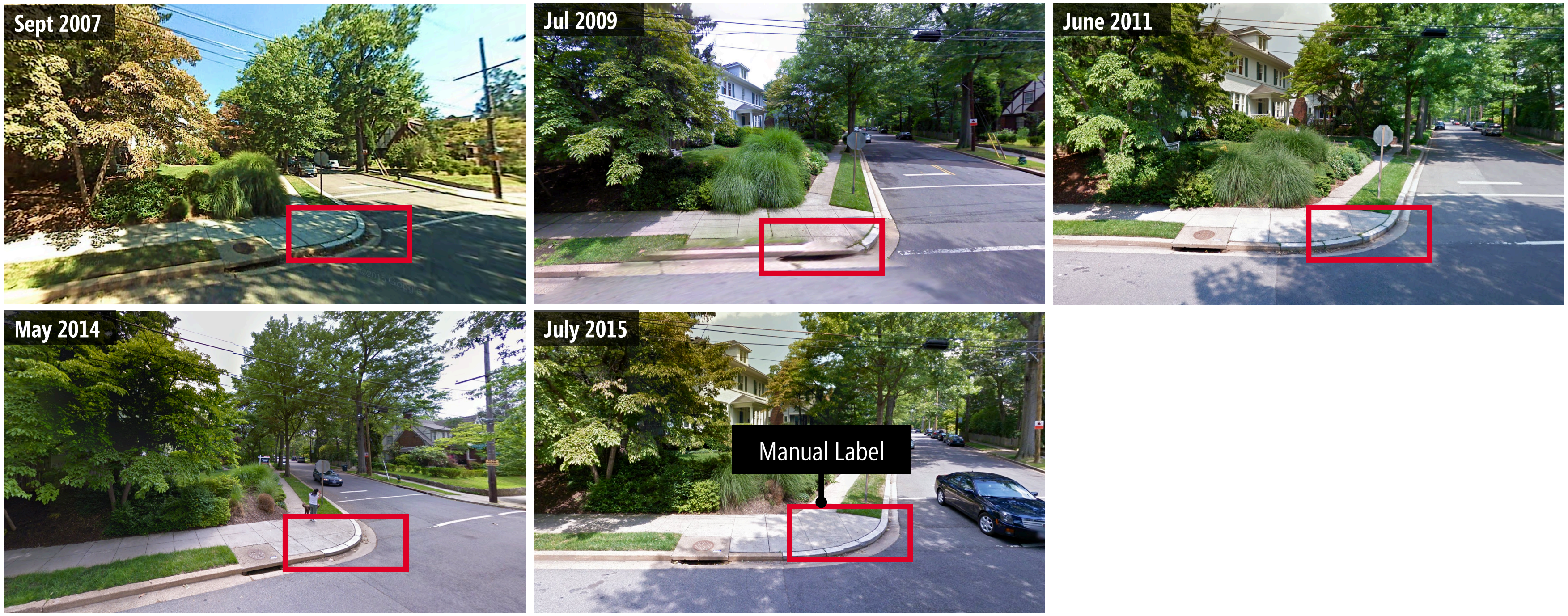

ACCESSIBILITY IS IMPORTANT

Crosscut. Politics Culture Equity Environment Opinion

GROWTH

Seattle's got terrible sidewalks. help fix them.

With UW's Project Sidewalk, volunteers look for bro
and missing curb ramps that make the city inaccess
with disabilities.

by Josh Cohen / April 26, 2019

A partly repaired sidewalk on Capitol Hill. Broken sidewalks and missing curb ramps make Sea mobility disabilities. (Dorothy Edwards/Crosscut)

For Vanessa Link, broken concrete and missing curb ram inconvenience. They're a barrier to her independence. T University of Washington student, disability rights advo Rights and power wheelchair user. She relies on reasonably sm curb ramps from sidewalk to the street in order to navigate the things are missing — an all-too-common occurrence in Seattle block or more out of her way or get "creative" by seeking out m

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SCIENCES

Nov. 30, 2016 9:57 am

How Project Sidewalk is making DC more accessible

With your help, researchers can use computer vision and machine learning to flag accessibility issues across the District.

By Aysha Khan / CONTRIBUTOR

Team Project Sidewalk at work.

(Photo by Aysha Khan)

TOP ARTICLES

1. NSA goes public with Windows security vulnerability
2. Virginia-based Cofense debuted its phishing defense podcast
3. Here's what Procurated's founder considered when making his first hire last year

As public transportation and ridesharing apps swell in popularity, we often talk about how walkable a city is: Can you get to work without a car? Can you walk to a grocery store, hospital and school from your home or office?

In D.C., the answer is often yes. The district has a walkability score of 77, making it by some counts America's seventh most walkable large city.

But of its approximately 1,000 miles, how many are accessible to someone in a wheelchair?

This fall, Jon Froehlich of the **University of Maryland's** Human-Computer Interaction Lab (HCIL) debuted a new tool that can help answer that question.

MENU NEXT CITY

You Can Help Map the Accessibility of the World

JOSH COHEN OCTOBER 3, 2016

As I cross through the intersection of Independence Ave and 19th Street in Washington, D.C.'s Hill East neighborhood, I make note of four high-quality curb ramps coming off the sidewalks and into the streets. Making my way past the D.C. Armory, I keep my eyes peeled for cracks in the sidewalk and pavement warped by tree roots, but this appears to be a pretty well-maintained stretch. I spot a few more curb ramps and note they're narrower than the previous bunch and perhaps not up to code. One driveway crossing is built at sidewalk height, but the asphalt touching the sidewalk is starting to crack, creating a little gap that could pose a problem.

ACKNOWLEDGEMENTS

PROJECT SIDEWALK TEAM


Manaswi Saha

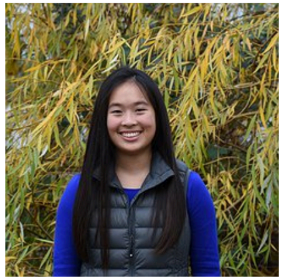

Michael Saugstad


Galen Weld


Ather Sharif


Hanuma Teja Maddali


Jon Froehlich


Aileen Zeng

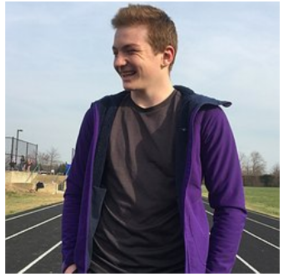

Hank Tadeusaik


Tim Nguyen


Marianne Aubin Le Quéré


Anthony Li


Steven Bower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Aditya Dash


Sage Chen


Kotaro Hara

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Project Sidewalk: Mapping the Accessibility of the Physical World **at Scale** using Interactive Computational Tools

Manaswi Saha

PhD Student | Computer Science | University of Washington

Any Questions?

Help make the world more accessible for everyone!

Join us. Contact manaswi@cs.uw.edu manaswisaha

https://github.com/ProjectSidewalk http://projectsidewalk.io/api

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