



CROWD + AI TOOLS FOR SCALABLE SIDEWALK ASSESSMENT

Jon E. Froehlich
University of Washington

Spatial Data Science Symposium
Dec 13, 2021

SDSS'21 URBAN ACCESSIBILITY

ABOUT ME



Minnesota
Childhood



**Computer
Engineering**
Bachelors



**Information &
Computer Science**
Masters



Computer Science
PhD



Computer Science
Professor (2012-2017)

*Back to UW in
2017 as a CS Prof!*



Voting with Your Feet: An Investigative Study of the Relationship Between Place Visit Behavior and Preference*

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Abstract. Real world recommendation systems, personalized mobile search, and online city guides could all benefit from data on personal place preferences. However, collecting explicit rating data of locations as users travel from place to place is impractical. This paper investigates the relationship between explicit place ratings and implicit aspects of travel behavior such as visit frequency and travel time. We conducted a four-week study with 16 participants using a novel sensor-based experience sampling tool, called My Experience (Me), which we developed for mobile phones. Over the course of the study Me was used to collect 3,458 in-situ questionnaires on 1,981 place visits. Our results show that, first, sensor-triggered experience sampling is a useful methodology for collecting targeted information in situ. Second, despite the complexities underlying travel routines and visit behavior, there exist positive correlations between place preference and automatically detectable features like visit frequency and travel time. And, third, we found that when combined, visit frequency and travel time result in stronger correlations with place rating than when measured individually. Finally, we found no significant difference in place ratings due to the presence of others.

1 Introduction

Why do we travel to some places but not others? What do these places say about our interests? Could a person's movements to and from places in the physical world be an implicit form of expressing preference? We studied the travel routines of 16 participants over the course of four-weeks to determine what factors of visit behaviors, if any, could be used to infer preference for places. Using GSM-based location sensing and experience sampling on mobile phones (a technique to capture self-report data from participants in situ), participants provided explicit ratings for the places they visited. We used these ratings to explore the correlation between place preference and two implicit aspects of place visit behavior, *visit frequency* and *travel distance*. In

* This work was approved by the University of Washington Human Subjects Division, application id: HSD# 05-6963-EC 01.

Route Prediction from Trip Observations

Jon Froehlich
University of Washington

John Krumm
Microsoft Research

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ABSTRACT

This paper develops and tests algorithms for predicting the end-to-end route of a vehicle based on GPS observations of the vehicle's past trips. We show that a large portion of a typical driver's trips are repeated. Our algorithms exploit this fact for prediction by matching the first part of a driver's current trip with one of the set of previously observed trips. Rather than predicting upcoming road segments, our focus is on making long term predictions of the route. We evaluate our algorithms using a large corpus of real world GPS driving data acquired from observing over 250 drivers for an average of 15.1 days per subject. Our results show how often and how accurately we can predict a driver's route as a function of the distance already driven.

INTRODUCTION

Route prediction is the missing piece in several proposed ideas for intelligent vehicles. In this paper, we present algorithms that predict a vehicle's entire route as it is driven. Such predictions are useful for giving the driver warnings about upcoming traffic hazards or information about upcoming points of interest, including advertising. One of the most innovative applications of end-to-end route prediction is for improving the efficiency of hybrid vehicles. Given knowledge of future changes in elevation and speed, a hybrid control system can optimize the vehicle's charge/discharge schedule. For example, if a hybrid vehicle knows about an upcoming opportunity to recharge its batteries from regenerative braking (e.g., stop-and-go traffic, sharp curves, or a steep hill), it can use up part of its battery power prior to the opportunity to make room for the expected incoming charge. Researchers from Nissan showed that it is possible to improve hybrid fuel economy by up to 7.8% if the route is known in advance [1]. Tate and Boyd also explore the optimal control scheme for a hybrid assuming the route is already known [2].

While the driver could be asked for his or her route before every drive, we suspect that most drivers would tire of this quickly. This is especially true for a driver's

regular routes, which is where we concentrate our efforts. We found that, for drivers observed for at least 40 days, nearly 60% of their trips were duplicated in our observations. Our prediction algorithms look at a GPS trace of a driver's current trip and attempt to find the best match to a previously driven trip. We find that, in some cases, we can predict a driver's route with 100% accuracy within the first two miles of the trip. Our accuracy is lower in other cases, and our results give details on how often our algorithm achieves various levels of prediction accuracy.

We trained and tested our algorithms on GPS data from 252 drivers. The next few sections describe how we cleaned our typically noisy GPS data, extracted distinct trips, and found drivers' regular routes. We then go on to describe two algorithms for route prediction and give details on how well they perform. First, we highlight some related work.

Route prediction for smart vehicles was addressed by Karbassi and Barth [3] for a car-sharing application. Their task was to predict which route a driver would take between given starting and ending drop-off stations. In our work, we do not rely on the driver to enter his/her destination. Torkkola *et al.* [4] learn destinations and routes from GPS data. As in our work, these learned routes are the basis for prediction, although their prediction algorithm is not given. Using a hidden Markov model learned from 46 sampled trips, Simmons *et al.* [5] predict destinations and routes based on knowledge of the road network. They quote an accuracy of predicting the next road segment as high as 99%, although in 95% of the cases the next road segment is the only one connected to the current one. Their rich model allows the incorporation of time-of-day, day-of-week, and speed sensitivity into their predictions. Their results show that only speed is a significant help in boosting their prediction accuracy. Patterson *et al.* [6] applied machine learning and a particle filter to people's GPS traces to predict their destination, route, and even mode of transportation from an inferred list of previous destinations. Our approach also differs from the short-term route prediction in [7]. In their work, the goal was to

2008-01-0201

UbiGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits

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ABSTRACT

The greatest contributor of CO₂ emissions in the average American household is personal transportation. Because transportation is inherently a mobile activity, mobile devices are well suited to sense and provide feedback about these activities. In this paper, we explore the use of personal ambient displays on mobile phones to give users feedback about sensed and self-reported transportation behaviors. We first present results from a set of formative studies exploring our respondents' existing transportation routines, willingness to engage in and maintain green transportation behavior, and reactions to early mobile phone "green" application design concepts. We then describe the results of a 3-week field study (N=13) of the UbiGreen Transportation Display prototype, a mobile phone application that semi-automatically senses and reveals information about transportation behavior. Our contributions include a working system for semi-automatically tracking transit activity, a visual design capable of engaging users in the goal of increasing green transportation, and the results of our studies, which have implications for the design of future green applications.

Author Keywords

Sustainability, transportation, ubicomp, ambient displays

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI); Miscellaneous.

INTRODUCTION

In 2005, Americans consumed 100 quadrillion British thermal units (BTUs) of energy [32], almost six times the worldwide average per person [20]. This in turn caused the release of 2.2 billion metric tons of carbon dioxide (CO₂), a greenhouse gas assumed to be a major cause of adverse climate change. To reverse this trend, action will be required on many levels, including policy, infrastructure,

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CHI 2009, April 4–9, 2009, Boston, Massachusetts, USA.
Copyright 2009 ACM 978-1-60558-246-7/09/04...\$5.00.



Figure 1 (left) The UbiGreen Transportation Display shows transit behavior as "wallpaper" on a phone's screen. Here the tree is mostly full of leaves, indicating that the user has completed several green trips for the week. (top) The MSP sensor worn near the waist and the phone's GSM cell tower data are used to semi-automatically infer transportation mode.

and individual change. Given the growing prevalence of mobile phones with sensing capabilities, one compelling opportunity to potentially impact human behavior is to offer immediate feedback about how currently sensed behaviors affect the environment. In this paper, we explore the use of personal ambient displays on mobile phones to give users feedback about their sensed and self-reported transportation behaviors (Figure 1).

Researchers have identified three areas responsible for a majority of energy consumption in American households: home heating and cooling; shopping and eating (and the associated transportation of goods); and commuting, flying and other daily transportation activities [3,35]. In this paper, we focus on the latter (personal transportation), the greatest individual contributor of CO₂ emissions (26%) in the average American household [35].

There is extensive literature in the areas of environmental sociology, public policy, and more recently, conservation psychology that discuss the promotion of environmentally responsible behavior [1,2,26,33]. Past work has shown that motivators such as public commitment, frequent feedback, and personalization can positively impact environmentally responsible behavior [1]. Since the 1990s, information campaigns and other programs have attempted to engage individuals in voluntary greening of transportation behavior

Sensing and Predicting the Pulse of the City through Shared Bicycling

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Abstract

City-wide urban infrastructures are increasingly reliant on network technology to improve and expand their services. As a side effect of this digitalization, large amounts of data can be sensed and analyzed to uncover patterns of human behavior. In this paper, we focus on the *digital footprints* from one type of emerging urban infrastructure: shared bicycling systems. We provide a spatiotemporal analysis of 13 weeks of bicycle station usage from Barcelona's shared bicycling system, called Bicing. We apply clustering techniques to identify shared behaviors across stations and show how these behaviors relate to location, neighborhood, and time of day. We then compare experimental results from four predictive models of near-term station usage. Finally, we analyze the impact of factors such as time of day and station activity in the prediction capabilities of the algorithms.



Figure 1. (top) A Bicing station; a close-up of a bicycle and parking slot; and a user at a station kiosk using RFID to check-out a bicycle; (bottom) The 390 Bicing stations distributed across the city of Barcelona, Spain.

1 Introduction

Observing and modeling human movement in urban environments is central to traffic forecasting, understanding the spread of biological viruses, designing location-based services, and improving urban infrastructure. However, little has changed since Whyte (1980) observed in his "Street Life Project" that the *actual* usage of New York's streets and squares clashed with the original ideas of architects and city planners. A key difficulty faced by urban planners, virologists, and social scientists is that obtaining large, real-world observational data of human movement is challenging and costly (Brockman *et al.*, 2006).

As websites have evolved to offer geo-located services, new sources of real-world behavioral data have begun to emerge. For example, Rattenbury *et al.* (2007) and Girardin *et al.* (2008) used geo-tagging patterns of photographs on Flickr to automatically detect interesting real-world events and draw conclusions about the flow of tourists in a city. In addition, as city-wide urban infrastructures such as buses, subways, public utilities, and roads become digitized, other sources of real-world datasets that can be implicitly sensed are emerging. Ratti *et al.* (2006) and González *et al.* (2008) used cellular network data to study city dynamics and

human mobility. McNamara *et al.* (2008) used data collected from an RFID-enabled subway system to predict co-location patterns amongst mass transit users. Such sources of data are ever-expanding and offer large, under-explored datasets of physically-based interactions with the real world.

In this paper, we introduce a novel source of real-world human behavioral data from a new type of urban infrastructure: shared bicycling systems. We show how station usage data from Barcelona's Bicing system (Figure 1) can be used to infer cultural and geographic aspects of the city and predict future bicycling station usage behavior, which corresponds to human movement in the city.

In particular, the main contributions of this paper are: (1) demonstrating the potential of using shared bicycling as a data source to gain insights into city dynamics and aggregated human behavior; (2) exploring the relationship between spatiotemporal patterns of bicycle usage and underlying city behavior and geography; and (3) studying patterns in bicycle station usage, including the prediction of usage patterns and an analysis of how factors such as the time of the day affect this prediction. In our analysis, we emphasize not just what the bicycling station usage data

UbiComp'06

SAE'08

CHI'09

IJCAI'09

MAKEABILITY LAB

2019 Retreat



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



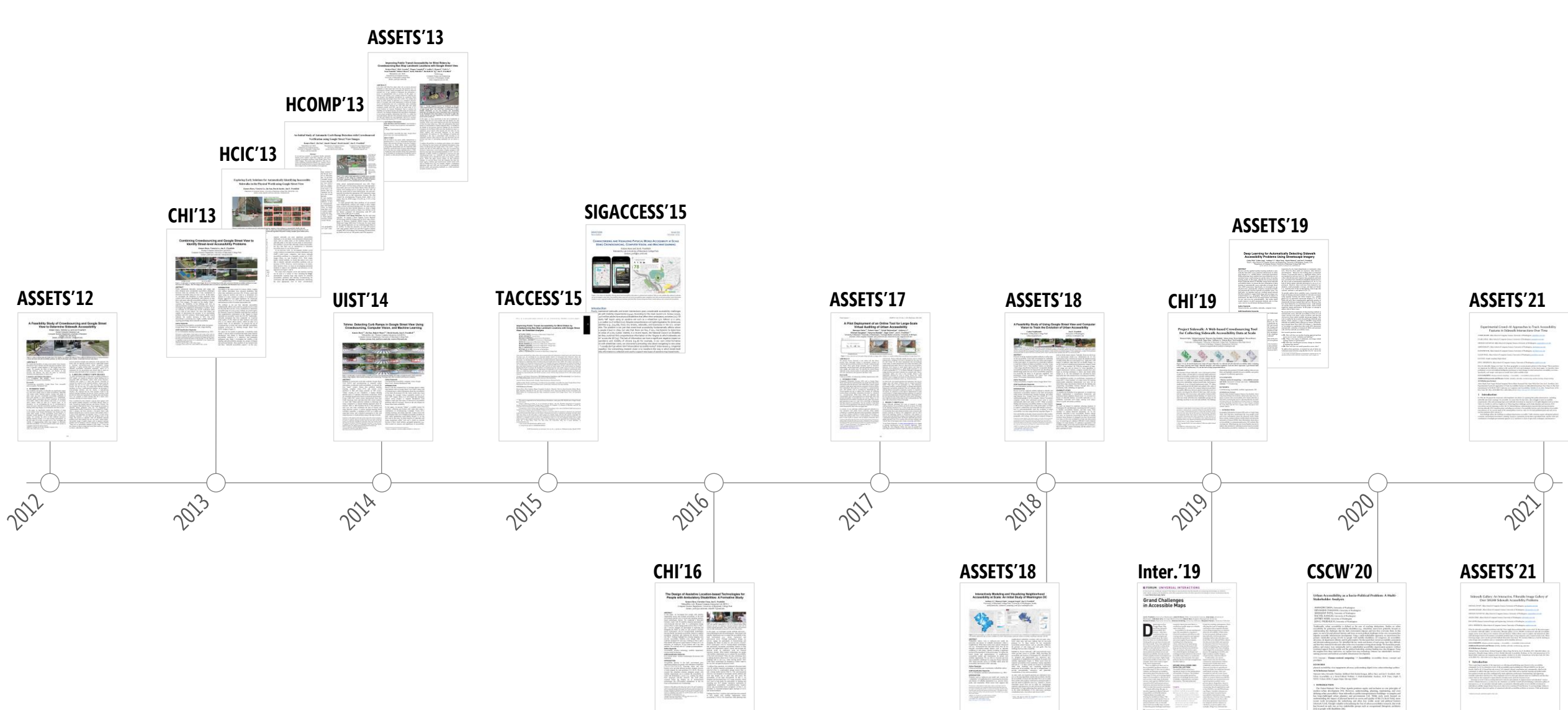
National Council on Disability, 2007

The impact of the Americans with Disabilities Act: Assessing the progress toward achieving the goals of the ADA



OUR OVERARCHING VISION

Develop crowd+AI techniques to map and assess every sidewalk in the world





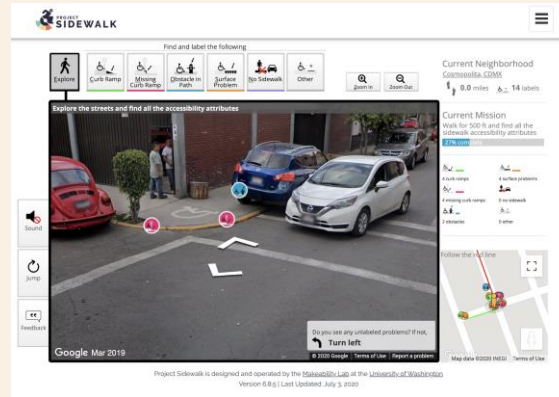
PROJECT
SIDEWALK

<http://projectsidewalk.org>

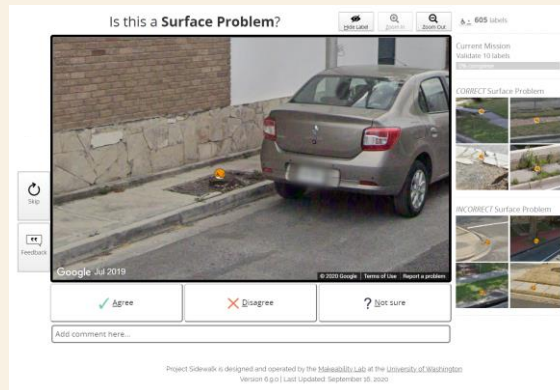
ONLINE MAP
IMAGERY



REMOTE
CROWDSOURCING
INTERFACES

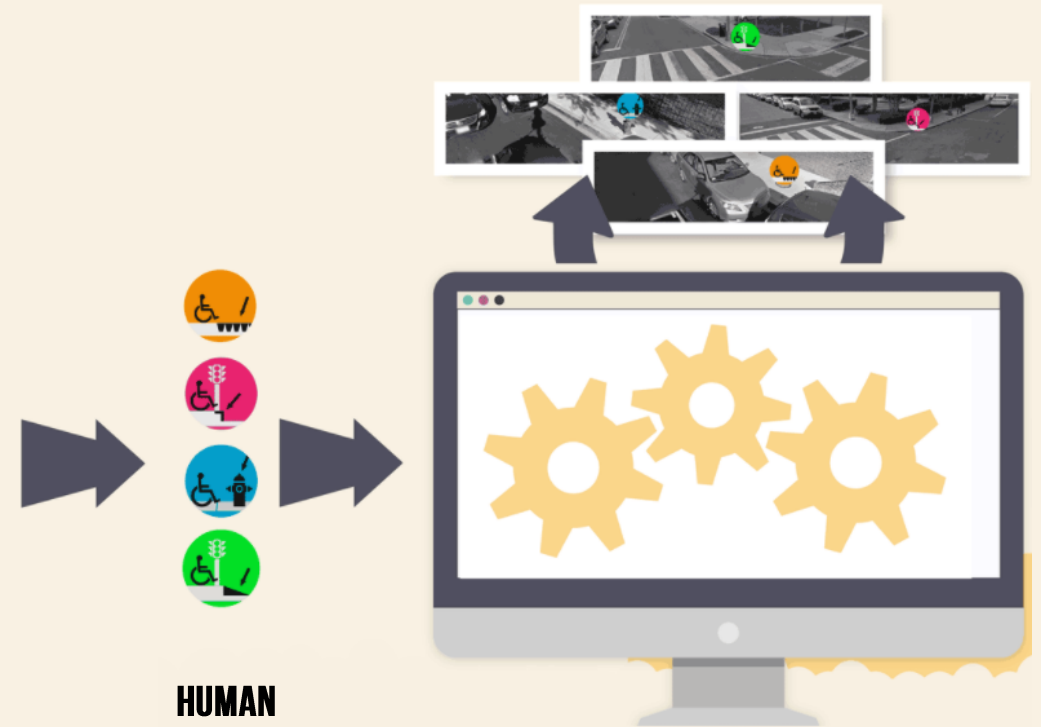


Labeling missions



Validation missions

MACHINE
LEARNING



HUMAN
LABELS



PROJECT

SIDEWALK

[HTTP://PROJECTSIDEWALK.IO](http://PROJECTSIDEWALK.IO)

PROJECT SIDEWALK

REMOTE CROWDSOURCING



**LABELING MEXICO
CITY FROM GERMANY!**

PILOT DEPLOYMENT IN 2017

Find and label the following

Explore Curb Ramp Missing Curb Ramp Obstacle in Path Surface Problem Other

Zoom In Zoom Out Undo Redo

Current Neighborhood
Monumental Core, D.C.

0.1 miles 0 labels

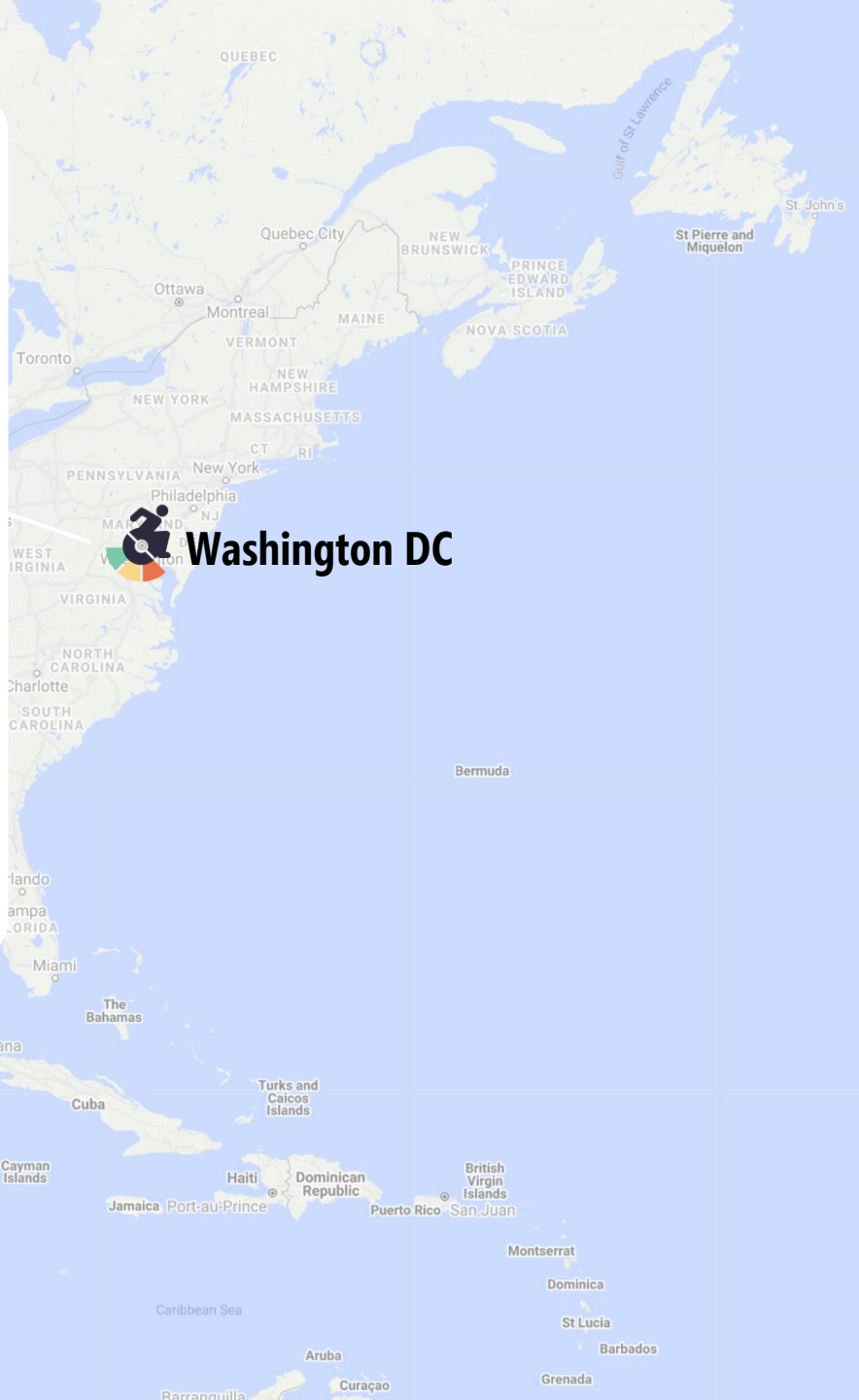
Current Mission
Audit 1000ft of this neighborhood
43% complete

5 curb ramps
0 missing curb ramp
0 obstacle
0 surface problem
0 other

Follow the red line

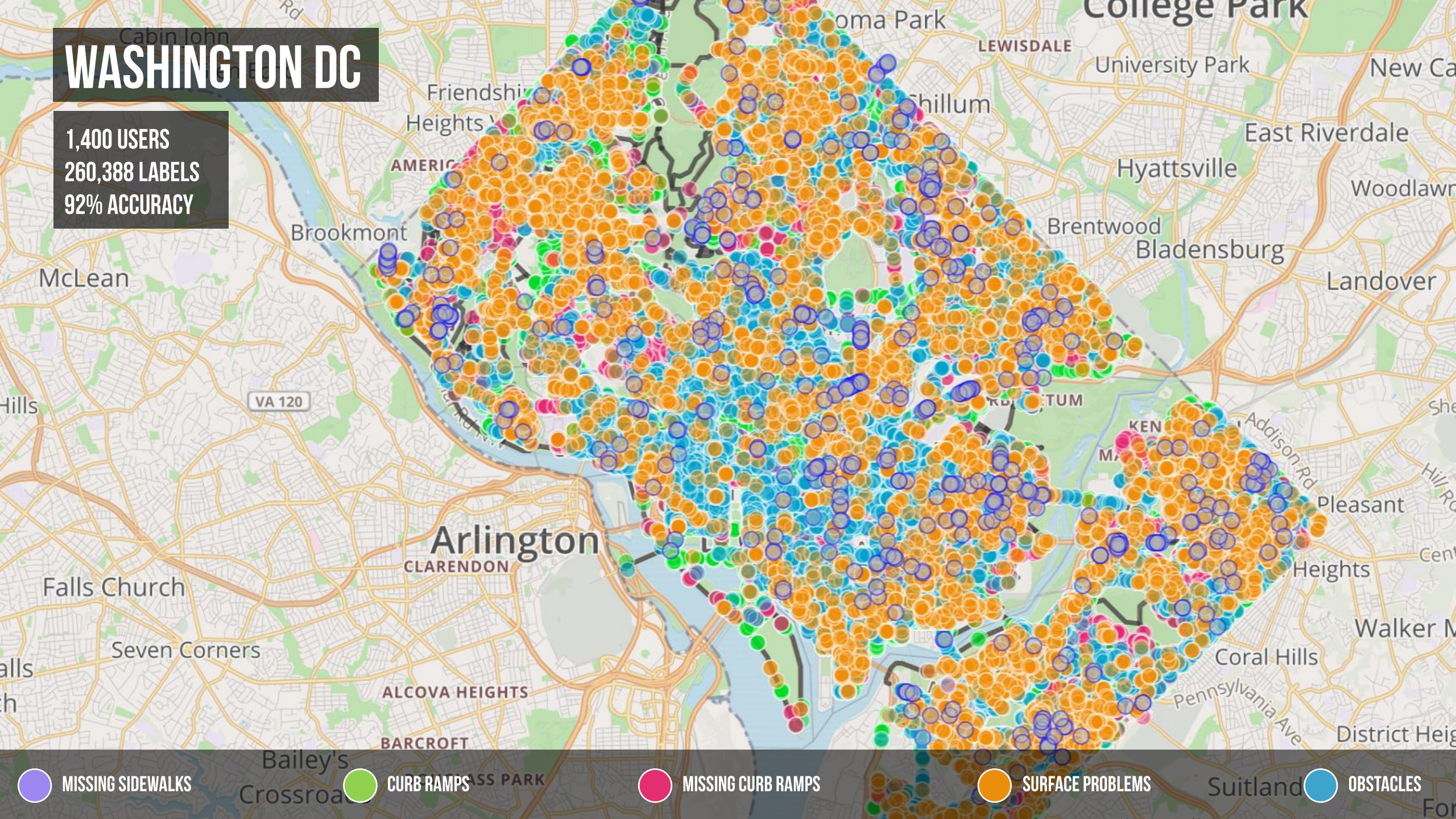
Do you see any unlabeled problems? If not, Turn right

© 2017 Google Terms of Use Report a problem



WASHINGTON DC

1,400 USERS
260,388 LABELS
92% ACCURACY



MISSING SIDEWALKS



CURB RAMPS



MISSING CURB RAMPS





SURFACE PROBLEMS




OBSTACLES

 **Seattle, WA**

 **Newberg, OR**

Chicago, IL 

Columbus, OH 

Pittsburgh, PA 

 **Washington DC**

 **San Pedro Garza García, MX**

 **Mexico City, MX**

GROWING DATA



10,000+
USERS




650,000
LABELS



235,000
VALIDATIONS

 **Seattle, WA**

 **Newberg, OR**

Chicago, IL 

Columbus, OH 

Pittsburgh, PA 

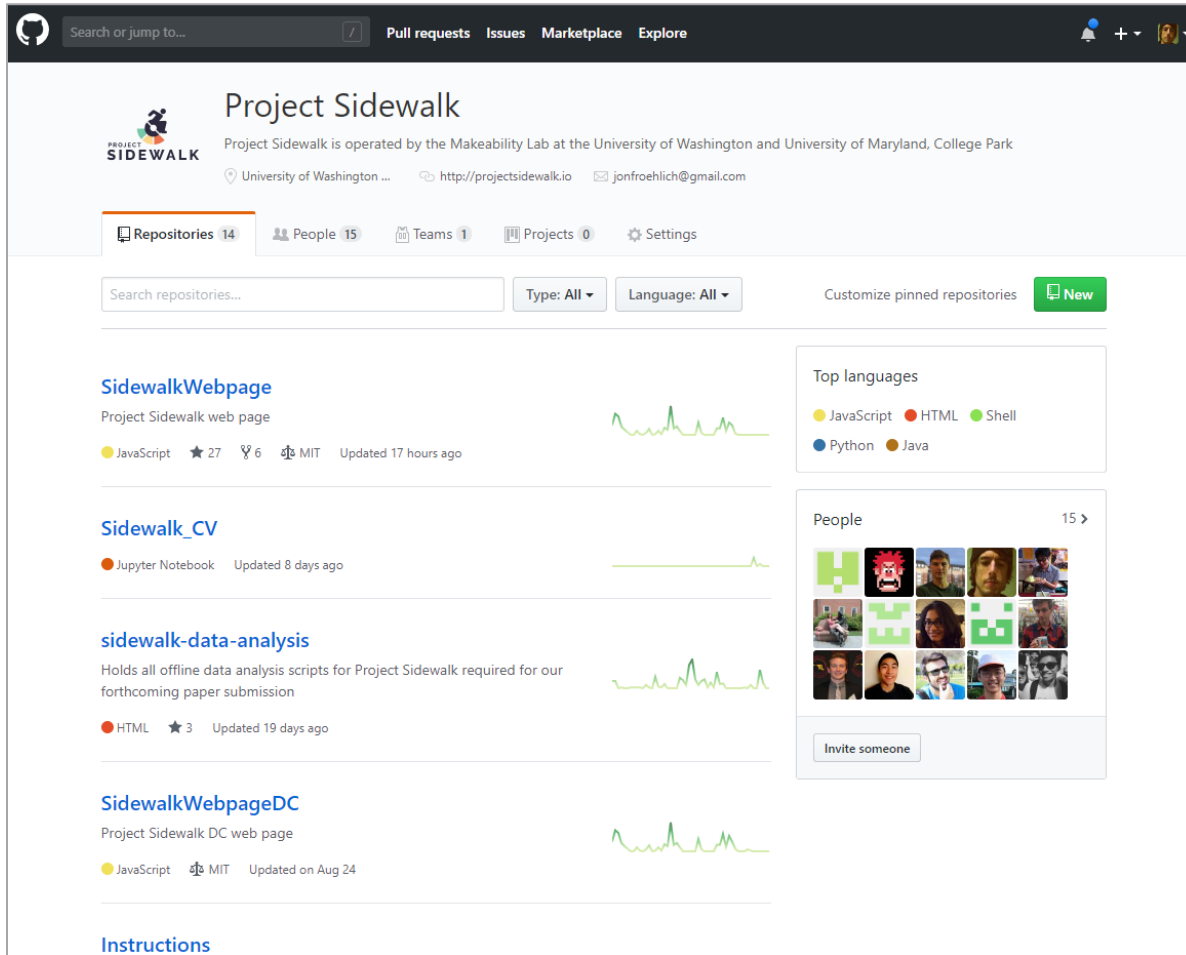
Washington, DC 

 **San Pedro Garza García, MX**

 **Mexico City, MX**

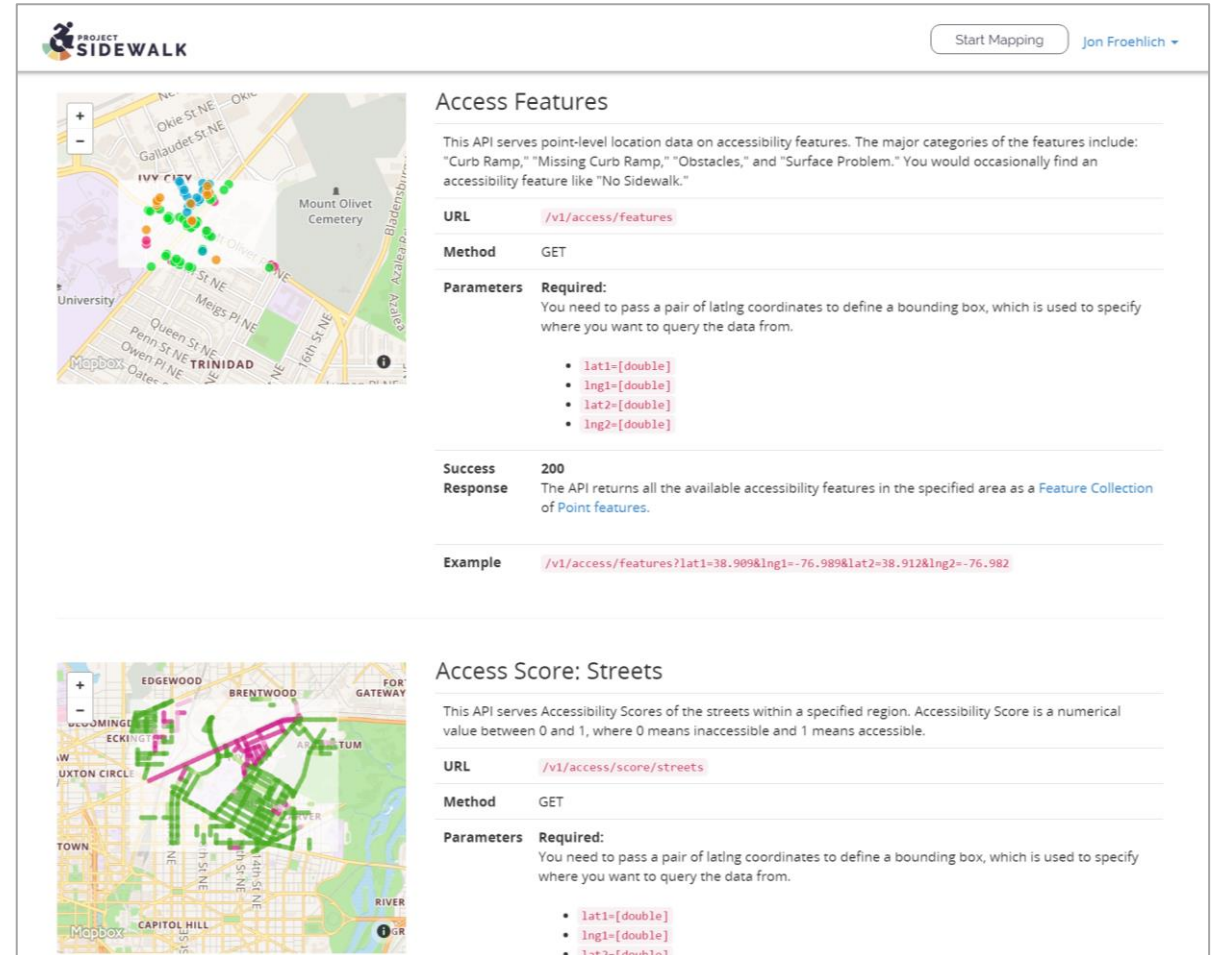
PROJECT SIDEWALK

ALL OUR CODE + DATA IS 100% OPEN SOURCE



The screenshot shows the GitHub repository page for Project Sidewalk. The header includes the GitHub logo, a search bar, and navigation links for Pull requests, Issues, Marketplace, and Explore. The repository name "Project Sidewalk" is prominently displayed, along with a description: "Project Sidewalk is operated by the Makeability Lab at the University of Washington and University of Maryland, College Park". Below this, there are statistics for Repositories (14), People (15), Teams (1), and Projects (0). A search bar for repositories is present, along with filters for Type and Language. The main content area lists several repositories: "SidewalkWebpage" (JavaScript, 27 stars, updated 17 hours ago), "Sidewalk_CV" (Jupyter Notebook, updated 8 days ago), "sidewalk-data-analysis" (HTML, 3 stars, updated 19 days ago), and "SidewalkWebpageDC" (JavaScript, updated on Aug 24). A sidebar on the right shows "Top languages" (JavaScript, HTML, Shell, Python, Java) and a "People" section with a grid of profile pictures and an "Invite someone" button.

<https://github.com/ProjectSidewalk>



The screenshot shows the Project Sidewalk API documentation page. The header includes the Project Sidewalk logo, a "Start Mapping" button, and the user name "Jon Froehlich". The page is divided into two main sections: "Access Features" and "Access Score: Streets". Each section includes a map of a city area with colored dots or lines representing the data. The "Access Features" section describes the API that serves point-level location data on accessibility features, with a list of categories: "Curb Ramp," "Missing Curb Ramp," "Obstacles," and "Surface Problem." It provides the URL `/v1/access/features`, the Method `GET`, and the Parameters `Required:` (You need to pass a pair of latlng coordinates to define a bounding box, which is used to specify where you want to query the data from). The Success `200` indicates that the API returns all the available accessibility features in the specified area as a `Feature Collection` of `Point` features. The Example URL is `/v1/access/features?lat1=38.909&lng1=-76.989&lat2=38.912&lng2=-76.982`. The "Access Score: Streets" section describes the API that serves Accessibility Scores of the streets within a specified region. It provides the URL `/v1/access/score/streets`, the Method `GET`, and the Parameters `Required:` (You need to pass a pair of latlng coordinates to define a bounding box, which is used to specify where you want to query the data from). The Example URL is `/v1/access/score/streets?lat1=38.909&lng1=-76.989&lat2=38.912&lng2=-76.982`.

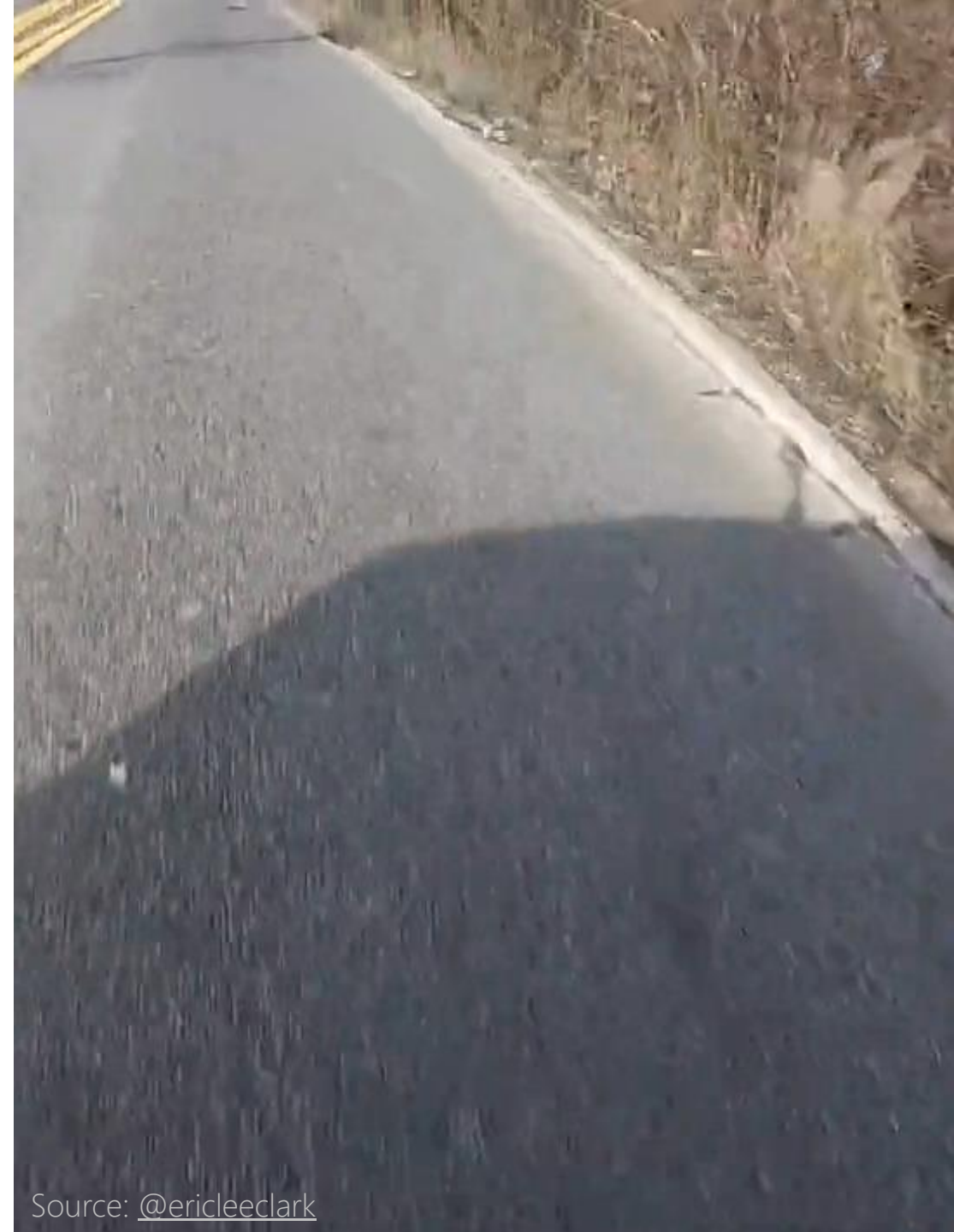
<http://projectsidewalk.io/api>

QUESTIONS

How can we combine crowds + AI in new ways to improve sidewalk labeling efficacy and quality?

How can these emerging, cross-city datasets enable new urban science research and advocacy tools?

How is urban accessibility changing and where is it not?



Source: [@ericleeclark](#)

Deep Learning for Automatically Detecting Sidewalk Accessibility Problems Using Streetscape Imagery

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ABSTRACT

Recent work has applied machine learning methods to automatically find and/or assess pedestrian infrastructure in online map imagery (*e.g.*, satellite photos, streetscape panoramas). While promising, these methods have been limited by two interrelated issues: small training sets and the choice of machine learning model. In this paper, aided by the recently released Project Sidewalk dataset of 300,000+ image-based sidewalk accessibility labels, we present the first examination of deep learning to automatically assess sidewalks in Google Street View (GSV) panoramas. Specifically, we investigate two application areas: automatically *validating* crowdsourced labels and automatically *labeling* sidewalk accessibility issues. For both tasks, we introduce and use a residual neural network (ResNet) modified to support both image and non-image (contextual) features (*e.g.*, geography). We present an analysis of performance, the effect of our non-image features and training set size, and cross-city generalizability. Our results significantly improve on prior automated methods and, in some cases, meet or exceed human labeling performance.

Author Keywords

Neural networks, accessibility, sidewalks, computer vision

ACM Classification Keywords

I.2.10 Artificial Intelligence; Vision and Graphics; H.3.1 Information Systems and Information Technology

inspections by city transit departments or community volunteers. However, these audits are expensive, labor intensive, and infrequent.¹ Moreover, the resulting data is in disparate formats, is not typically open (*i.e.*, published online), and is not intended for end-user tools [23, 50]. To expand who can collect sidewalk data and to improve data granularity and freshness, researchers have introduced smartphone-based tools [15, 46, 52] as well as instrumented wheelchairs [35, 39, 51, 57], both of which capture sidewalk information *in situ* as it's experienced. However, these tools have been limited by low adoption, small geographic coverage, and high user burden (*e.g.*, requiring users to take out their phones, load an app, take a picture, annotate it, and upload it) [20, 23].

To partially address these scalability issues, researchers have begun developing automated methods for sidewalk assessment using machine learning and online imagery (*e.g.*, satellite photos [10, 8], panoramic streetscape imagery [31, 32, 59]). While still early, these complementary approaches promise to dramatically decrease manual labor and cost. However, they have been limited by two interrelated issues: small training sets and the choice in machine learning model—both of which negatively impact performance. In this paper, we attempt to address both of these issues.

We present the first examination of deep learning methods to

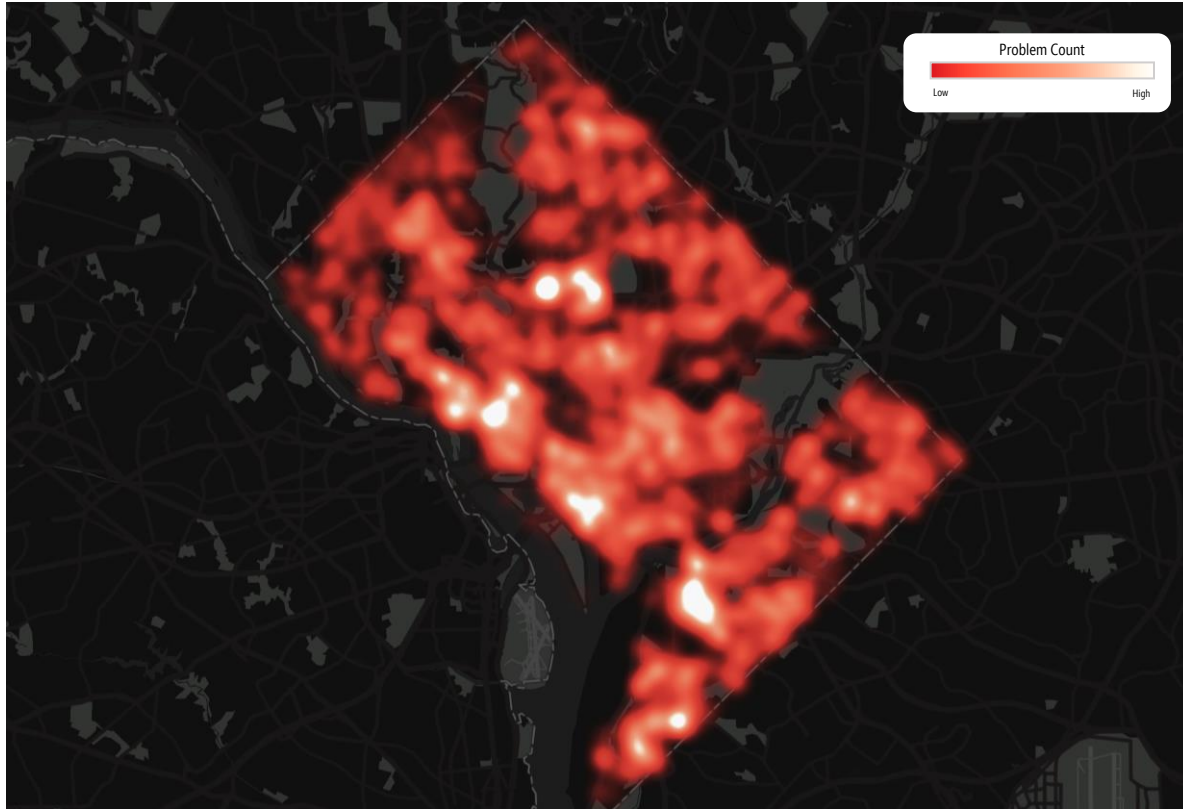
QUESTIONS

How can we combine crowds + AI in new ways to improve sidewalk labeling efficacy and quality?

How can these emerging, cross-city datasets enable new urban science research and advocacy tools?

How is urban accessibility changing and where is it not?

SUPPORT NEW URBAN SCIENCE EXPLORATIONS



What are the geo-spatial patterns and key correlates of sidewalk accessibility?

How does accessible infrastructure correspond to racial and socio-economic factors? How do these patterns compare across cities?



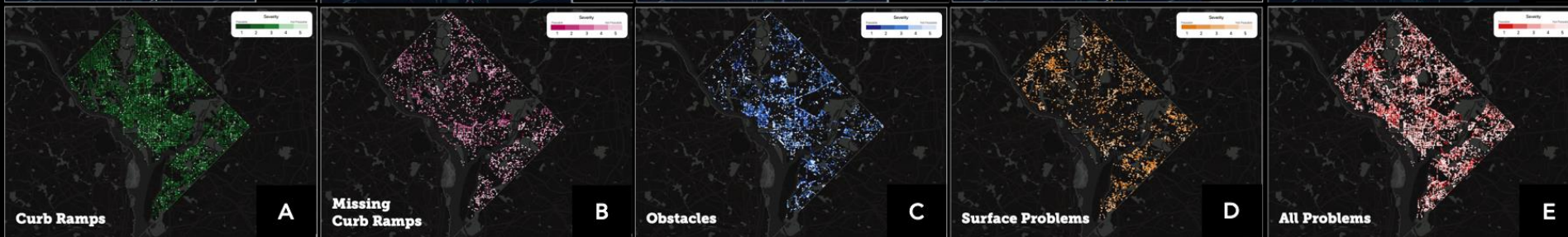
What do sidewalks look like across cities and countries? How does accessibility vary and why?

How does sidewalk accessibility reflect the socio-cultural and-political context of that region?

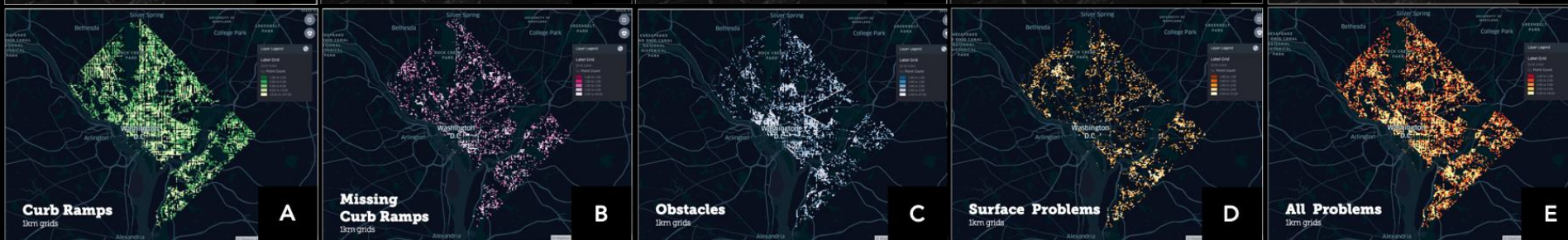
Type 1: Point-based



Type 2: Severity Point-based



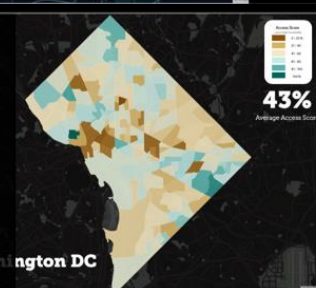
Type 3: Grid Maps



Type 4: Heatmaps



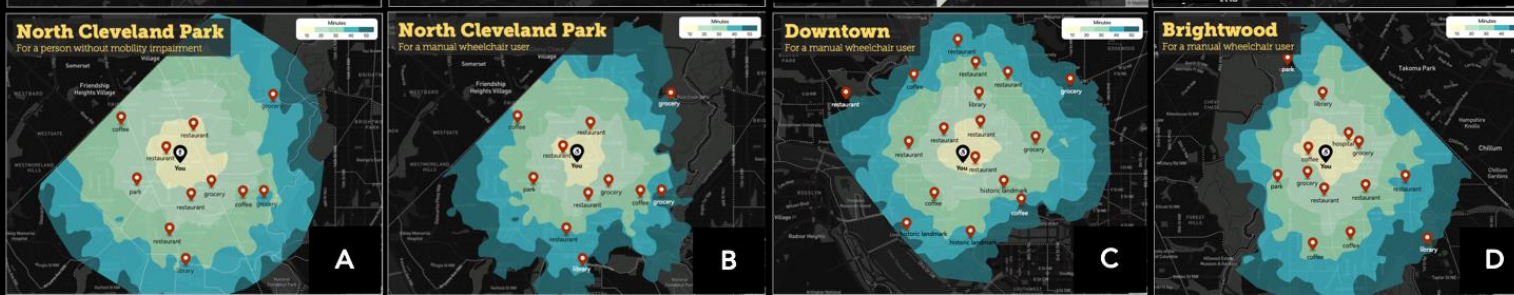
Type 5: Choropleth



Type 6: Street Viz



Type 7: Ego-centric Isochrones



7 Map Types
Total maps: 24

QUESTIONS

How can we combine crowds + AI in new ways to improve sidewalk labeling efficacy and quality?

How can these emerging, cross-city datasets enable new urban science research and advocacy tools?

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Go back in time with Street View

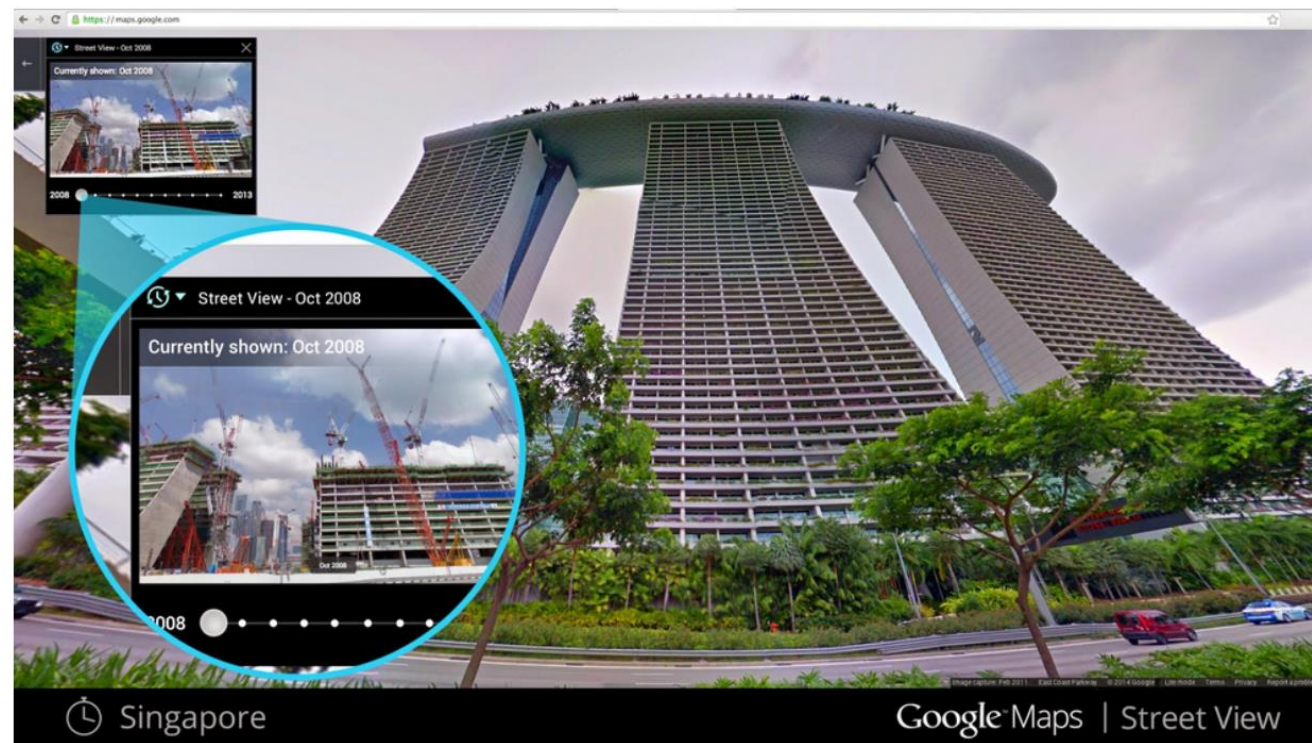


Vinay Shet

Google Street View Product Manager

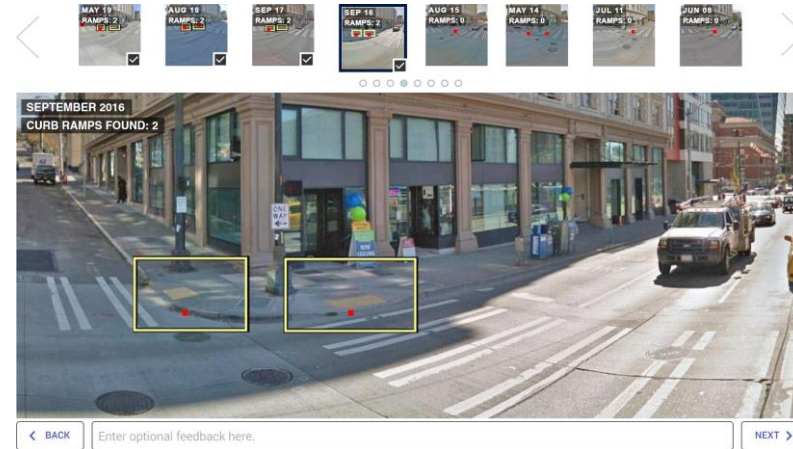
Apr 23, 2014 · 1 min read

Share



If you see a clock icon in the upper left-hand portion of a Street View image, click on it and move the slider through time and select a thumbnail to see that same place in previous years or seasons.

Prototype 1 Single View



Prototype 2 Grid View



Prototype 3 Panorama View



Experimental Crowd+AI Approaches to Track Accessibility Features in Sidewalk Intersections Over Time

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KAVI DEY, Seattle Academy High School

JON E. FROELICH, Allen School of Computer Science, University of Washington, jonf@cs.uw.edu

How do sidewalks change over time? Are there geographic or socioeconomic patterns to this change? These questions are important but difficult to address with current GIS tools and techniques. In this demo paper, we introduce three preliminary crowd+AI (Artificial Intelligence) prototypes to track changes in street intersection accessibility over time—specifically, curb ramps—and report on results from a pilot usability study.

CCS CONCEPTS • Human-centered computing → Accessibility → Accessibility systems and tools

Additional Keywords and Phrases: Mobility, disability, sidewalks, crowdsourcing, machine learning, change tracking

ACM Reference Format:

Ather Sharif, Paari Gopal, Michael Saugstad, Shiven Bhatt, Raymond Fok, Galen Weld, Kavi Dey, Jon E. Froelich. 2021. Experimental Crowd+AI Approaches to Track Accessibility Features in Sidewalk Intersections Over Time. In The 23rd International ACM SIGACCESS Conference on Computers and Accessibility, October 18–22, 2021, Virtual Event, ACM, New York, NY, USA. ACM ISBN 978-1-4503-8306-6/21/10. <https://doi.org/10.1145/3441852.3476549>

1 Introduction

In 1990, the US passed the *Americans with Disabilities Act* (ADA) [1] requiring that public infrastructure—including sidewalks and street crossings—be accessible. Yet, more than 30 years later, cities struggle to meet accessibility requirements, often only pursuing large-scale sidewalk renovations in response to civil rights litigation such as in New York [12], Seattle [3], and Los Angeles [13]. Observing these challenges and to help stimulate and structure ADA renovations and city planning, in 2015, the *US Federal Highway Administration* requested that local governments develop sidewalk ADA transition plans, including an inventory of accessibility barriers and a description of accessible renovations [25]. In a recent study of 401 municipalities, however, only 54 (13%) had published plans and only seven met the minimum ADA criteria [2].

Such findings reflect the challenge in making infrastructure accessible. Viable solutions require substantial political, economic, and technical investment—training, resources, community involvement, specialized tools, and the work and coordination of multiple governmental agencies [10]. And there is a lack of open tools, techniques, and datasets to



THANK YOU!

Jon E. Froehlich | jonf@cs.uw.edu

Visit <http://projectsidewalk.org/>