"YOU DON'T DO HCI"

STORIES OF PERSISTENCE, PUSHBACK, & PURSUIT

Jon E. Froehlich
Professor, Computer Science
Core Faculty, Urban Design & Planning
Associate Director, CREATE & PacTrans

SIGCHI Societal Impact Talk
Apr 14, 2026

MAKEABILITY LAB
DESIGN USE BUILD
CREATE Center for Research and Education on Accessible Technology and Experiences
PAUL G. ALLEN SCHOOL OF COMPUTER SCIENCE & ENGINEERING
UNIVERSITY of WASHINGTON

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UW CS


Kotaro Hara
UMD CS


Liang He
UW CS


Jared Hwang
UW CSE


Dhruv Jain
UW CS


Seokbin Kang
UMD CS


Jaewook Lee
UW CSE


Chu Li
UW CS


Matthew L Mauriello
UMD CS


Manaswi Saha
UW CSE


Mikey Saugstad
UW CS


Lee Stearns
UMD CS


Xia Su
UW CS


Daniel Campos Zamora
UW CS

SEVEN LESSONS

PhD Student

A MOUNTAIN
2008

A PIVOT
2006

A KNOCKDOWN
2009

Professor

A LAB
2011

A CULMINATION
2016


2008
VIEW FROM MY APARTMENT
BARCELONA CATHEDRAL
Photo by Jon E. Froehlich

2008

SHARED BICYCLING SYSTEMS

NURIA OLIVER

Froehlich *et al.*, IJCAI'09

Photos by Jon E. Froehlich

IJCAI'09

Froehlich, Neumann, Oliver
Sensing & Predicting the Pulse of the City through Shared Bicycling

Sensing and Predicting the Pulse of the City through Shared Bicycling

Jon Froehlich[1], Joachim Neumann[2], Nuria Oliver[2]

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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 in 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

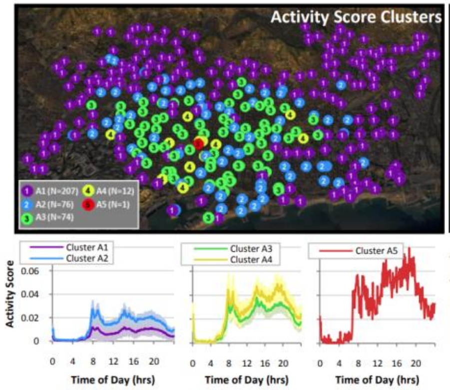


Figure 5. The five Activity Clusters created by progressively combining similar Activity Score station DayViews via dendrogram clustering.

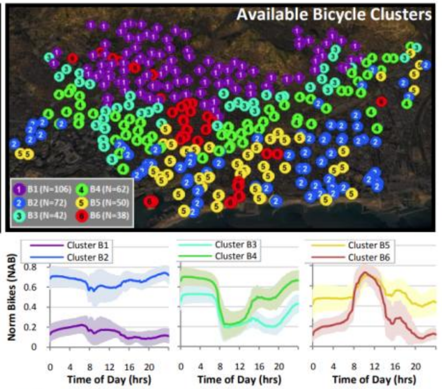


Figure 6. The six Bicycle Clusters created by progressively combining similar available bicycle DayView clusters via dendrogram clustering.

Activity Clusters. The clustering algorithm returned five activity clusters (Figure 5), each with a similar three-pronged spike shape (see also Figure 3). The clusters generally become more active (from A1 to A5) as one moves from the outward edges of the city into downtown. The least active cluster, Cluster A1 (N=207), surrounds nearly the entire perimeter of Barcelona. The more active clusters (A3, A4, and A5) become noticeably more active as the day advances.

Bicycle Clusters. Our algorithm identified six bicycle clusters (depicted in Figure 6) with three classes of behavior: *outgoing* (Clusters B3 and B4), *incoming* (Clusters B5 and B6) and *flat* (Clusters B1 and B2). The *outgoing* clusters show a precipitous drop in available bicycles around 7-8AM as people leave for work, a slight rise at 2-3PM during lunch and a return to early morning levels by 10-11PM. These stations are spread around the edges of the downtown and midtown sections of the city. The *incoming* stations are located in high density commercial areas and along two major arterial routes: Rambla de Catalunya and Avinguda Diagonal. The incoming station shape is nearly inverse of the outgoing stations: people begin arriving around 7-8AM and begin leaving around 1-2PM. Many financial businesses in Barcelona open at 9AM and close around 2:30PM, which aligns well with the temporal patterns of these two clusters. Finally, clusters B1 and B2 have relatively *flat* usage patterns. Cluster B2 tends to have a high degree of available bicycles (on average, it is 66% full) whereas cluster B1 is just the opposite (15% availability). One reason for this discrepancy is likely due to Barcelona's topography: the city itself is built on a long incline. Stations located at the top of Figure 6 are between 80-110 meters above sea level versus those at the bottom, which are at 0-10 meters above sea level. People tend not to bicycle up to the higher altitudes, thus leaving those stations in Cluster B1 starving for bicycles.

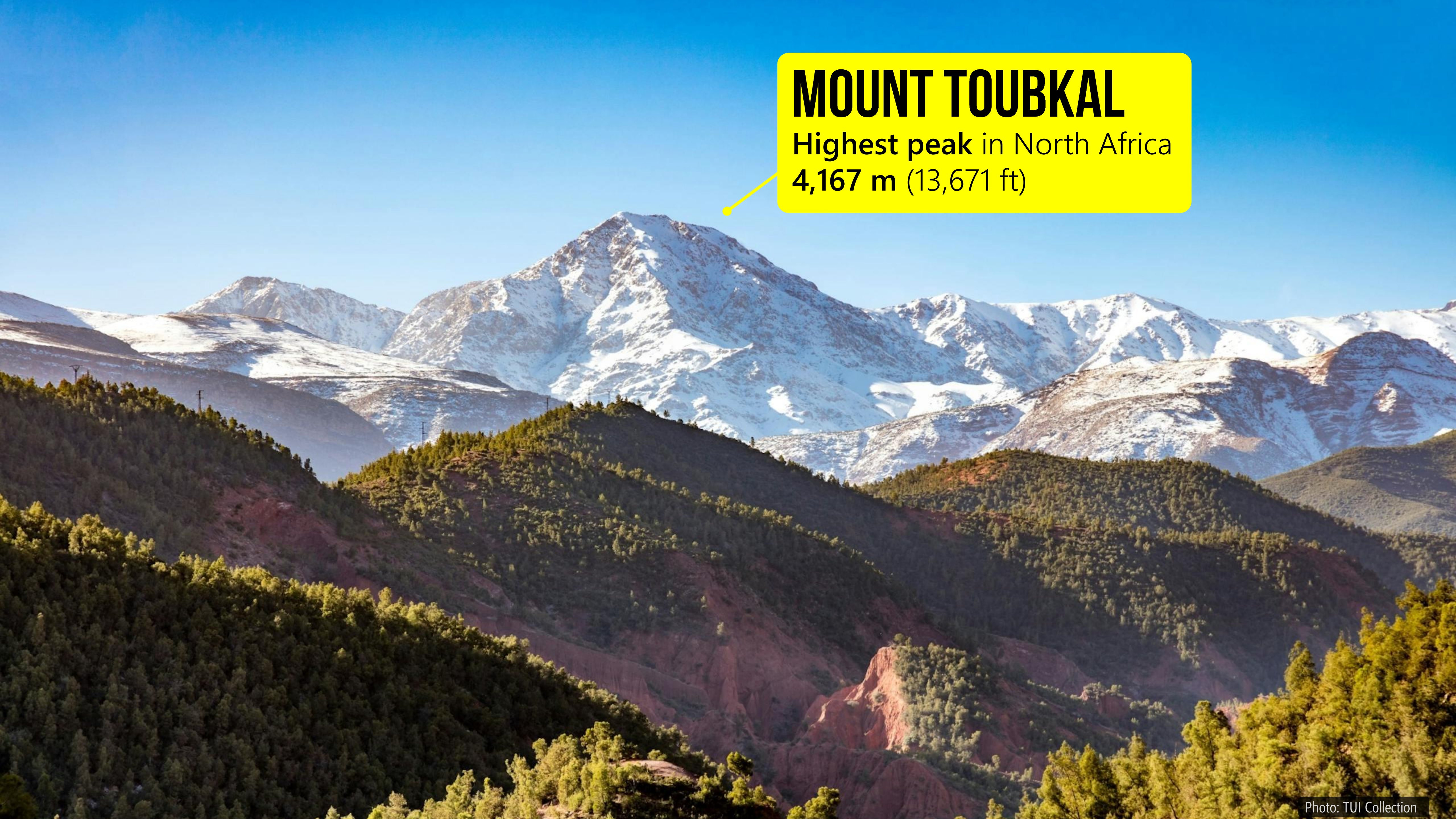
4 Station Behavior Prediction

We focus next on the prediction of station usage. In particular, we are interested in predicting the number of available bicycles at each station at a given time in the future. This work is related to traffic forecasting. Most approaches in traffic engineering rely on flow theory and incorporate queue-theoretic models (Vandaele *et al.*, 2000). Horvitz *et al.* (2005) took an alternative approach that is closely related to ours: they successfully modeled key traffic bottleneck areas using a Bayesian network and ignored the underlying flows. Similarly, we do not attempt to model individual bicycle movements in the city but rather focus on modeling Bicing station usage directly.

Predictive station usage models would (a) allow for more accurate load balancing of the stations; (b) assist urban planners and city officials by providing them with information about *expected* activity in the city; and (c) open the way to new mobile services for Bicing users. In the previously mentioned online survey, Bicing users identified *finding an available bicycle and parking slot* as the two most important problems in their Bicing experience (76% and 66% of respondents, respectively). Therefore, we are also interested in predicting the probability of finding a free bicycle and slot in a station at a given time in the future. Furthermore, our models shed light on some of the factors that influence the *predictability* of station usage behavior.

4.1 Models of Station Behavior

We have implemented four simple predictive models, including a Bayesian network (BN) to predict the availability of bicycles at each station. All models have three input parameters: (1) the current time t_0; (2) the last


MOUNT TOUBKAL
Highest peak in North Africa
4,167 m (13,671 ft)
Photo: TUI Collection

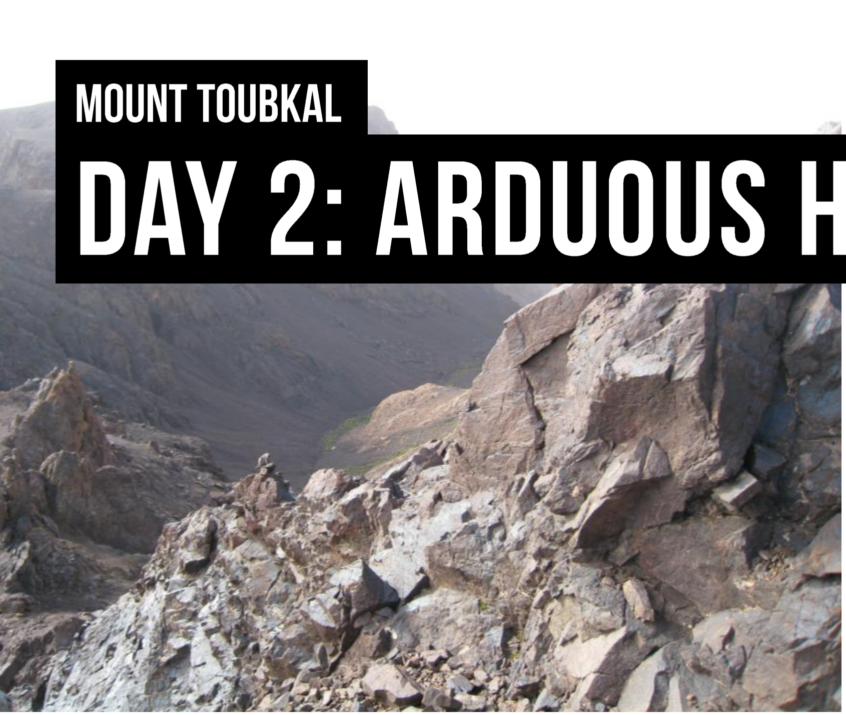
MOUNT TOUBKAL

DAY 1: HIKING TO BASE CAMP


MOUNT TOUBKAL
DAY 2: SUNRISE DEPARTURE
BASE CAMP

MOUNT TOUBKAL

DAY 2: ARDUOUS HIKE







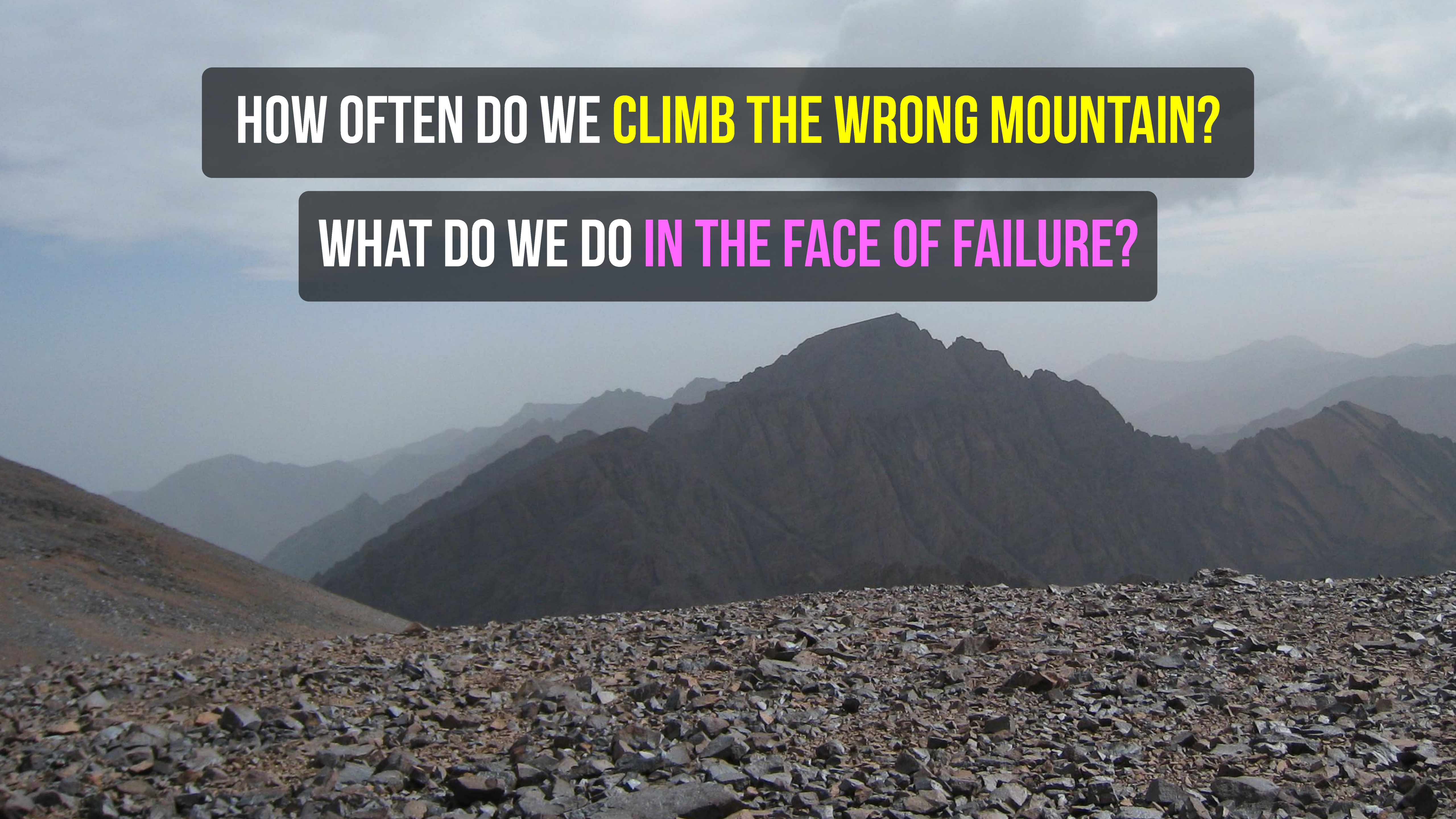
MOUNT TOUBKAL
DAY 2: THE PEAK
MADE IT!
Photo by Jon E. Froehlich

Photo by Jon E. Froehlich


MOUNT TOUBKAL
DAY 2: THE PEAK
TALLER MOUNTAIN!
Photo by Jon E. Froehlich


MOUNT TOUBKAL
DAY 2: THE PEAK
The Wrong
NOT ON MOUNT TOUBKAL
Photo by Jon E. Froehlich


HOW OFTEN DO WE CLIMB THE WRONG MOUNTAIN?


HOW OFTEN DO WE CLIMB THE WRONG MOUNTAIN?
WHAT DO WE DO IN THE FACE OF FAILURE?

MOUNT TOUBKAL

DAY 3: BEGIN AGAIN

MOUNT TOUBKAL

DAY 3: HIKING THE REAL MOUNT TOUBKAL


TOP OF MOUNT TOUBKAL
dub
Photo by Jon E. Froehlich

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key

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Oct 23, 2022	Not Accepted	Paper #23	ASSETS 2023 Technical Papers
Oct 23, 2022	Not Accepted	Paper #24	ASSETS 2023 Technical Papers
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Jan 12, 2021	Not Accepted	Paper #26	CHI 2021 Papers
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Apr 25, 2020	Not Accepted	Paper #32	CHI 2020 Papers
Jun 23, 2019	Not Accepted	Paper #33	DIS 2019 Papers
Feb 15, 2019	Not Accepted	Paper #34	IMWUT 2018 February 2019
	Not Accepted	Paper #35	CHI 2022 Papers
	Not Accepted	Paper #36	CHI 2022 Late-Breaking Work

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NSF			Utah State University View SAM Legal Business Name	NSF Convergence Accelerator Track H: Universal Pathways: AI...	Declined	12/08/2023	08/29/2023	$4,999,987
NSF			U of Washington View SAM Legal Business Name	Collaborative Research: Frameworks: Cyberinfrastructure to Catalyze and Sustain...	Declined	08/06/2023	12/15/2022	$1,047,892
NSF			U of Washington View SAM Legal Business Name	RETTL: Collaborative Research: Making Circuit Prototyping Accessible for...	Declined	06/04/2021	01/20/2021	$425,000
NSF			U of MD, College Park View SAM Legal Business Name	CHS: Medium: Collaborative Research: Wearable Sound Sensing and...	Declined	06/21/2017	10/19/2016	$1,099,579
NSF			U of MD, College Park View SAM Legal Business Name	CAREER: MakerWear: Computational Clothing as a Design Platform...	Declined	12/17/2015	07/21/2015	$694,147
NSF			U of MD, College Park View SAM Legal Business Name	HCC: Small: Personalizing Touchscreen Interaction Through Large-Scale Online...	Declined	09/20/2013	12/17/2012	$496,812

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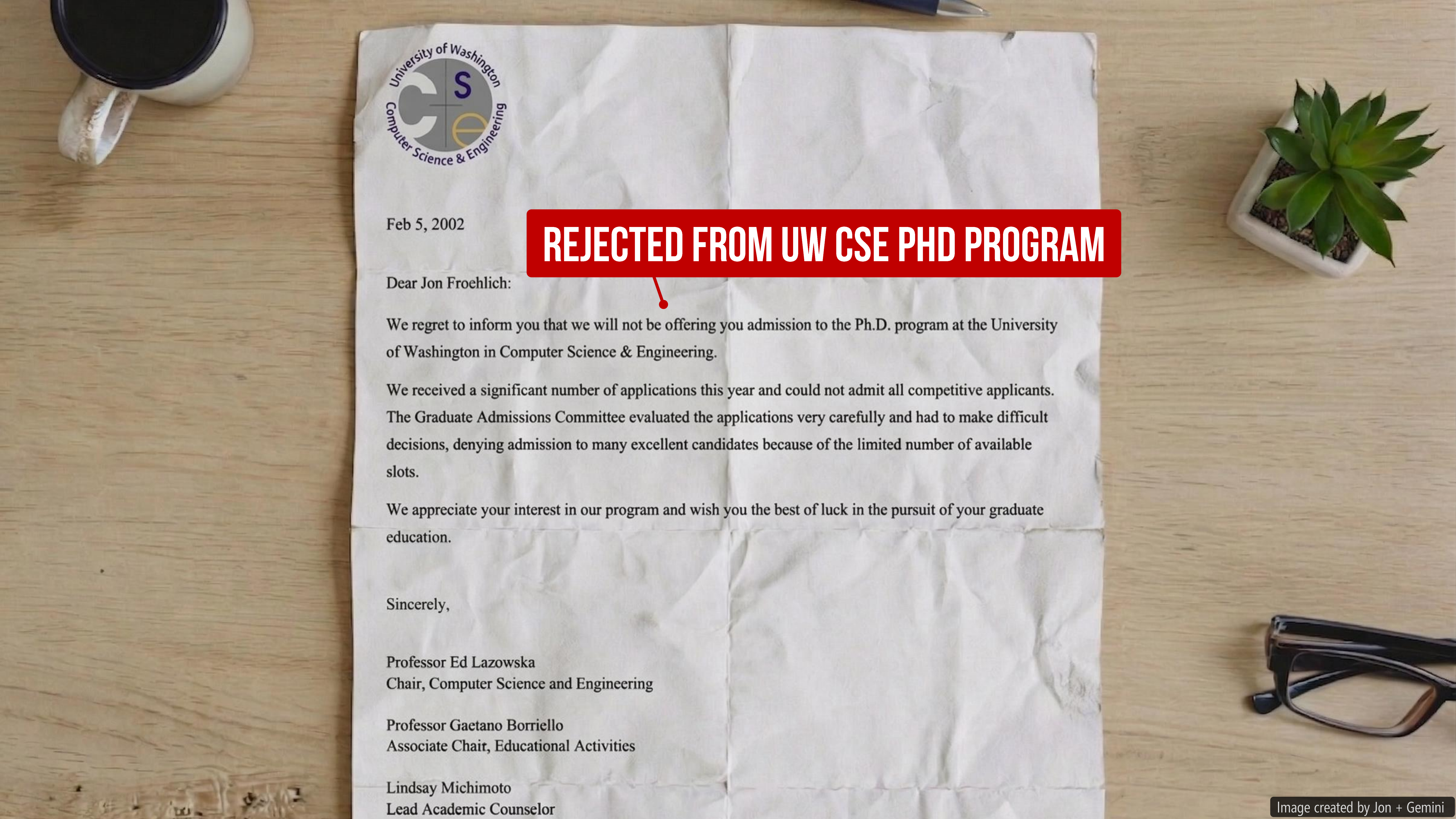

University of Washington
Computer Science & Engineering

Feb 5, 2002

Dear Jon Froehlich:

We regret to inform you that we will not be offering you admission to the Ph.D. program at the University of Washington in Computer Science & Engineering.

We received a significant number of applications this year and could not admit all competitive applicants. The Graduate Admissions Committee evaluated the applications very carefully and had to make difficult decisions, denying admission to many excellent candidates because of the limited number of available slots.

We appreciate your interest in our program and wish you the best of luck in the pursuit of your graduate education.

Sincerely,

Professor Ed Lazowska
Chair, Computer Science and Engineering

Professor Gaetano Borriello
Associate Chair, Educational Activities

Lindsay Michimoto
Lead Academic Counselor

Image created by Jon + Gemini

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key

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CHU LI

My PhD Student

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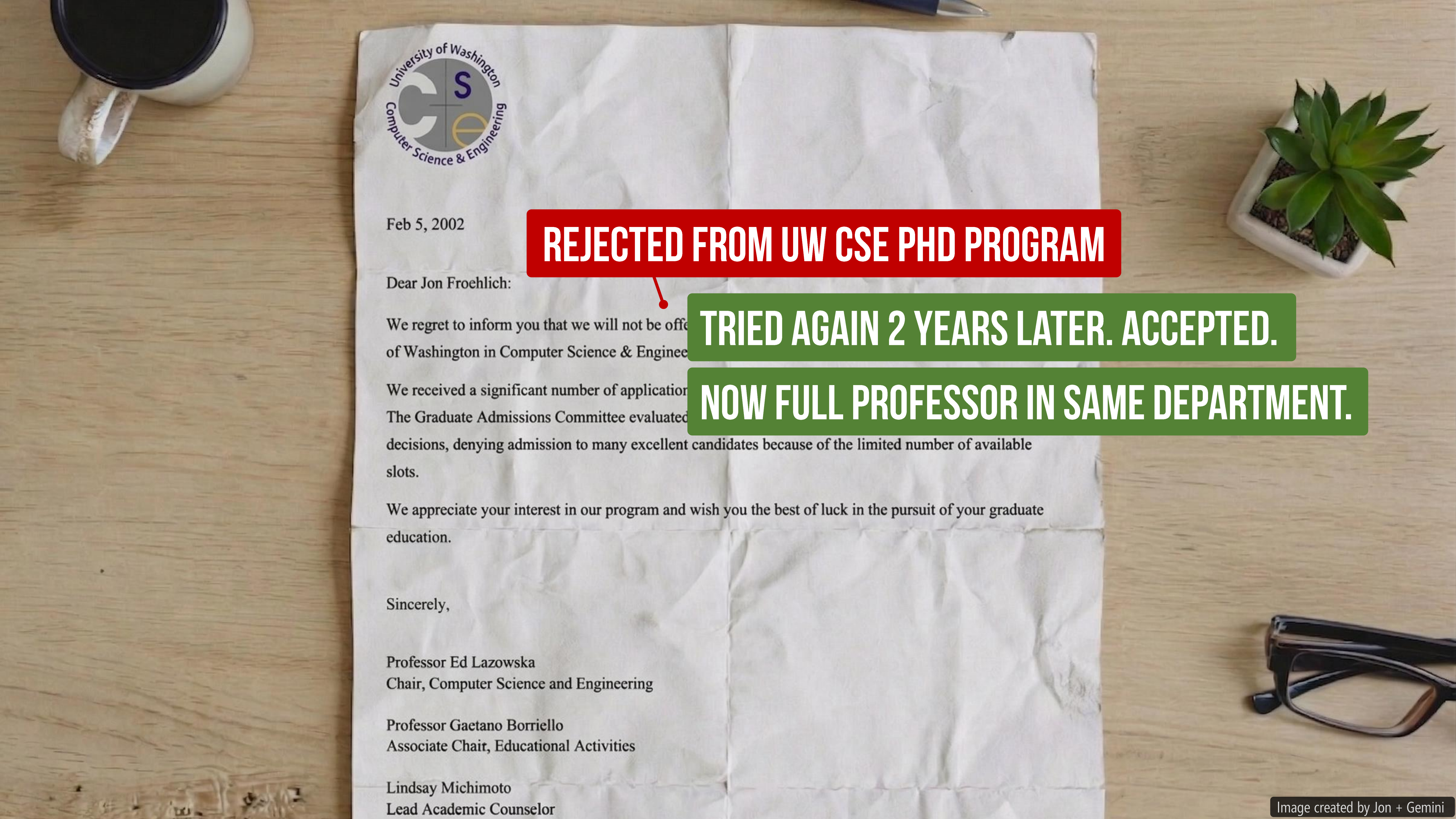

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Lead Academic Counselor


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MY CSE OFFICE
JAMES LANDAY

SIGCHI SOCIETAL IMPACT

SEVEN LESSONS LEARNED

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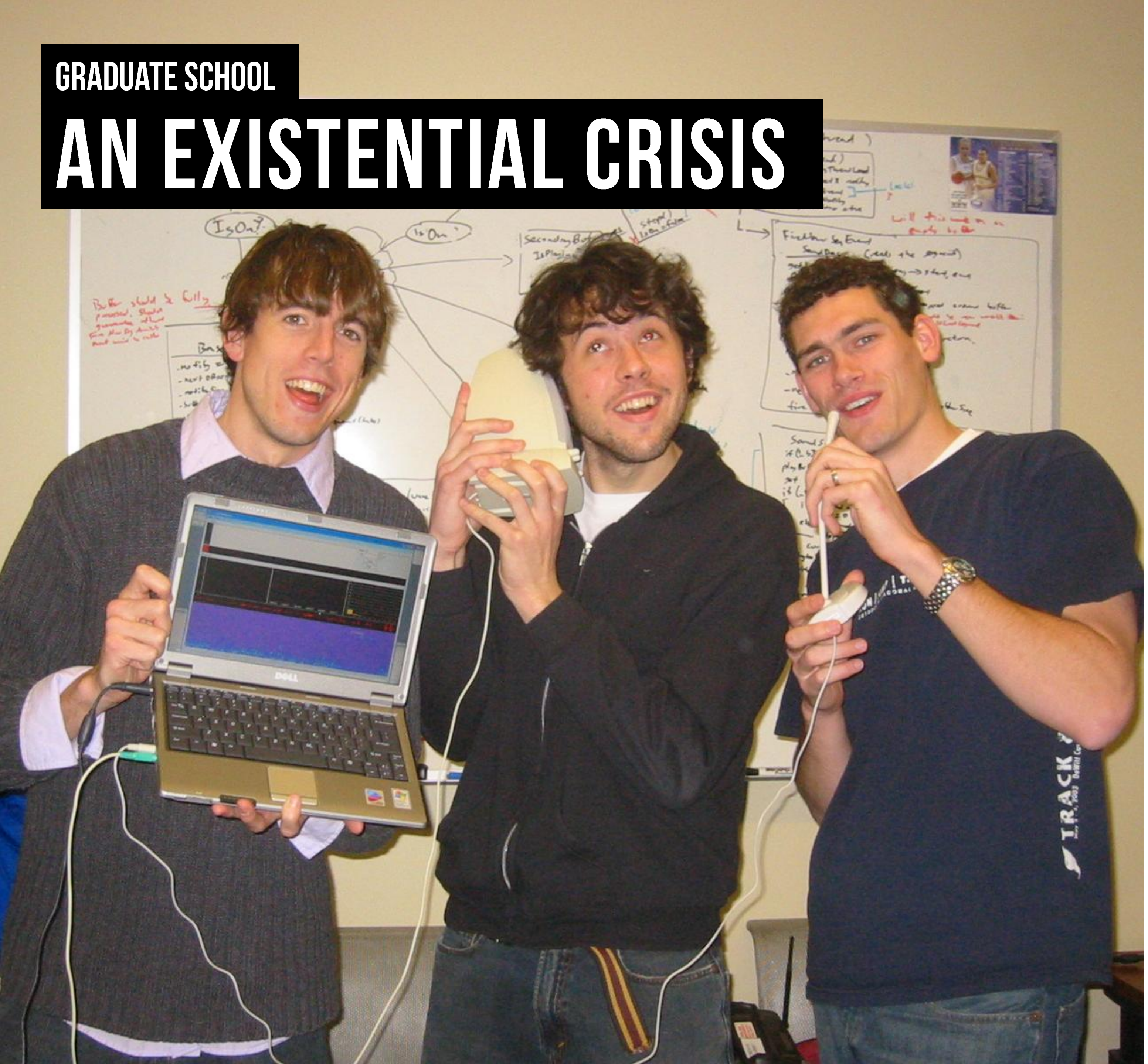
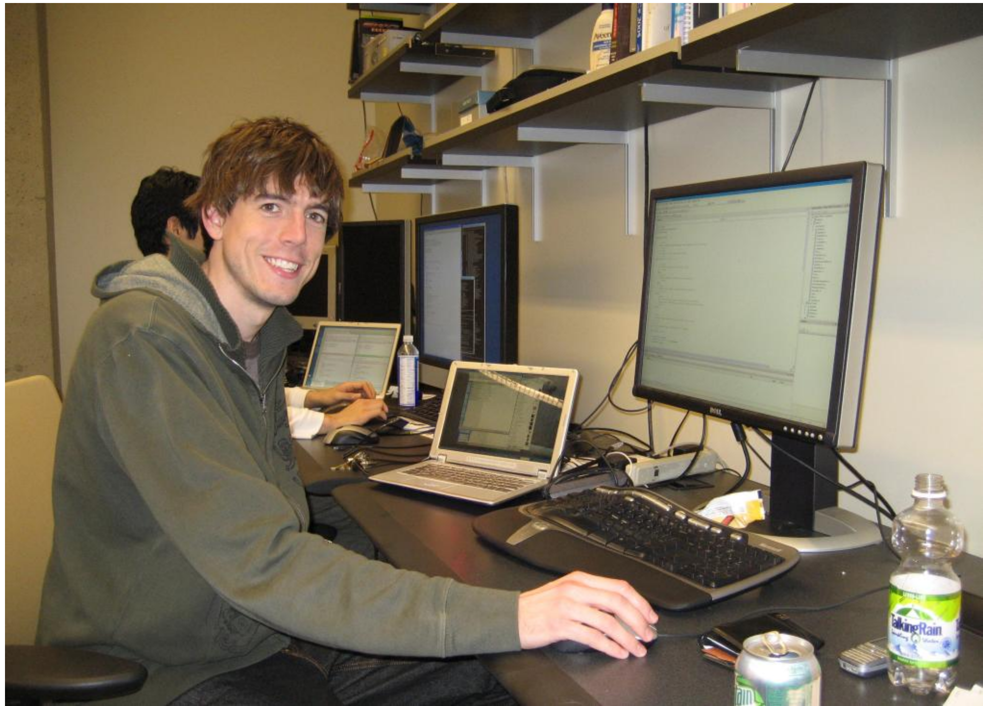
AN EXISTENTIAL CRISIS





GRADUATE SCHOOL

NSF PANEL OF GRAD EXPERIENCE

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HOW MANY OF YOU HAVE THOUGHT ABOUT DROPPING OUT?
CONFERENCE ROOM
Image created by Jon + Gemini


CONFERENCE ROOM
I NEEDED TO WORK ON SOMETHING THAT MATTERED
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Image modified by Gemini

JAKE WOBBROCK

New professor, UW iSchool'06

Photo by Jon E. Froehlich

PDA TOUCH SCREENS

Require fly-in directly to target

Limited tactile feedback

Lift-action difficult

Video by Jon E. Froehlich

ASSETS'07

Froehlich, Wobbrock, Kane

Barrier Pointing: Using Physical Edges to Assist Target Acquisition on Mobile Device Touch Screens

SHAUN KANE

Barrier Pointing: Using Physical Edges to Assist Target Acquisition on Mobile Device Touch Screens

Jon Froehlich,[1] Jacob O. Wobbrock,[2] Shaun K. Kane[2]

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ABSTRACT

Mobile phones and personal digital assistants (PDAs) are incredibly popular pervasive technologies. Many of these devices contain touch screens, which can present problems for users with motor impairments due to small targets and their reliance on tapping for target acquisition. In order to select a target, users must tap on the screen, an action which requires the precise motion of flying into a target and lifting without slipping. In this paper, we propose a new technique for target acquisition called *barrier pointing*, which leverages the elevated physical edges surrounding the screen to improve pointing accuracy. After designing a series of barrier pointing techniques, we conducted an initial study with 9 able-bodied users and 9 users with motor impairments in order to discover the parameters that make barrier pointing successful. From this data, we offer an in-depth analysis of the performance of two motor-impaired users for whom barrier pointing was especially beneficial. We show the importance of providing physical stability by allowing the stylus to press against the screen and its physical edge. We offer other design insights and lessons learned that can inform future attempts at leveraging the physical properties of mobile devices to improve accessibility.

Categories and Subject Descriptors

H.5.2. [**Information interfaces and presentation**]: User interfaces – *input devices and strategies*. K.4.2. [**Computers and society**]: Social issues – *assistive technologies for persons with disabilities*.

General Terms: Design, Experimentation, Human Factors.

Keywords: Target acquisition, touch screens, edges, corners, accessible interfaces, motor impairments, mobile phones, PDAs.

1. INTRODUCTION

In 2006, the number of mobile phone subscribers in the world surpassed 2.5 billion.[1] This is more than *twice* the number of PC users worldwide. The technology curve shows mobile phones and PDAs getting smaller and more powerful every year, providing features that extend beyond voice calls and text messaging. People with motor impairments, however, often find these devices difficult to use [3][14]. Their reduced size makes input challenging as the buttons are small, condensed and sometimes recessed. Prior work has shown that motor-impaired users may not have the physical strength to press hard physical buttons [14]. And certain device form factors (e.g., clamshell phones) require dexterity and strength just to open.

ASSETS'07, October 15–17, 2007, Tempe, Arizona, USA.

(a) Fly-in directly to barrier target **(b)** Rest the stylus against the screen and stroke into the target.

Figure 1. Two ways the physical properties of a touch screen device can be leveraged to assist movement: (a) The screen's physical edge catches the stylus as it flies into a target. (b) The screen itself provides an additional flat plane to aid movement.

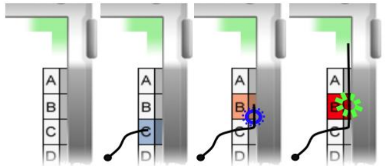
Many emerging high-end phones such as the Microsoft Windows Mobile Smartphone and the Apple iPhone contain touch screens. The iPhone features only one physical button, relying instead almost exclusively on touch screen interactions.[2] However, touch screens pose an additional set of challenges for mobile device accessibility: they lack tactile feedback and the physical stability available with hard buttons, and their interfaces often require dexterous motor control.

Still, touch screen devices offer rich potential for motor-impaired users. Myers et al. [14] demonstrated the use of Palm PDAs as viable alternatives to the mouse and keyboard for users with muscular dystrophy. Touch screens have the potential to support more fluid interactions than their button-based counterparts as they are *direct interaction* systems; that is, the point of stylus or finger contact is co-located with the screen's output. Thus, unlike traditional mobile phones, where target selection is accomplished *indirectly* via button presses and/or joystick movements, touch screen-based targets can be selected and manipulated directly.

Wobbrock et al. [24][25] demonstrated how physical edges could be used to assist motor-impaired users with touch screen-based text entry. Walker and Smelcer [21] demonstrated the benefits of impenetrable borders on targets to reduce mouse movement time. Our work expands into the realm of target acquisition on mobile

[1] http://www.wirelessintelligence.com/

[2] http://www.apple.com/iphone/



(a) *Normal* **(b)** *Hover –* Stylus over target *C* **(c)** *Select –* Stylus into barrier trough for *B* **(d)** *Confirm –* Rapidly move stylus towards screen corner

Figure 5. The "velocity stroke with corner confirmation" interaction. By eliminating the need for lift, the stylus is able to rest on the screen throughout a series of interactions; however, the user must reach the escape velocity before exiting the selected target.

3.2.2 Velocity Stroke with Corner Confirmation

This interaction is similar to the previous technique except for the confirmation step. Rather than lift, the user must stroke into a *confirmation corner* to confirm his/her selection (Figure 5). Confirmation corners allow the user to operate the device with the stylus continuously pressed against the screen. Once a target is selected and a confirmation corner is accessed, the user may begin another target acquisition *without lifting* the stylus.

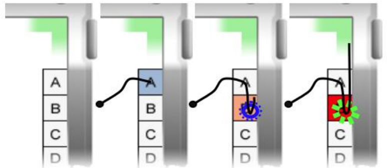
In order to distinguish between a confirmation corner stroke and a target selection stroke, a speed threshold ("escape velocity") is used as a mode switch. The user must maintain this escape velocity after exiting a selected target until the stylus reaches the confirmation corner. If the velocity is not maintained, the current selection is canceled or if the stylus is over another target's trough, this new target becomes selected. Currently, this threshold is set to 200 pixels/second, which was derived empirically with able-bodied testers. This value is slightly slower than the threshold used to ignore mouse clicks in *Steady Clicks* [18].

3.2.3 Reverse Stroke with Corner Confirmation

Because moving the stylus at escape speeds may be difficult for motor-impaired users, we developed an alternative method for selection. The "reverse stroke with corner confirmation" technique uses a direction reversal stroke along the target's edge to indicate a selection. For example, if the user is running south along the right edge of the screen, the user would reverse directions (by stroking north) within a target to select that target (Figure 6). The user must then move the stylus along the edge to a corner to confirm. Note that unlike the previous two barrier techniques, "reverse stroke with corner confirmation" does not use selection troughs—thus, its selectable area is the full size of the widget. We found this made it easier for subjects to reverse directions accurately. Note that the direction change can be made as slowly or quickly as desired; speed is not an issue.

4. INITIAL STUDY

In order to better understand barrier pointing, we conducted an initial study of 18 subjects, 9 of whom had motor impairments and 9 of whom did not. For each subject, we administered the 3 aforementioned barrier techniques in addition to the two baseline fly-in-and-tap conditions. This study was meant to provide both quantitative and qualitative insights into how barrier techniques may be used by motor-impaired and able-bodied users.



(a) *Normal* **(b)** *Hover –* Stylus over target *A* **(c)** *Select –* Reverse direction against edge while over target *B* **(d)** *Confirm –* Stylus continues in north direction towards corner

Figure 6. The "reverse stroke with corner confirmation" barrier interaction. For illustrative purposes, these figures demonstrate a reverse stroke slightly away from the edge. The ideal interaction, however, is simply running the stylus along the edge and reversing direction.

4.1 Method

4.1.1 Subjects

Eighteen subjects volunteered for the initial study: 9 able-bodied (AB) and 9 motor-impaired (MI). Two females participated in the AB group and 4 in the MI group. The average age was 23.9 (*SD*=2.4) and 37.7 (12.5) for the AB and MI groups, respectively. All subjects indicated that they used a desktop computer for at least an hour every day. Similarly, all subjects, with the exception of one MI participant, owned and used a mobile phone multiple times a day. Two MI subjects (MI1 and MI6) indicated that they currently own a touch screen mobile device. The MI subjects and their health conditions are listed in Table 1. Note that the motor impairments of our subjects covered a very broad range. This was by design, as we wanted to determine what types of users might benefit most from barrier pointing.

4.1.2 Apparatus

The initial study was conducted on two HTC Wizard Pocket PC Phones running Windows Mobile 5. One of the devices was outfitted with Velcro and attached to a clipboard for stability; the other was held in the hand. Participants were able to choose either device. The HTC Wizard is 5.3 ounces, 2.83"×4.25"×0.93" in size, and contains a 1.75"×2.25" single-touch touch screen with a QVGA resolution of 320×240 pixels. The touch screen sampling rate was measured empirically at ~100 Hz. The screen edge is 1.7 mm high. As the HTC Wizard ships with a small, ponderous stylus, we offered two alternatives: (1) a thick 5.75" stylus with a rubber grip, or (2) a 6.25" stylus, which was much lighter than (1) and about 40% smaller in diameter.

Subj	Sex	Age	Condition
MI1	M	48	Neuromuscular condition, low strength
MI2	F	55	Parkinson's, slight jitter, good motor control
MI3	M	38	Limited hand function, limited trunk balance
MI4	M	39	Tetraplegia (SCI C5), no use of triceps, pectorals, hands.
MI5	M	50	Limited coordination, episodic peripheral neuropathy
MI6	F	21	Cerebral Palsy (CP)
MI7	F	41	Degeneration of neck and spine
MI8	M	23	Spastic CP, lack of fine motor skills
MI9	F	24	Poor motor control as result of injury

Table 1. MI Study Participants

BARRIER POINTING

Screen supports motor action

Edges guide movement

Smoothing reduces errors

Video by Jon E. Froehlich

SOCIAL IMPACT AREAS

ACCESSIBILITY

HEALTH
& WELLNESS

ENVIRONMENTAL
SUSTAINABILITY

STEM
EDUCATION

Icons from the Noun Project: Heart by Timothy Miller; Leaf by NeueDeutsche; Microscope by Maxim Kulikov; Access icon from http://accessibleicon.org

SIGCHI SOCIETAL IMPACT TALK

SOCIAL IMPACT AREAS

ACCESSIBILITY

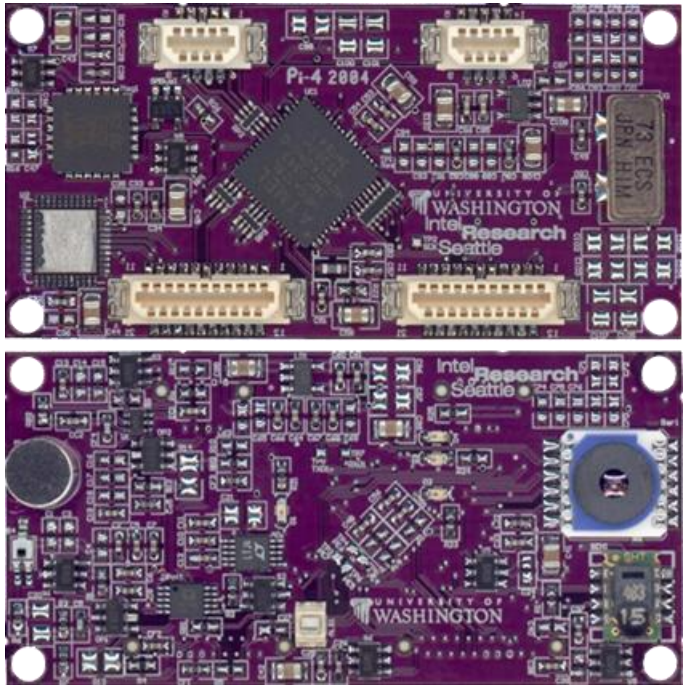
HEALTH
& WELLNESS

ENVIRONMENTAL
SUSTAINABILITY

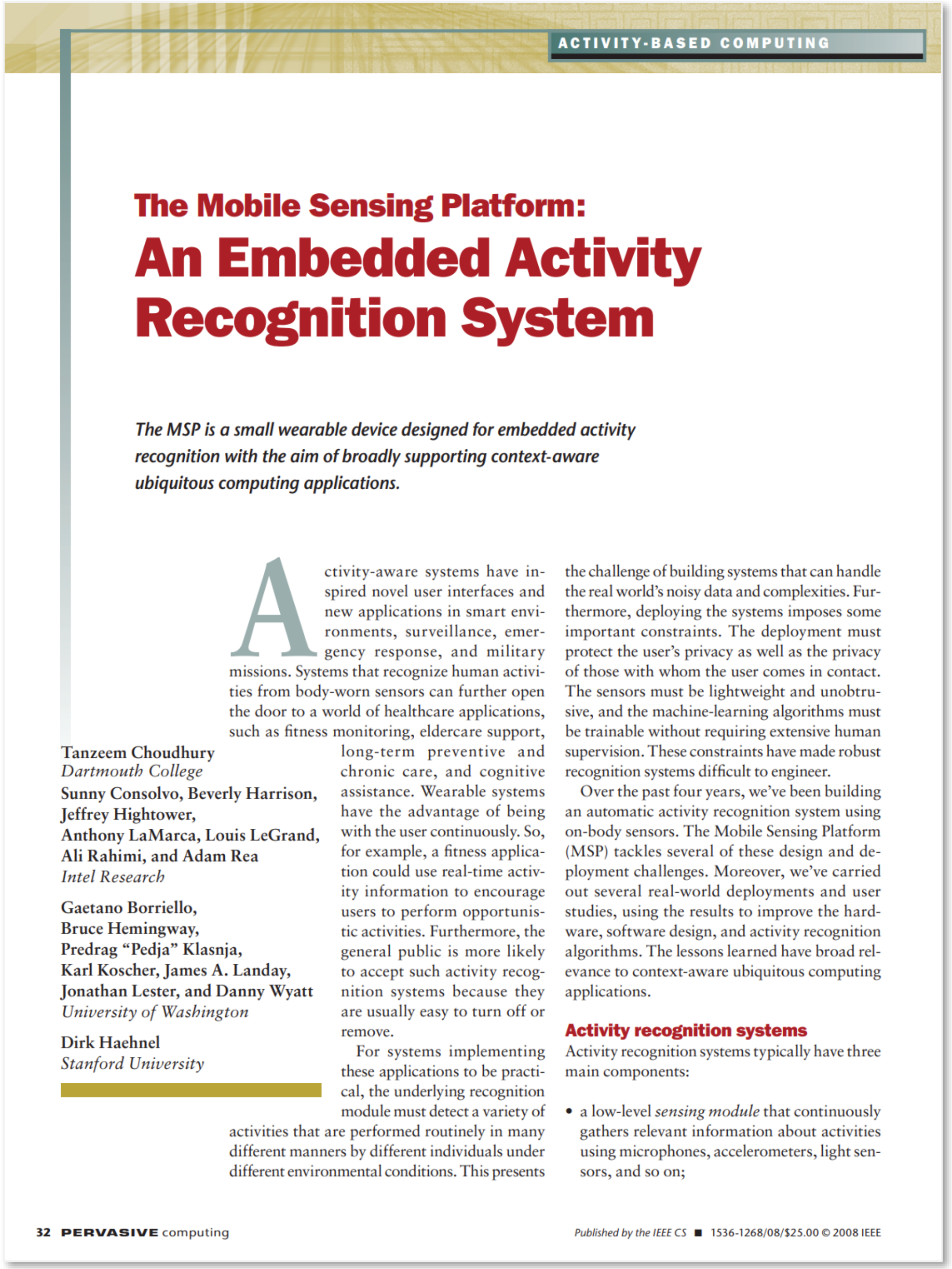
STEM
EDUCATION

Icons from the Noun Project: Heart by Timothy Miller; Leaf by NeueDeutsche; Microscope by Maxim Kulikov; Access icon from http://accessibleicon.org

INTEL RESEARCH
MOBILE SENSING PLATFORM



Wearable activity tracking device



The Mobile Sensing Platform: An Embedded Activity Recognition System

The MSP is a small wearable device designed for embedded activity recognition with the aim of broadly supporting context-aware ubiquitous computing applications.

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Activity-aware systems have inspired novel user interfaces and new applications in smart environments, surveillance, emergency response, and military missions. Systems that recognize human activities from body-worn sensors can further open the door to a world of healthcare applications, such as fitness monitoring, eldercare support, long-term preventive and chronic care, and cognitive assistance. Wearable systems have the advantage of being with the user continuously. So, for example, a fitness application could use real-time activity information to encourage users to perform opportunistic activities. Furthermore, the general public is more likely to accept such activity recognition systems because they are usually easy to turn off or remove.

For systems implementing these applications to be practical, the underlying recognition module must detect a variety of activities that are performed routinely in many different manners by different individuals under different environmental conditions. This presents the challenge of building systems that can handle the real world's noisy data and complexities. Furthermore, deploying the systems imposes some important constraints. The deployment must protect the user's privacy as well as the privacy of those with whom the user comes in contact. The sensors must be lightweight and unobtrusive, and the machine-learning algorithms must be trainable without requiring extensive human supervision. These constraints have made robust recognition systems difficult to engineer.

Over the past four years, we've been building an automatic activity recognition system using on-body sensors. The Mobile Sensing Platform (MSP) tackles several of these design and deployment challenges. Moreover, we've carried out several real-world deployments and user studies, using the results to improve the hardware, software design, and activity recognition algorithms. The lessons learned have broad relevance to context-aware ubiquitous computing applications.

Activity recognition systems

Activity recognition systems typically have three main components:

- a low-level *sensing module* that continuously gathers relevant information about activities using microphones, accelerometers, light sensors, and so on;

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INTEL RESEARCH
MOBILE SENSING PLATFORM
SMARTPHONE
Real-time Bluetooth communication.
MOBILE SENSING PLATFORM
Pager-size wearable device automatically tracks physical activities throughout day
[Lester, IJAI'05; Pervasive'06]
Photo by Jon E. Froehlich
BUS
43

CHI'08

Consolvo, et al. Activity Sensing in the Wild: A Field Trial of UbiFit Garden

SUNNY CONSOLVO

Activity Sensing in the Wild: A Field Trial of UbiFit Garden

Sunny Consolvo[1,2], David W. McDonald[2], Tammy Toscos[1], Mike Y. Chen[1], Jon Froehlich[3], Beverly Harrison[1], Predrag Klasnja[1,2], Anthony LaMarca[1], Louis LeGrand[1], Ryan Libby[3], Ian Smith[1], & James A. Landay[1,3]

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ABSTRACT
Recent advances in small inexpensive sensors, low-power processing, and activity modeling have enabled applications that use on-body sensing and machine learning to infer people's activities throughout everyday life. To address the growing rate of sedentary lifestyles, we have developed a system, UbiFit Garden, which uses these technologies and a personal, mobile display to encourage physical activity. We conducted a 3-week field trial in which 12 participants used the system and report findings focusing on their experiences with the sensing and activity inference. We discuss key implications for systems that use on-body sensing and activity inference to encourage physical activity.

Author Keywords
persuasive technology, sensing, activity inference, mobile phone, ambient display, fitness, activity-based applications.

ACM Classification Keywords
H.5.2 User Interfaces, H.5.m Miscellaneous.

INTRODUCTION
Recent advances in small inexpensive sensors, low-power processing, and activity modeling have enabled new classes of technologies that use on-body sensing and machine learning to automatically infer people's activities throughout the day. These emerging technologies have seen success with participants in controlled and "living" lab settings [11] and with researchers in situ [18]. The next step is to conduct in situ studies with the target user population. Such studies expose important issues, for example, how the systems are used as part of everyday experiences, where the technology is brittle, and user reactions to activity inference and the presentation of those inferences.

One application domain for on-body sensing and activity inference is addressing the growing rate of sedentary lifestyles. Regular physical activity is critical to everyone's physical and psychological health, regardless of their being normal weight, overweight, or obese [6,16]. Physical activity reduces risk of premature mortality, coronary heart disease, type II diabetes, colon cancer, and osteoporosis, and has also been shown to improve symptoms associated with mental health conditions such as depression and anxiety. Yet despite the importance of physical activity, many adults in the U.S. do not get enough exercise [1].

Technologies that apply on-body sensing and activity inference to the fitness domain are faced with a challenge regarding which physical activities should be detected. The American College of Sports Medicine (ACSM) recommends that physical activity be regular and include *cardiorespiratory training* (or "cardio") where large muscle groups are involved in dynamic activity such as running or cycling; *resistance training*, that is weight training that builds muscular strength and endurance; and *flexibility training* where muscles are slowly elongated to improve or maintain range of motion [22]. Technologies that attempt to encourage physical activity should support the *range of activities* that contribute to a physically active lifestyle, rather than focus on a single activity such as walking.

Our goal in this work is to investigate users' experiences with a system that we have developed, UbiFit Garden, which uses on-body sensing, activity inference, and a novel personal, mobile display to encourage physical activity. While our future work will focus on how the system affects awareness and sustained behavior change, at this stage, we are exploring how the system affects individuals' everyday lives, how they interpret and reflect on the data about their physical activities, and how they interact with that data. We conducted a three-week field trial (n=12) with participants who were representative of UbiFit Garden's target audience. In this paper, we discuss the types of physical activities participants performed, how those activities were recorded and manipulated, and participants' qualitative reactions to activity inference and manual journaling. We also discuss participants' general reactions to the system.

done by Fish'n'Steps, Houston, and Shakra), providing positive reinforcement rather than punishment (drawing from Houston's success and problems found by Fish'n'Steps), providing frequent opportunities for self-reflection (similar to Houston, Chick Clique, and Shakra), and integrating use into everyday life (all projects).

THE UBIFIT GARDEN SYSTEM
Mistress Mary, quite contrary, how does your garden grow? With silver bells, and cockle shells, and marigolds all in a row.
– Frances Hodgson Burnett

We have designed a healthy lifestyle technology, *UbiFit Garden*, which uses on-body sensing, real-time statistical modeling, and a personal, mobile display to encourage regular physical activity. UbiFit Garden is designed for individuals who have recognized the need to incorporate regular physical activity into their everyday lives but have not yet done so, at least not consistently[1].

The UbiFit Garden system consists of three components: (1) fitness device, (2) interactive application, and (3) glanceable display. The *fitness device* automatically infers and communicates information about several types of physical activities to the glanceable display and interactive application. The *interactive application* includes detailed information about the individual's physical activities and a journal where activities can be added, edited, and deleted. The *glanceable display* uses a non-literal, aesthetic representation of physical activities and goal attainment to motivate behavior (Fig 1). It resides on the background screen, or "wallpaper," of a mobile phone to provide a subtle reminder whenever and wherever the phone is used.

We are using an iterative process to design UbiFit Garden. In addition to drawing from prior work (including our own [5]), we conducted a survey (n=75) with respondents from 13 states across the U.S. that covered a range of attitudes and behaviors with mobile devices and physical activity. This survey tested assumptions about the glanceable display and elicited general feedback. Overall, respondents were very positive about the concept and confirmed that the display was understandable. A majority of respondents could imagine using UbiFit Garden. Common concerns had to do with assuming that all exercise data would have to be manually entered into the phone or that the phone would have to be carried during exercise (the fitness device and interactive application were not addressed in the survey).

UbiFit Garden's Fitness Device
UbiFit Garden is part of a larger research program to explore how sensing and activity inference technologies can be applied to real world problems, such as encouraging people

[1] UbiFit Garden targets the contemplation, preparation, and action stages of change of the *Transtheoretical Model*, which describes the stages through which individuals progress to intentionally modify addictive and other problematic behaviors [19].

a) b) c)

Figure 1. UbiFit Garden's glanceable display. a) at the beginning of the week—small butterflies indicate recent goal attainments; the absence of flowers means no activity this week; b) a garden with workout variety; c) the display on a mobile phone—the large butterfly indicates this week's goal was met.

to engage in healthy activities. UbiFit Garden relies on the *Mobile Sensing Platform (MSP)* [4,9], a research platform for mobile sensing and inference applications.

The MSP is a pager-sized, battery powered computer with sensors chosen to facilitate a wide range of mobile sensing applications (Fig 2). The MSP's sensors include: 3-d accelerometer, barometer, humidity, visible and infrared light, temperature, microphone, and compass. It includes a 400MHz XScale microprocessor, 32MB RAM, 2GB of flash memory for storing programs and logging data, and a rechargeable lithium ion battery. The MSP's Bluetooth networking allows it to communicate with other Bluetooth-enabled devices such as mobile phones.

UbiFit Garden uses the MSP to automatically infer physical activities in real time. The MSP runs a set of boosted decision stump classifiers that have been trained to infer walking, running, cycling, using an elliptical trainer, and using a stair machine. These inferences are derived from two sensors: the 3-d accelerometer and barometer. The sensor data is processed and the activity is inferred on the MSP, then the inferences are communicated via Bluetooth to a mobile phone that runs the interactive application and glanceable display (Fig 3). The MSP communicates a list of activities and their predicted likelihoods to the phone four times per second. The phone application aggregates and "smoothes" these fine-grain, noisy data resulting in "human scale"

Figure 2. UbiFit Garden's fitness device–the MSP. At left is the MSP worn by a woman; at center is the MSP in its waist-mount case; and at right are the sensor boards inside the casing.

HEALTH & WELLNESS

UBIFIT

Walk

Cardio

Strength

Flexibility

Primary goal met

Alternate goal met

Recent goal met

Consolvo *et al.*, CHI'08; Consolvo *et al.*, UbiComp'08

HEALTH & WELLNESS

UBIFIT INFLUENCE

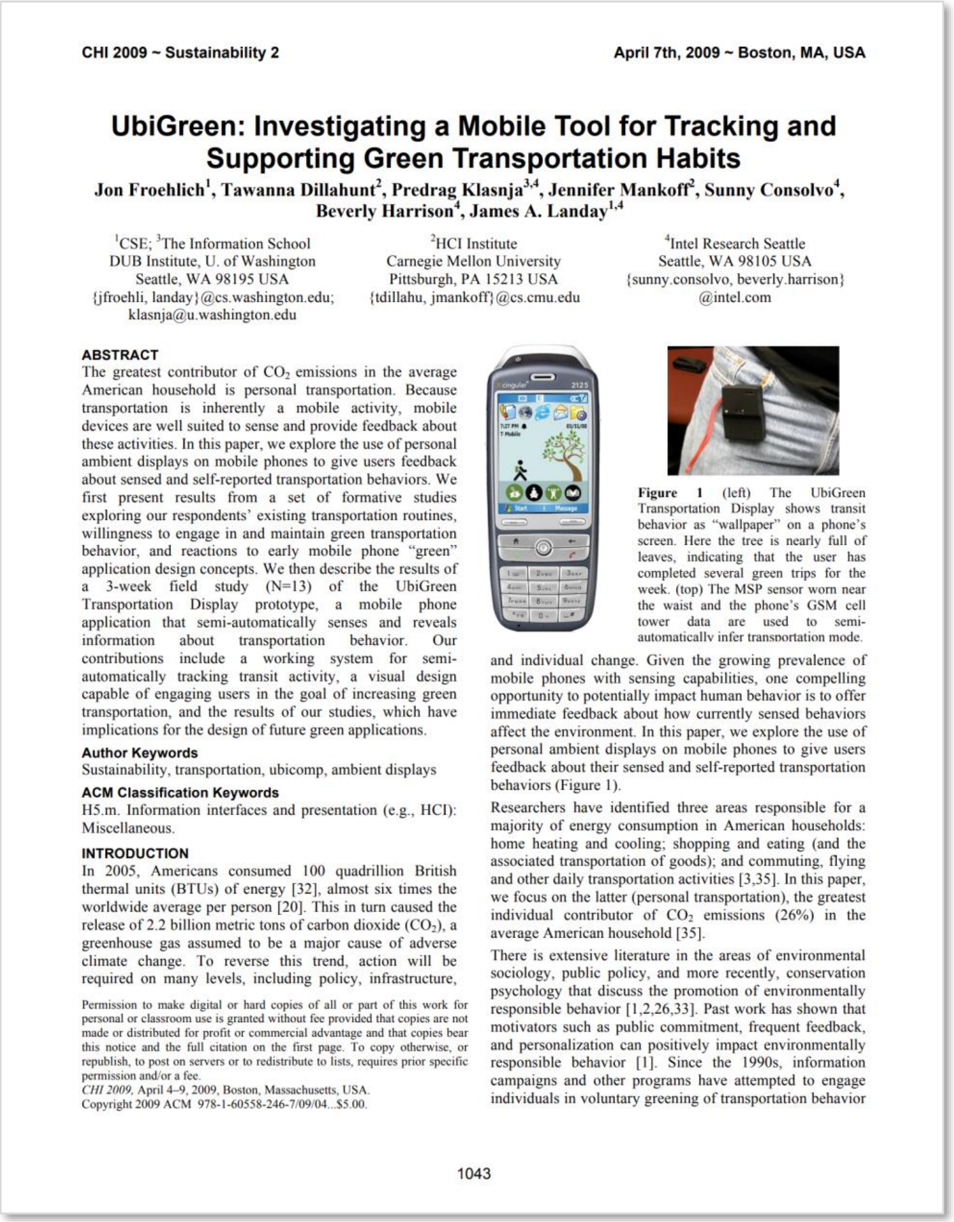
Google Fit Activity Tracking

Apple Watch Activity Tracking

CHI'09

Froehlich, Dillahunt, *et al.*
UbiGreen: Investigating a Mobile Tool for Tracking & Supporting Green Transportation Habits

TAWANNA DILLAHUNT



CHI 2009 ~ Sustainability 2 April 7th, 2009 ~ Boston, MA, USA

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

Jon Froehlich[1], Tawanna Dillahunt[2], Predrag Klasnja[3,4], Jennifer Mankoff[2], Sunny Consolvo[4], Beverly Harrison[4], James A. Landay[1,4]

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ABSTRACT

The greatest contributor of CO_2 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 (CO_2), 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, 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 CO_2 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

Figure 1 (left) The UbiGreen Transportation Display shows transit behavior as "wallpaper" on a phone's screen. Here the tree is nearly 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.

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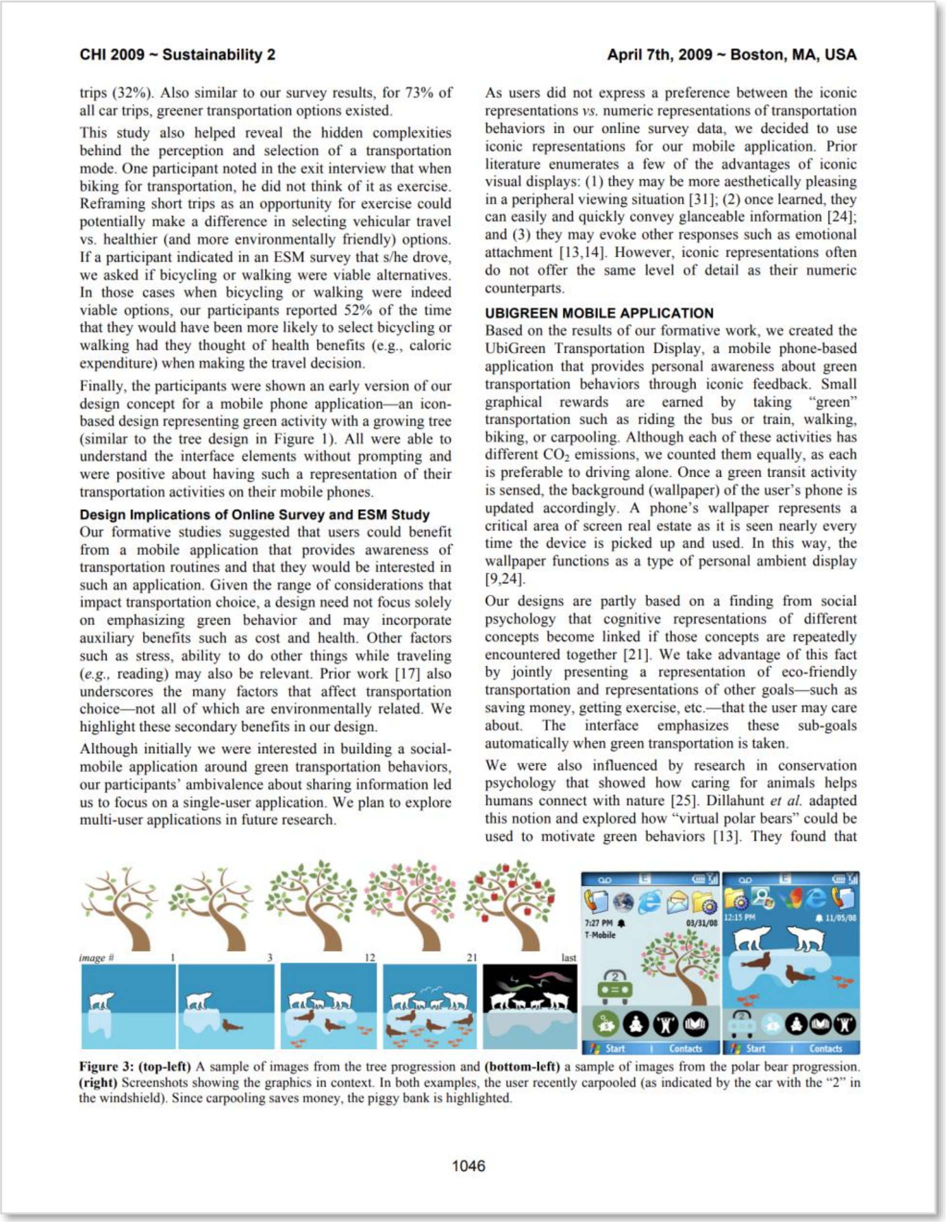

CHI 2009 ~ Sustainability 2 April 7th, 2009 ~ Boston, MA, USA

trips (32%). Also similar to our survey results, for 73% of all car trips, greener transportation options existed.

This study also helped reveal the hidden complexities behind the perception and selection of a transportation mode. One participant noted in the exit interview that when biking for transportation, he did not think of it as exercise. Reframing short trips as an opportunity for exercise could potentially make a difference in selecting vehicular travel vs. healthier (and more environmentally friendly) options. If a participant indicated in an ESM survey that s/he drove, we asked if bicycling or walking were viable alternatives. In those cases when bicycling or walking were indeed viable options, our participants reported 52% of the time that they would have been more likely to select bicycling or walking had they thought of health benefits (e.g., caloric expenditure) when making the travel decision.

Finally, the participants were shown an early version of our design concept for a mobile phone application—an icon-based design representing green activity with a growing tree (similar to the tree design in Figure 1). All were able to understand the interface elements without prompting and were positive about having such a representation of their transportation activities on their mobile phones.

Design Implications of Online Survey and ESM Study

Our formative studies suggested that users could benefit from a mobile application that provides awareness of transportation routines and that they would be interested in such an application. Given the range of considerations that impact transportation choice, a design need not focus solely on emphasizing green behavior and may incorporate auxiliary benefits such as cost and health. Other factors such as stress, ability to do other things while traveling (*e.g.,* reading) may also be relevant. Prior work [17] also underscores the many factors that affect transportation choice—not all of which are environmentally related. We highlight these secondary benefits in our design.

Although initially we were interested in building a social-mobile application around green transportation behaviors, our participants' ambivalence about sharing information led us to focus on a single-user application. We plan to explore multi-user applications in future research.

As users did not express a preference between the iconic representations *vs.* numeric representations of transportation behaviors in our online survey data, we decided to use iconic representations for our mobile application. Prior literature enumerates a few of the advantages of iconic visual displays: (1) they may be more aesthetically pleasing in a peripheral viewing situation [31]; (2) once learned, they can easily and quickly convey glanceable information [24]; and (3) they may evoke other responses such as emotional attachment [13,14]. However, iconic representations often do not offer the same level of detail as their numeric counterparts.

UBIGREEN MOBILE APPLICATION

Based on the results of our formative work, we created the UbiGreen Transportation Display, a mobile phone-based application that provides personal awareness about green transportation behaviors through iconic feedback. Small graphical rewards are earned by taking "green" transportation such as riding the bus or train, walking, biking, or carpooling. Although each of these activities has different CO_2 emissions, we counted them equally, as each is preferable to driving alone. Once a green transit activity is sensed, the background (wallpaper) of the user's phone is updated accordingly. A phone's wallpaper represents a critical area of screen real estate as it is seen nearly every time the device is picked up and used. In this way, the wallpaper functions as a type of personal ambient display [9,24].

Our designs are partly based on a finding from social psychology that cognitive representations of different concepts become linked if those concepts are repeatedly encountered together [21]. We take advantage of this fact by jointly presenting a representation of eco-friendly transportation and representations of other goals—such as saving money, getting exercise, etc.—that the user may care about. The interface emphasizes these sub-goals automatically when green transportation is taken.

We were also influenced by research in conservation psychology that showed how caring for animals helps humans connect with nature [25]. Dillahunt *et al.* adapted this notion and explored how "virtual polar bears" could be used to motivate green behaviors [13]. They found that

Figure 3: (top-left) A sample of images from the tree progression and **(bottom-left)** a sample of images from the polar bear progression. **(right)** Screenshots showing the graphics in context. In both examples, the user recently carpooled (as indicated by the car with the "2" in the windshield). Since carpooling saves money, the piggy bank is highlighted.

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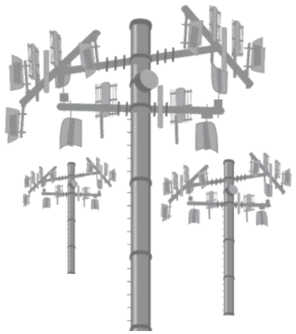
ENVIRONMENTAL SUSTAINABILITY

UBIGREEN TRANSIT SENSING

The MSP
Activity inference

Cell Towers
Transit inference



Manual Entry
Context-triggered mobile surveys

Drive Alone | **Walk** **Bike** **Train** **Carpool** **Bus**

Minimum activity duration: **7 mins**

Froehlich *et al.*, CHI'09

UBIGREEN

tree design:

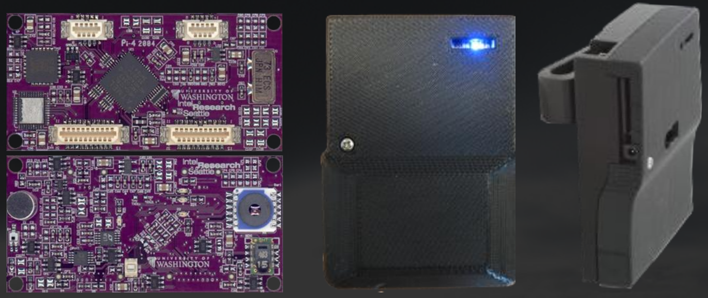
wednesday thursday friday

Froehlich *et al.*, CHI'09

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**

MSP AS UNIQUE ENABLER



2009

I’m **feeling good**. My research has **momentum**.


HCIC 2009
Snow Mountain Ranch
Fraser, Colorado
Photo by Jon E. Froehlich

HCIC'09

BANQUET DINNER

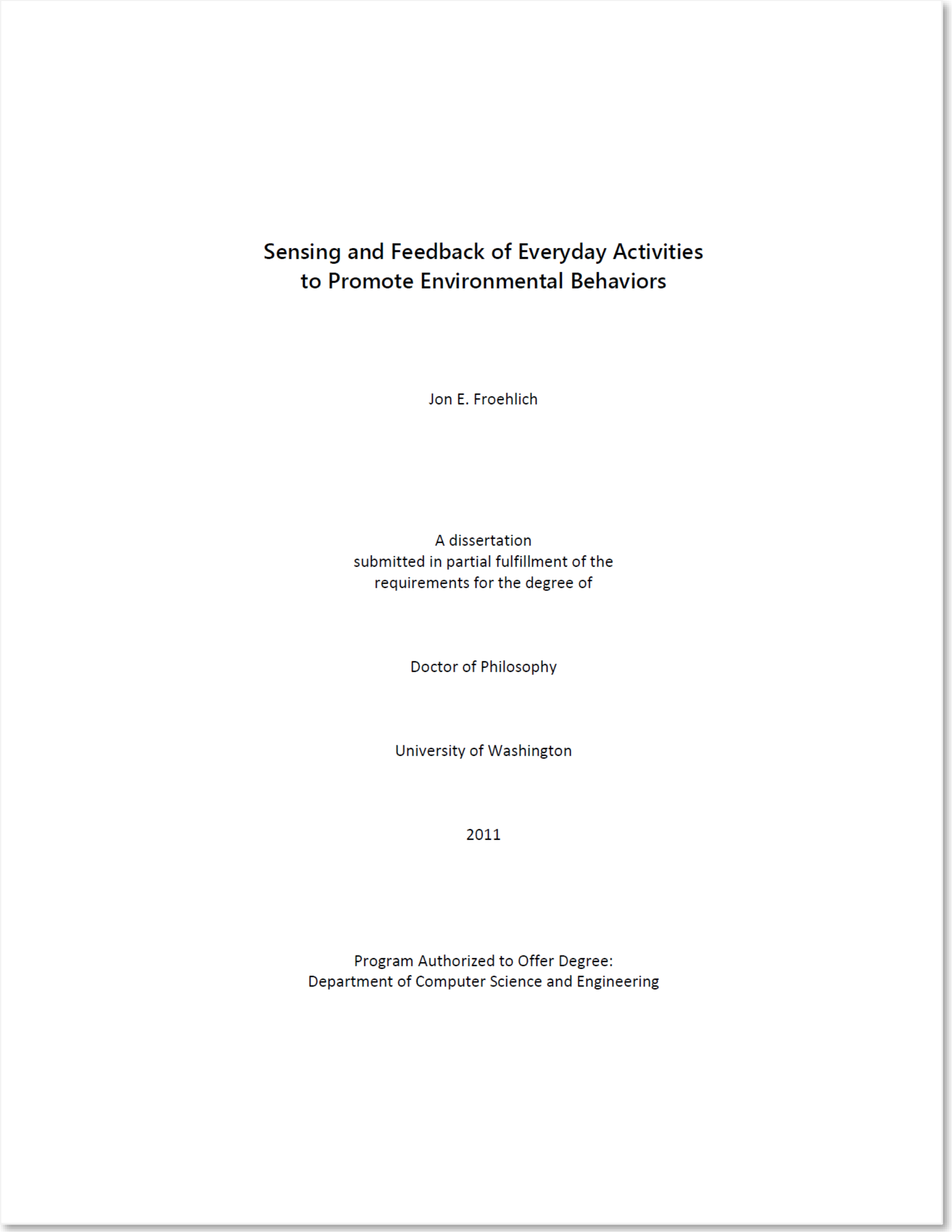
"But that's **not** HCI..."

-HCI LUMINARY

SIGCHI SOCIETAL IMPACT

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**
5. **Believe in yourself**, believe in your work


Sensing and Feedback of Everyday Activities
to Promote Environmental Behaviors

Jon E. Froehlich

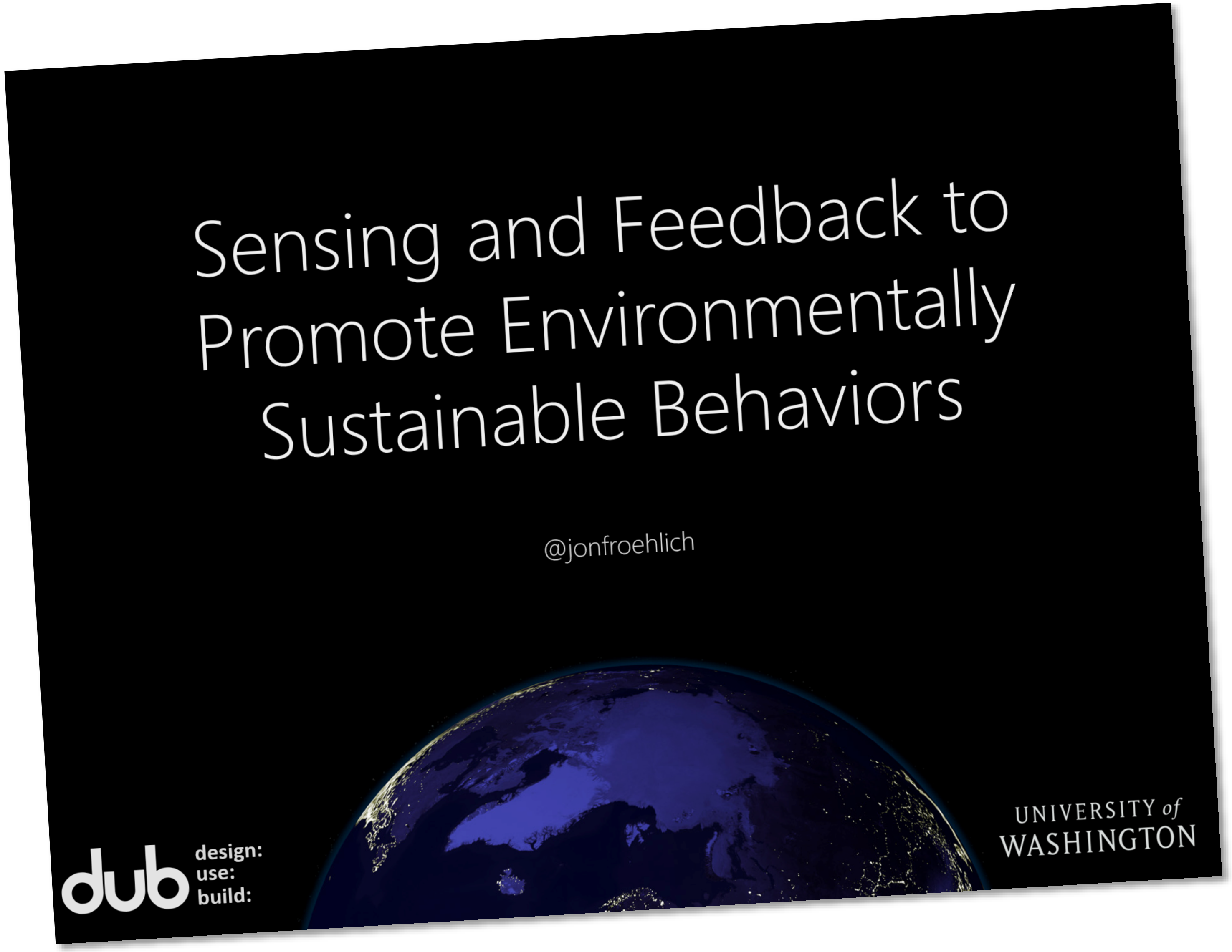
A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2011

Program Authorized to Offer Degree:
Department of Computer Science and Engineering



CHI'10

Froehlich, Findlater, Landay

The Design of Eco-Feedback Technology

BEST PAPER

The Design of Eco-Feedback Technology

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ABSTRACT
Eco-feedback technology provides feedback on individual or group behaviors with a goal of reducing environmental impact. The history of eco-feedback extends back more than 40 years to the origins of environmental psychology. Despite its stated purpose, few HCI eco-feedback studies have attempted to measure behavior change. This leads to two overarching questions: (1) what can HCI learn from environmental psychology and (2) what role should HCI have in designing and evaluating eco-feedback technology? To help answer these questions, this paper conducts a comparative survey of eco-feedback technology, including 89 papers from environmental psychology and 44 papers from the HCI and UbiComp literature. We also provide an overview of predominant models of proenvironmental behaviors and a summary of key motivation techniques to promote this behavior.

Author Keywords
Eco-feedback, Environmental HCI, Reflective HCI, Survey

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI)

General Terms
Design, Human Factors

INTRODUCTION
As environmental issues such as climate change, air pollution, and water scarcity become more salient in the global consciousness, so too have they become more active targets of research within HCI and Ubiquitous Computing [6, 19, 57]. One particularly popular form of environmental HCI research is the design and study of *eco-feedback technology*, which we define as technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact (adapted from [39] and [28], see Figure 1 for examples). Despite this goal, few HCI eco-feedback studies have even attempted to measure behavior change. Although eco-feedback may be seen as an extension of research in *persuasive technology* [17], it actually extends back much further to over 40 years of research in environmental psychology. This leads to two

Figure 1. Examples of eco-feedback technology. (left-to-right) The Infotropism display uses sensors and living plants to provide feedback about recycling and waste disposal [29]. WaterBot provides ambient feedback information about water usage [3]. The UbiGreen Transportation Display semi-automatically senses and feeds back information about transportation to encourage green transit [19].

interrelated questions: (1) What can HCI learn from environmental psychology and (2) what should be the role of the HCI community in contributing to eco-feedback research? To explore these questions in detail, we present a review of the related environmental psychology literature as well as a comparative survey of eco-feedback studies in both HCI and environmental psychology.

Eco-feedback technology is based on the working hypothesis that most people lack awareness and understanding about how their everyday behaviors such as driving to work or showering affect the environment; technology may bridge this "environmental literacy gap" by automatically sensing these activities and feeding related information back through computerized means (e.g., mobile phones, ambient displays, or online visualizations). HCI and UbiComp researchers have built eco-feedback technologies for a variety of domains including energy consumption [28], water usage [3], transportation [19], and waste disposal practices [29].

Contributing to this growing interest in eco-feedback technology is the parallel advancement and availability of sensing systems for environmentally related activities (e.g., human activity inference [35]) *and* interactive displays to feedback this data (e.g., iPods and mobile phones). Such advances provide a rich space of opportunities for new types of eco-feedback that could not be considered in the past. Moreover, the next generation of resource measurement systems (often referred to as "smart meters") will soon provide real-time (or near real-time) data on electricity, gas, and water usage in homes and businesses. This will produce tremendous amounts of data that can be

PC, with some amount of historical data available for self-comparison. Almost all (10/12) of the devices used were semi-interactive, but interactions were often limited, for example, to pressing a button that would cycle through statistics like the current day's electricity rate or the amount of the last month's bill (e.g., [48]).

In contrast, the eco-feedback designs in the HCI papers were much more diverse and fully explained. Of the 27 HCI papers that provide some sort of study of their eco-feedback technology, only four papers do not disclose a screenshot of the interface. In addition, the studies employed a range of presentation mediums for their feedback including: ambient displays (e.g., [3, 25, 42, 44]), mobile phone applications (e.g., [19, 45]), desktop games (e.g., [4]), and social websites [38]—see Figure 3.

Unfortunately, many of the eco-feedback designs in HCI do not link back to work in environmental or behavioral psychology. In our survey, less than half of the HCI eco-feedback papers referenced behavioral psychology literature and 58% referenced environmental psychology literature. Even more dramatically, no study in environmental psychology referred back to HCI. This represents a profound gap between disciplines. Interestingly, one author McCalley (e.g., [40]) has published in both fields—having published in both the Persuasive conference and journals in psychology and energy. Perhaps a future goal for HCI should be to initiate collaborations with environmental psychologists.

Discussion of Treatment
The primary motivation of eco-feedback technologies in both disciplines is to promote proenvironmental behaviors. Despite the relatively simple interfaces and lack of focus on design, the environmental psychology studies have achieved impressive results, a finding which should be cause for reflection by eco-feedback researchers in HCI. HCI researchers/practioners should ground their designs in the basic principles uncovered by environmental psychology. They can then apply the unique methodologies and approaches found in HCI (e.g., user centered design) to further the design of eco-feedback technology.

Although the environmental psychology studies show that eco-feedback can reduce consumption, they do not clarify the extent to which this impact is based on specific design elements. Considering only the designs that appeared in the environmental psychology studies, we can see questions that HCI researchers are well-suited to study: How

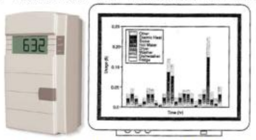


Figure 2. Two of the most commonly reported eco-feedback designs in environmental psychology: (left) a simple LCD display [32]; (right) a bar chart showing current and historical consumption data [13].

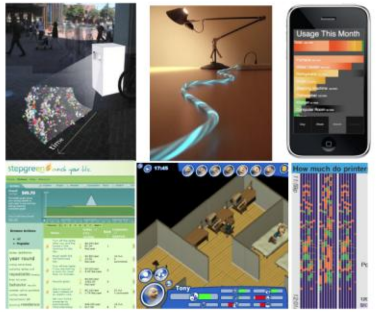


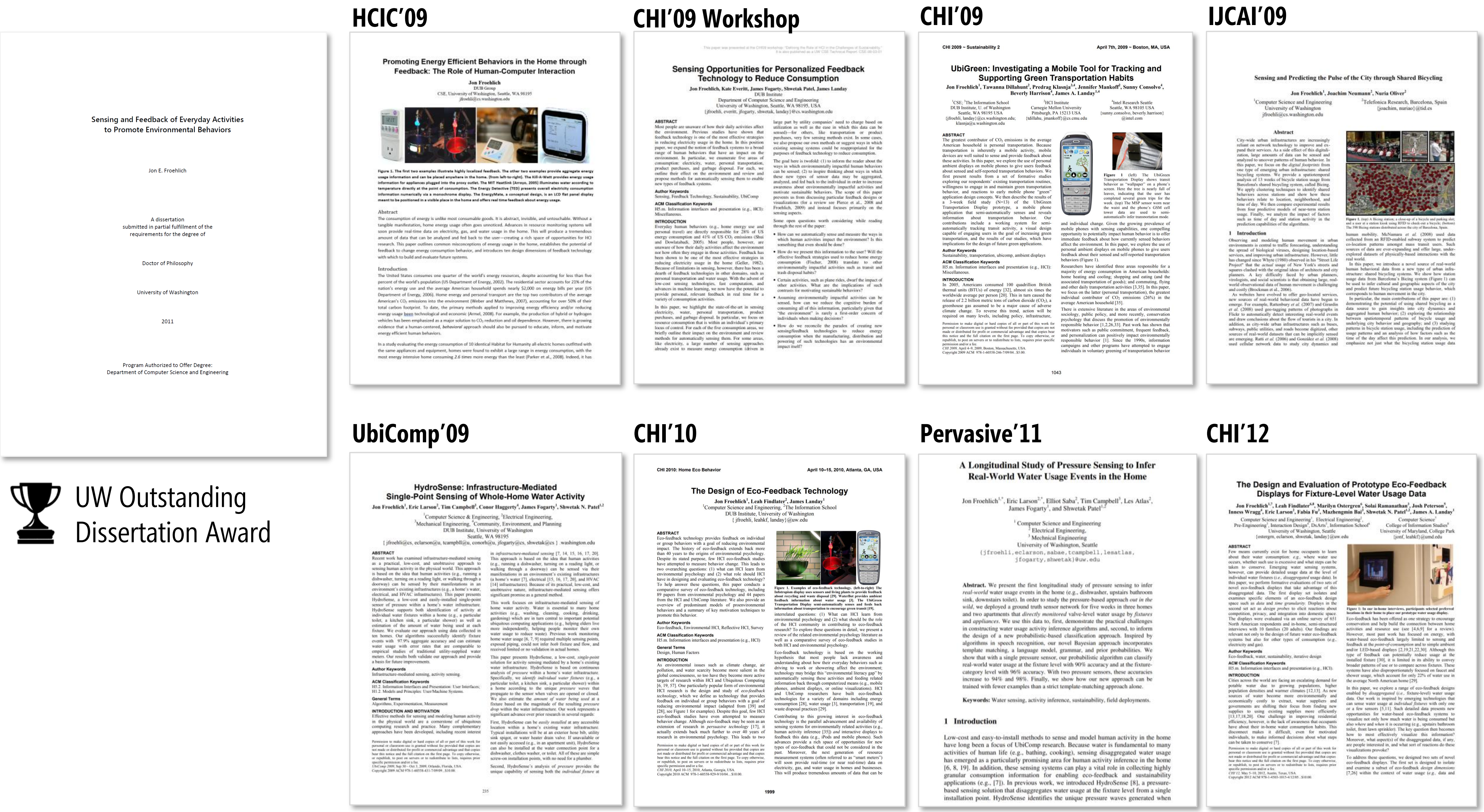
Figure 3. (clockwise): JetSam: ambient display for trash [42]; Power-Aware-Cord: ambient energy usage display [25]; WattBot: mobile phone home energy feedback [45]; Stepgreen: proenvironmental behavior tracking social website [38]; ThePowerHouse: resource eco-feedback in a virtual game environment [4]; Imprint: environmental impact of printing ambient public display [44].

important is it that eco-feedback be even minimally interactive? What types of information and presentation mediums are most effective (e.g., graphs vs. abstract ambient representations)? To what degree does the physical placement and access to the device impact its overall effectiveness? Answering these questions should allow us to identify how environmental psychologists may improve on the advances they have already made.

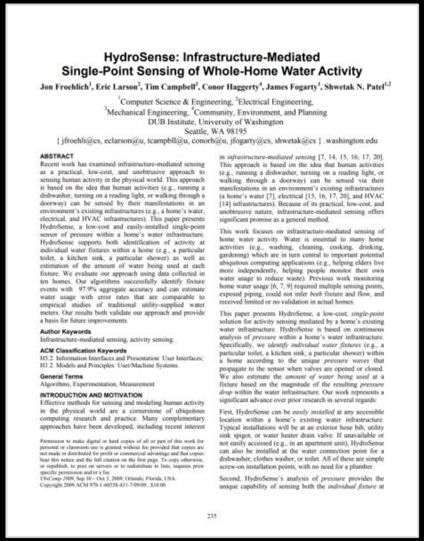
Consumption Targets of Eco-Feedback Technology
Eco-feedback technologies have been developed to target many types of consumption. The most common target is residential electricity usage: 41% of the papers in HCI and 92% of the papers in environmental psychology. This emphasis is both a reflection of the impact that electricity usage behaviors have on the environment as well as the ease with which energy usage can be automatically sensed.

As a field partially composed of computer scientists and designers, HCI researchers often have the resources to construct both their own novel sensing systems as well as their own feedback interfaces. HCI has also developed techniques to test and iterate on prototypes for exploring interactions and interfaces independent of the current state of technology (e.g., Wizard-of-Oz evaluations). As such, HCI has explored eco-feedback technologies for a larger set of behaviors than have been studied in environmental psychology. We found 20 HCI papers on eco-feedback for electricity, 4 on water, 4 on transportation, 4 on carbon tracking, 3 on garbage and recycling behaviors, 3 on the environmental impact of product purchases, 2 on paper usage and 1 on eco-feedback for a virtual game world.

Discussion of Consumption Targets
The HCI studies have shown that people are open to new types of eco-feedback for behaviors outside of energy usage. One role for HCI is then to challenge the limitations


Sensing and Feedback of Everyday Activities to Promote Environmental Behaviors
Jon E. Froehlich
A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
University of Washington
2011
Program Authorized to Offer Degree: Department of Computer Science and Engineering
UW Outstanding Dissertation Award
HCIC'09
Promoting Energy Efficient Behaviors in the Home through Feedback: The Role of Human-Computer Interaction
CHI'09 Workshop
Sensing Opportunities for Personalized Feedback Technology to Reduce Consumption
CHI'09
UbiGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits
IJCAI'09
Sensing and Predicting the Pulse of the City through Shared Bicycling
UbiComp'09
HydroSense: Infrastructure-Mediated Single-Point Sensing of Whole-Home Water Activity
CHI'10
The Design of Eco-Feedback Technology
Pervasive'11
A Longitudinal Study of Pressure Sensing to Infer Real-World Water Usage Events in the Home
CHI'12
The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data

UbiComp'09



HydroSense: Infrastructure-Mediated Single-Point Sensing of Whole-Home Water Activity

Jon Froehlich[1], Eric Larson[2], Tim Campbell[3], Conor Haggerty[4], James Fogarty[1], Shwetak N. Patel[1,2]

[1]Computer Science & Engineering, [2]Electrical Engineering,
[3]Mechanical Engineering, [4]Community, Environment, and Planning
DUB Institute, University of Washington
Seattle, WA 98195
{ jfroehli@cs, eclarson@u, tcampbll@u, conorh@u, jfogarty@cs, shwetak@cs } .washington.edu

ABSTRACT

Recent work has examined infrastructure-mediated sensing as a practical, low-cost, and unobtrusive approach to sensing human activity in the physical world. This approach is based on the idea that human activities (e.g., running a dishwasher, turning on a reading light, or walking through a doorway) can be sensed by their manifestations in an environment's existing infrastructures (e.g., a home's water, electrical, and HVAC infrastructures). This paper presents HydroSense, a low-cost and easily-installed single-point sensor of pressure within a home's water infrastructure. HydroSense supports both identification of activity at individual water fixtures within a home (e.g., a particular toilet, a kitchen sink, a particular shower) as well as estimation of the amount of water being used at each fixture. We evaluate our approach using data collected in ten homes. Our algorithms successfully identify fixture events with 97.9% aggregate accuracy and can estimate water usage with error rates that are comparable to empirical studies of traditional utility-supplied water meters. Our results both validate our approach and provide a basis for future improvements.

Author Keywords

Infrastructure-mediated sensing, activity sensing.

ACM Classification Keywords

H5.2. Information Interfaces and Presentation: User Interfaces; H1.2. Models and Principles: User/Machine Systems.

General Terms

Algorithms, Experimentation, Measurement

INTRODUCTION AND MOTIVATION

Effective methods for sensing and modeling human activity in the physical world are a cornerstone of ubiquitous computing research and practice. Many complementary approaches have been developed, including recent interest in *infrastructure-mediated sensing* [7, 14, 15, 16, 17, 20]. This approach is based on the idea that human activities (e.g., running a dishwasher, turning on a reading light, or walking through a doorway) can be sensed via their manifestations in an environment's existing infrastructures (a home's water [7], electrical [15, 16, 17, 20], and HVAC [14] infrastructures). Because of its practical, low-cost, and unobtrusive nature, infrastructure-mediated sensing offers significant promise as a general method.

This work focuses on infrastructure-mediated sensing of home water activity. Water is essential to many home activities (e.g., washing, cleaning, cooking, drinking, gardening) which are in turn central to important potential ubiquitous computing applications (e.g., helping elders live more independently, helping people monitor their own water usage to reduce waste). Previous work monitoring home water usage [6, 7, 9] required multiple sensing points, exposed piping, could not infer *both* fixture and flow, and received limited or no validation in actual homes.

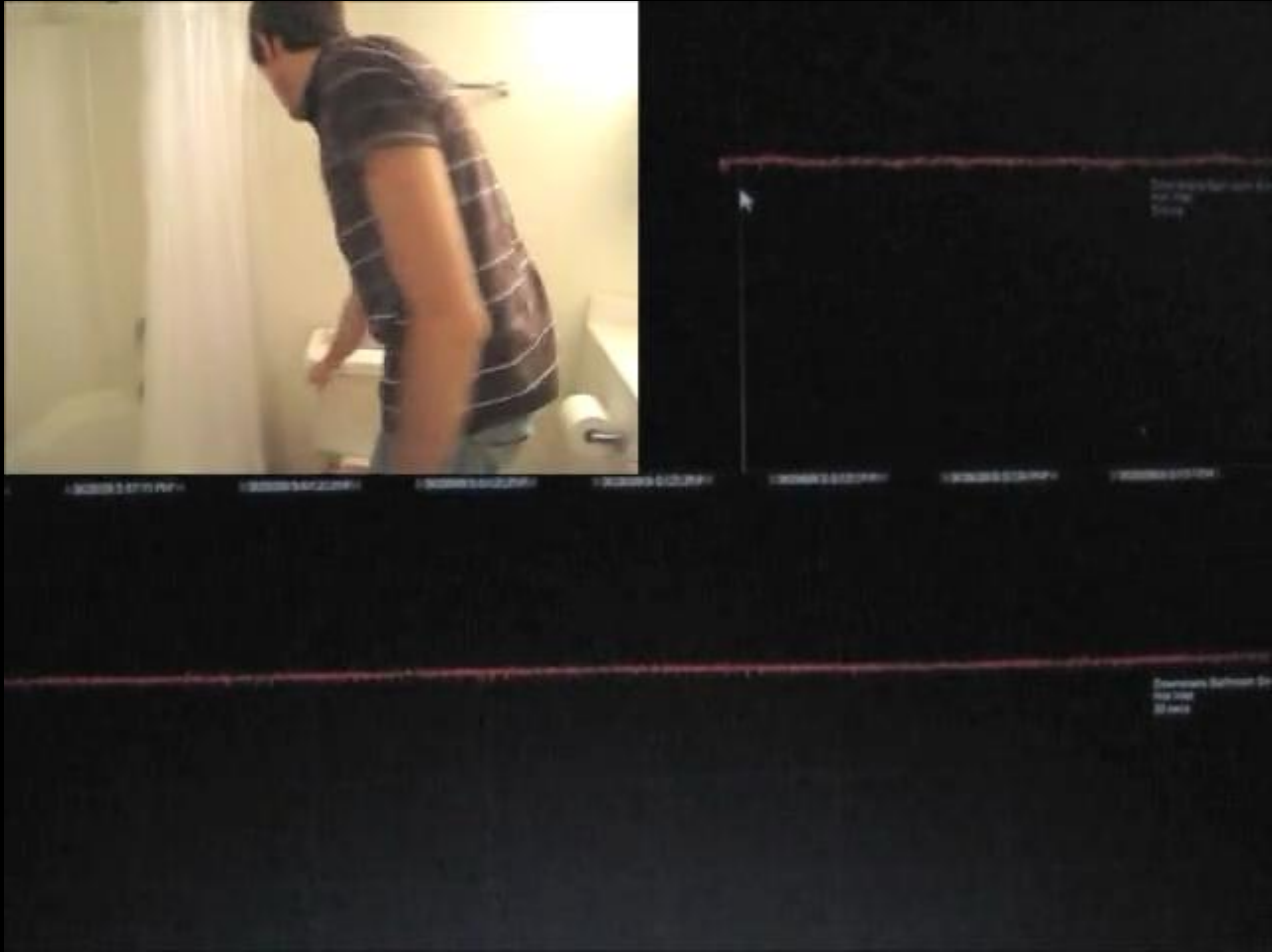
This paper presents HydroSense, a low-cost, *single-point* solution for activity sensing mediated by a home's existing water infrastructure. HydroSense is based on continuous analysis of *pressure* within a home's water infrastructure. Specifically, we *identify individual water fixtures* (e.g., a particular toilet, a kitchen sink, a particular shower) within a home according to the unique *pressure waves* that propagate to the sensor when valves are opened or closed. We also estimate the *amount of water being used* at a fixture based on the magnitude of the resulting *pressure drop* within the water infrastructure. Our work represents a significant advance over prior research in several regards:

First, HydroSense can be *easily installed* at any accessible location within a home's existing water infrastructure. Typical installations will be at an exterior hose bib, utility sink spigot, or water heater drain valve. If unavailable or not easily accessed (e.g., in an apartment unit), HydroSense can also be installed at the water connection point for a dishwasher, clothes washer, or toilet. All of these are simple screw-on installation points, with no need for a plumber.

Second, HydroSense's analysis of *pressure* provides the unique capability of sensing both the *individual fixture* at

UbiComp 2009, Sep 30 – Oct 3, 2009, Orlando, Florida, USA.

ERIC LARSON



Froehlich *et al.*, UbiComp'09

CHI’12

The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data

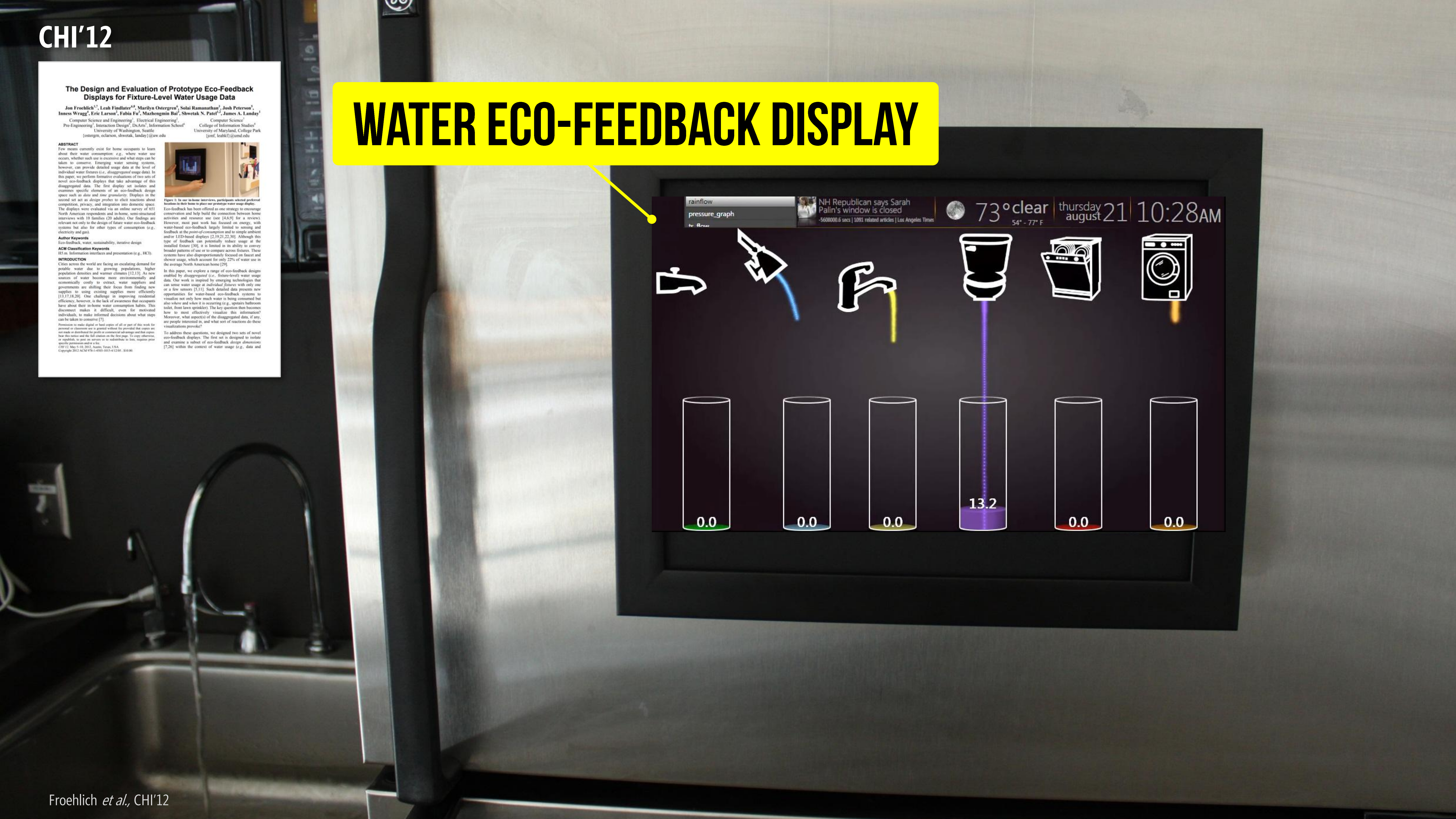
Jon Froehlich[1,7], Leah Findlater[6,8], Marilyn Ostergren[6], Solai Ramanathan[3], Josh Peterson[5], Inness Wragg[4], Eric Larson[2], Fabia Fu[3], Mazhengmin Bai[3], Shwetak N. Patel[1,2], James A. Landay[1]

Computer Science and Engineering[1], Electrical Engineering[2], Pre-Engineering[3], Interaction Design[4], DxArts[5], Information School[6]
University of Washington, Seattle
{ostergm, eclarson, shwetak, landay}@uw.edu

Computer Science[7]
College of Information Studies[8]
University of Maryland, College Park
{jonf, leahkf}@umd.edu

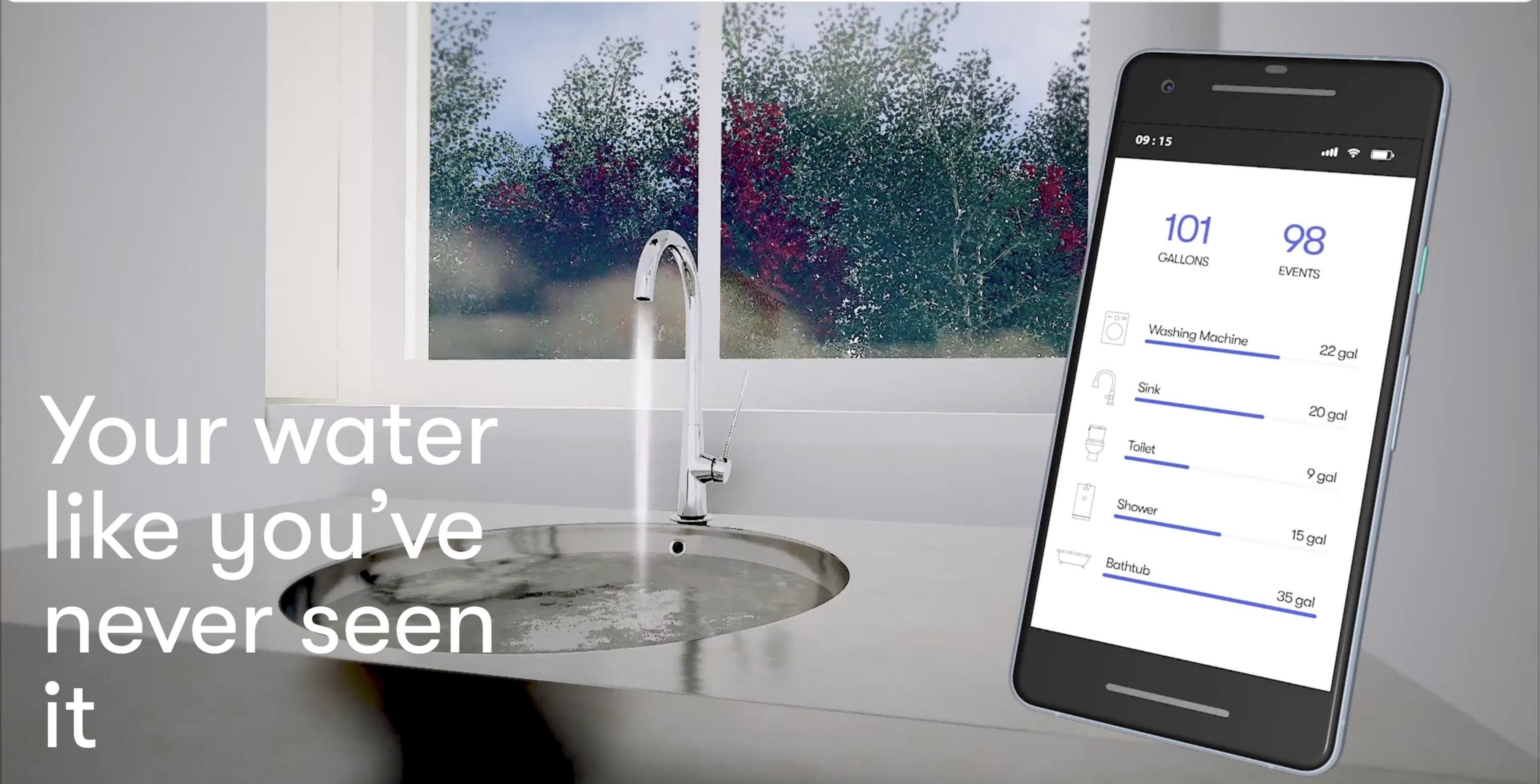
ABSTRACT

Few means currently exist for home occupants to learn about their water consumption: e.g., where water use occurs, whether such use is excessive and what steps can be taken to conserve. Emerging water sensing systems, however, can provide detailed usage data at the level of individual water fixtures (i.e., disaggregated usage data). In this paper, we perform formative evaluations of two sets of novel eco-feedback displays that take advantage of this



WATER ECO-FEEDBACK DISPLAY

Froehlich *et al.*, CHI’12



Your water like you've never seen it

JAMES LANDAY
PhD Co-Advisor

SHWETAK PATEL
PhD Co-Advisor

GRADUATED 2011

Photo by Bruce Hemingway

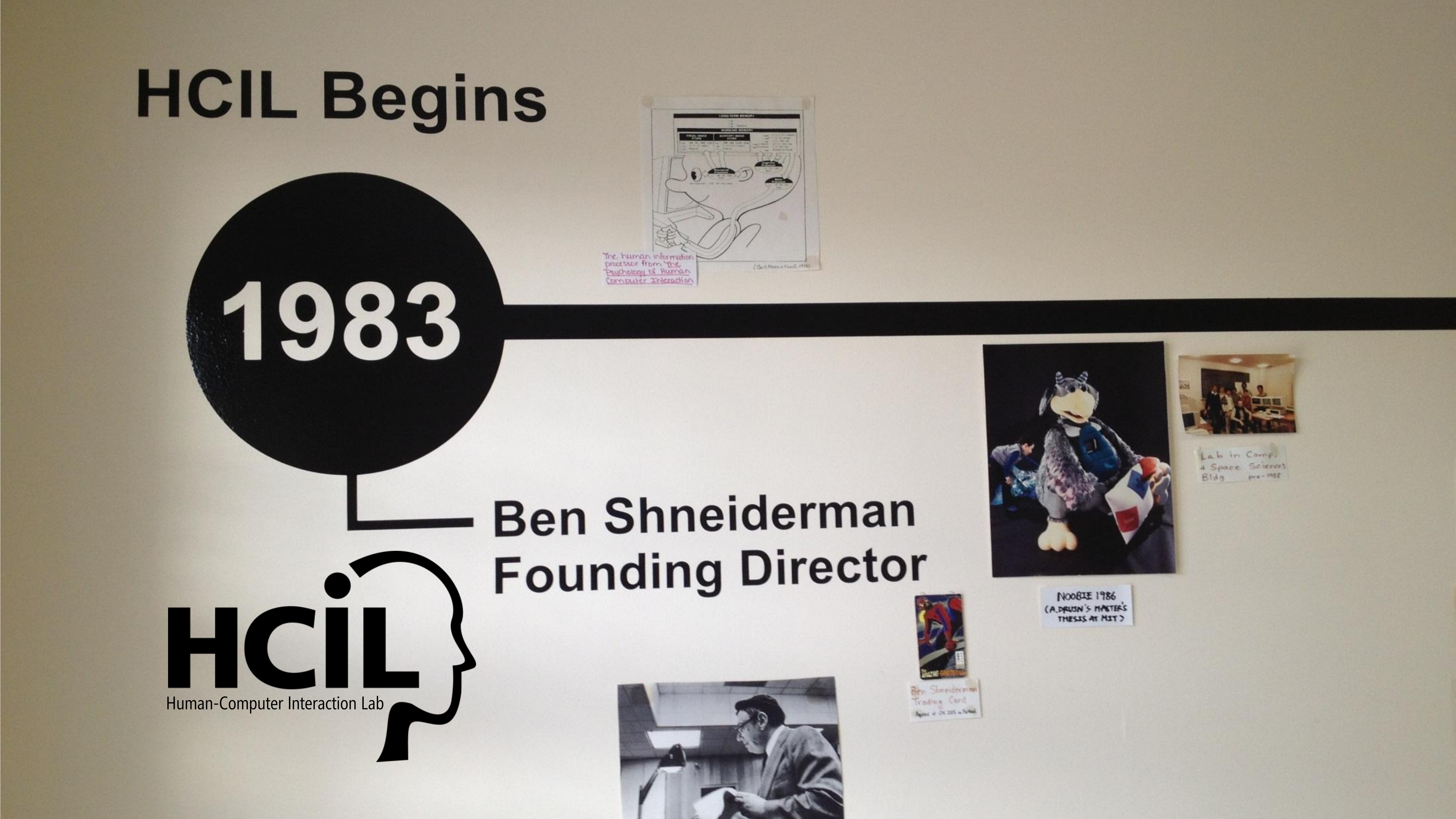

MAKEABILITY LAB
University of Maryland


2013
MAKEABILITY LAB
HCIL
MAKEABILITY LAB


2024
MAKEABILITY LAB
MAKEABILITY LAB
MAKEABILITY LAB
MAKEABILITY LAB

Our Mission

DESIGN, BUILD, & STUDY INTERACTIVE TOOLS & TECHNIQUES TO ADDRESS PRESSING SOCIETAL CHALLENGES


HCIL Begins
The human information processor from The Psychology of Human Computer Interaction
1983
Ben Shneiderman
Founding Director
Lab in Comp. & Space Sciences Bldg pre-1988
NOOBIE 1986
(A. DRUIN'S MASTER'S THESIS AT MIT)
Ben Shneiderman Trading Card
HCIL
Human-Computer Interaction Lab

SIGCHI SOCIAL IMPACT AWARD 2010

HCIL

BEN BEDERSON

ALLISON DRUIN


LeahFindlater
JenGolbeck
BenShneiderman
BenBederson
JonFroehlich
AnneRose
CatherinePlaisant
MarshiniChetty
KariKraus
computer science
ischool
english & journalism
HCIL
education
psychology
JennyPreece
IraChinoy
AllisonDruin
MonaLeighGuha
TammyClegg
JuneAhn
EvanGolub
JessicaVitak
KentNorman

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**
5. **Believe in yourself**, believe in your work
6. The **people matter** the most

PARTICIPATORY DESIGN

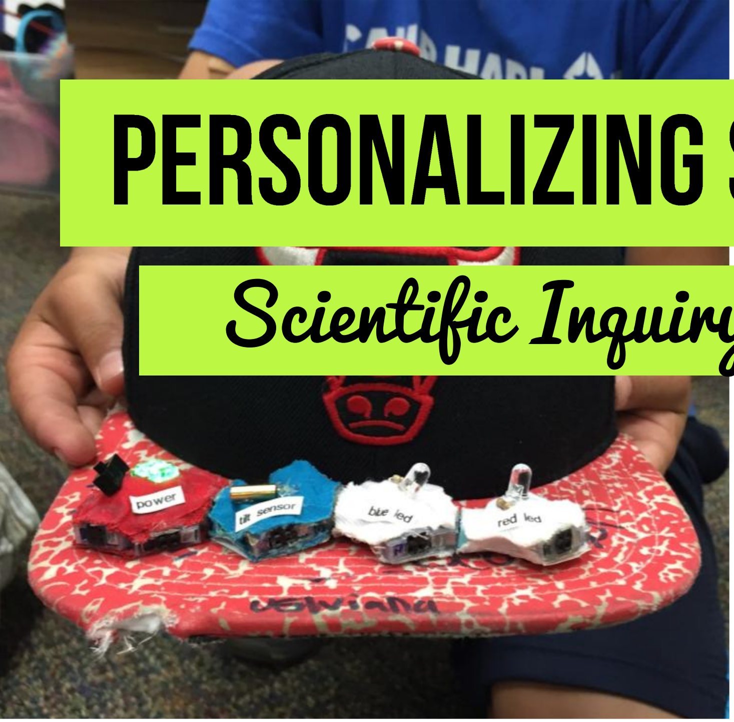
Cooperative Inquiry

Cooperative Inquiry: Druin, CHI'99; Guha, Druin, & Fails, 2013

Photos by Jon E. Froehlich

PERSONALIZING SCIENCE

Scientific Inquiry



Clegg, IDC'2012

TAMARA CLEGG

Photos by Jon E. Froehlich

SOCIAL IMPACT AREAS

ACCESSIBILITY

HEALTH
& WELLNESS

ENVIRONMENTAL
SUSTAINABILITY

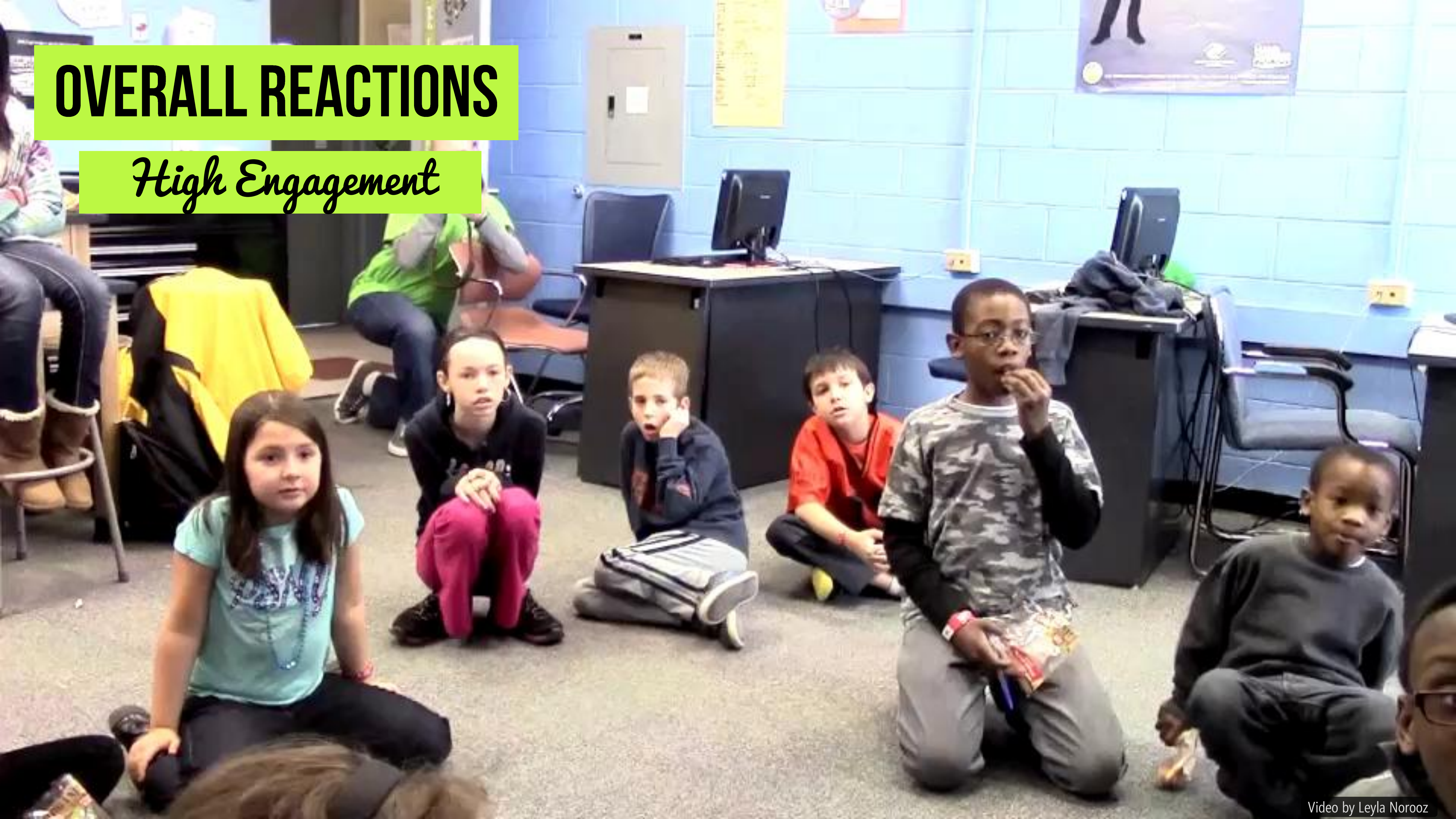
STEM
EDUCATION


Optical Heart Rate Sensor
LEYLA NOROOZ
Norooz, CHI'15
Photo by Jon E. Froehlich

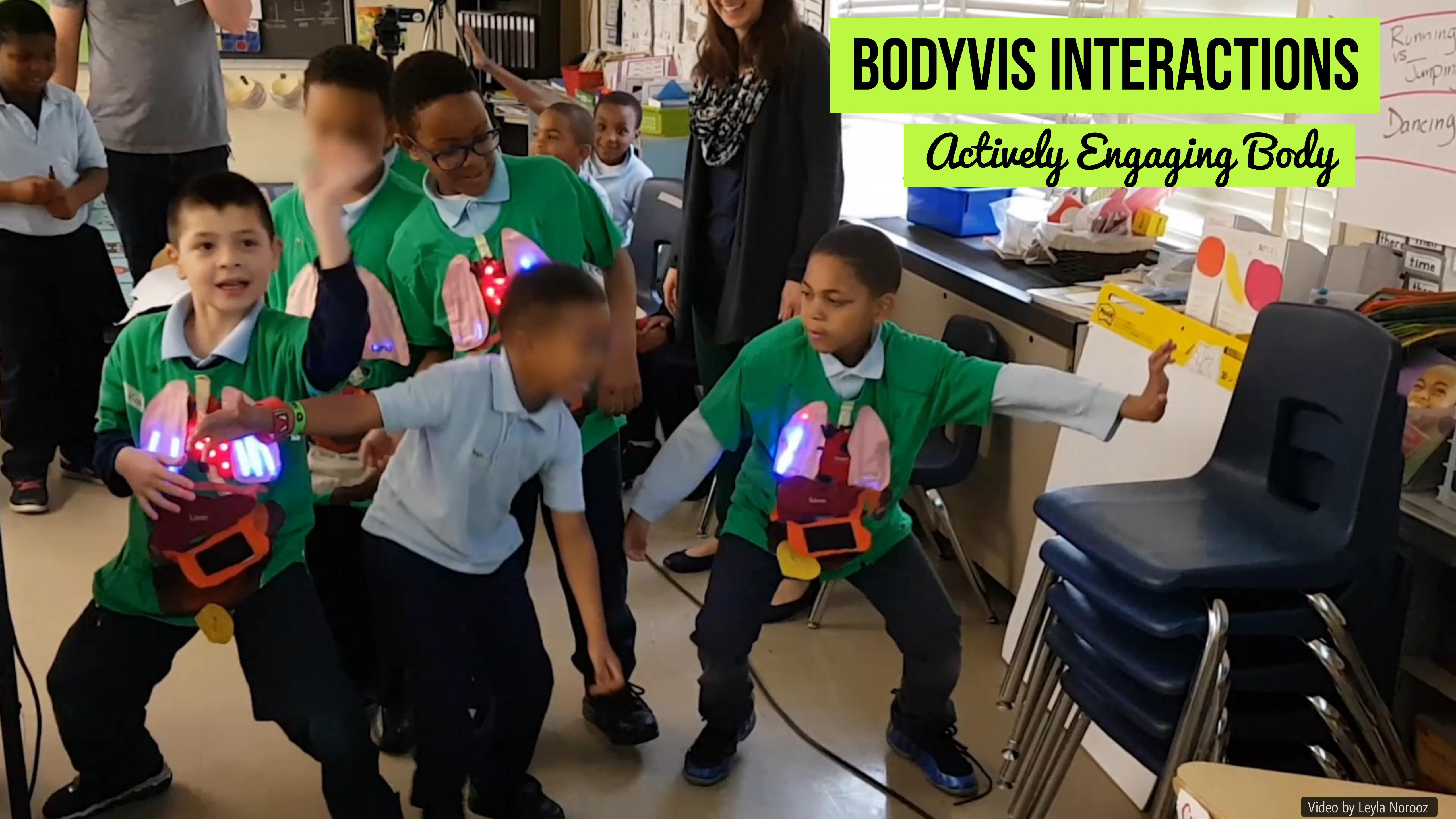

Liver
Small Intestine
The heart and lungs visualize wearers' live heart and breathing rate.
Video by Leyla Norooz

OVERALL REACTIONS

High Engagement

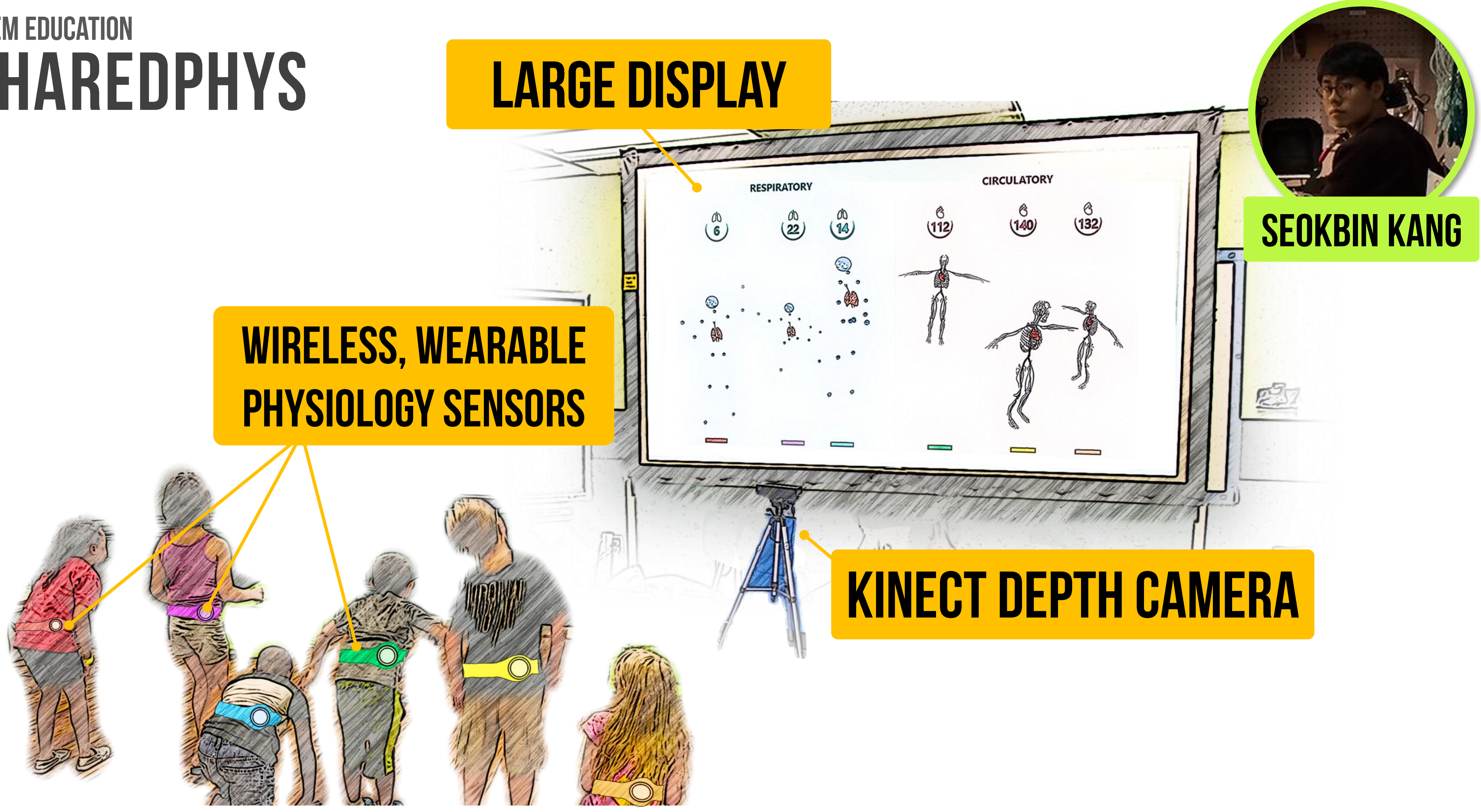


Video by Leyla Norooz


BODYVIS INTERACTIONS
Actively Engaging Body
Video by Leyla Norooz

STEM EDUCATION

SHAREDPHYS



Kang *et al.*, IDC'17; Clegg, CHI'17; Byrne, ICLS'18

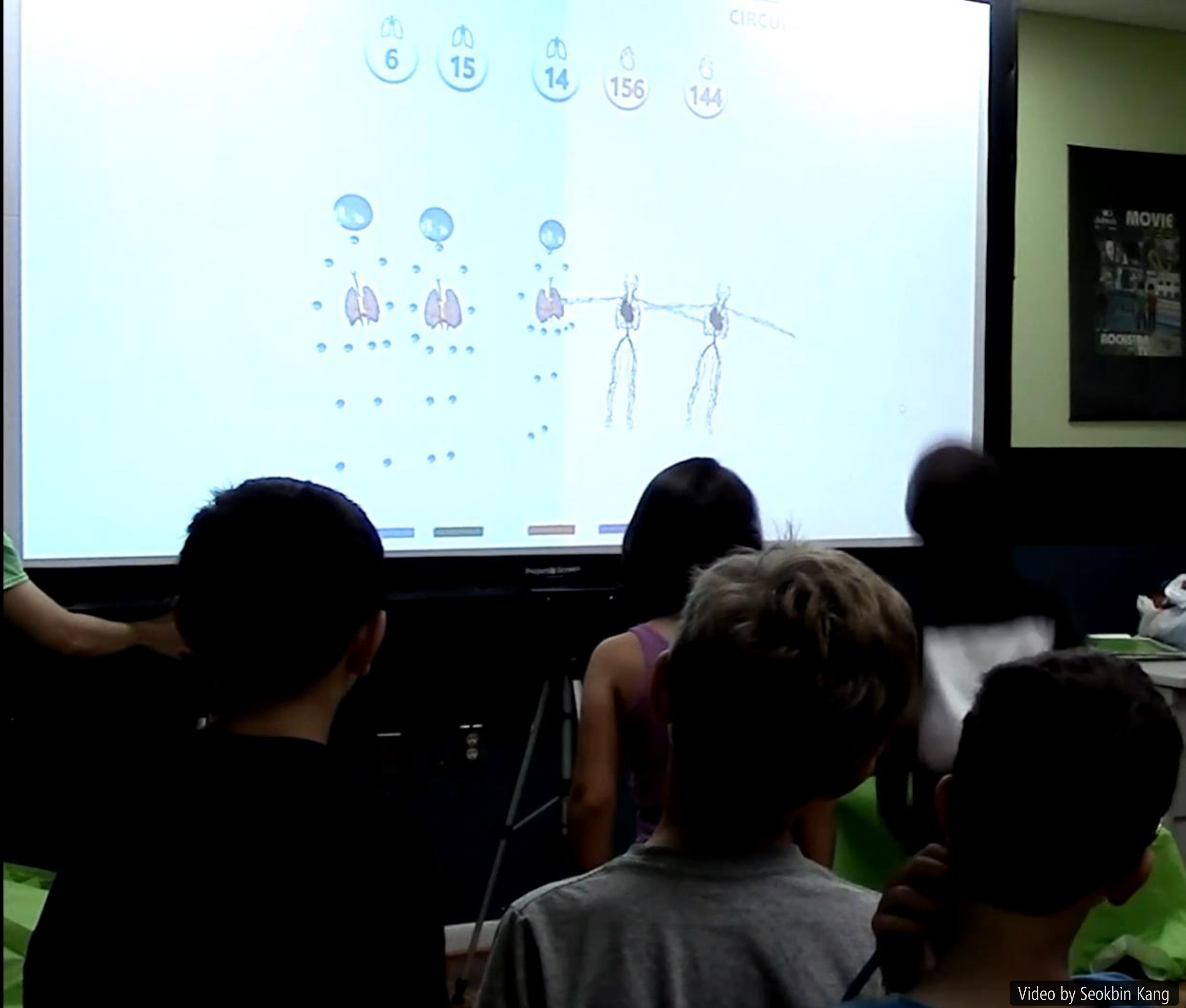
Prototype #1

Magic Mirror

Mirror metaphor

Peer inside live body

Whole-body interactio



Video by Seokbin Kang

Kang *et al.*, IDC'17; Clegg, CHI'17; Byrne, ICLS'18

Prototype #2

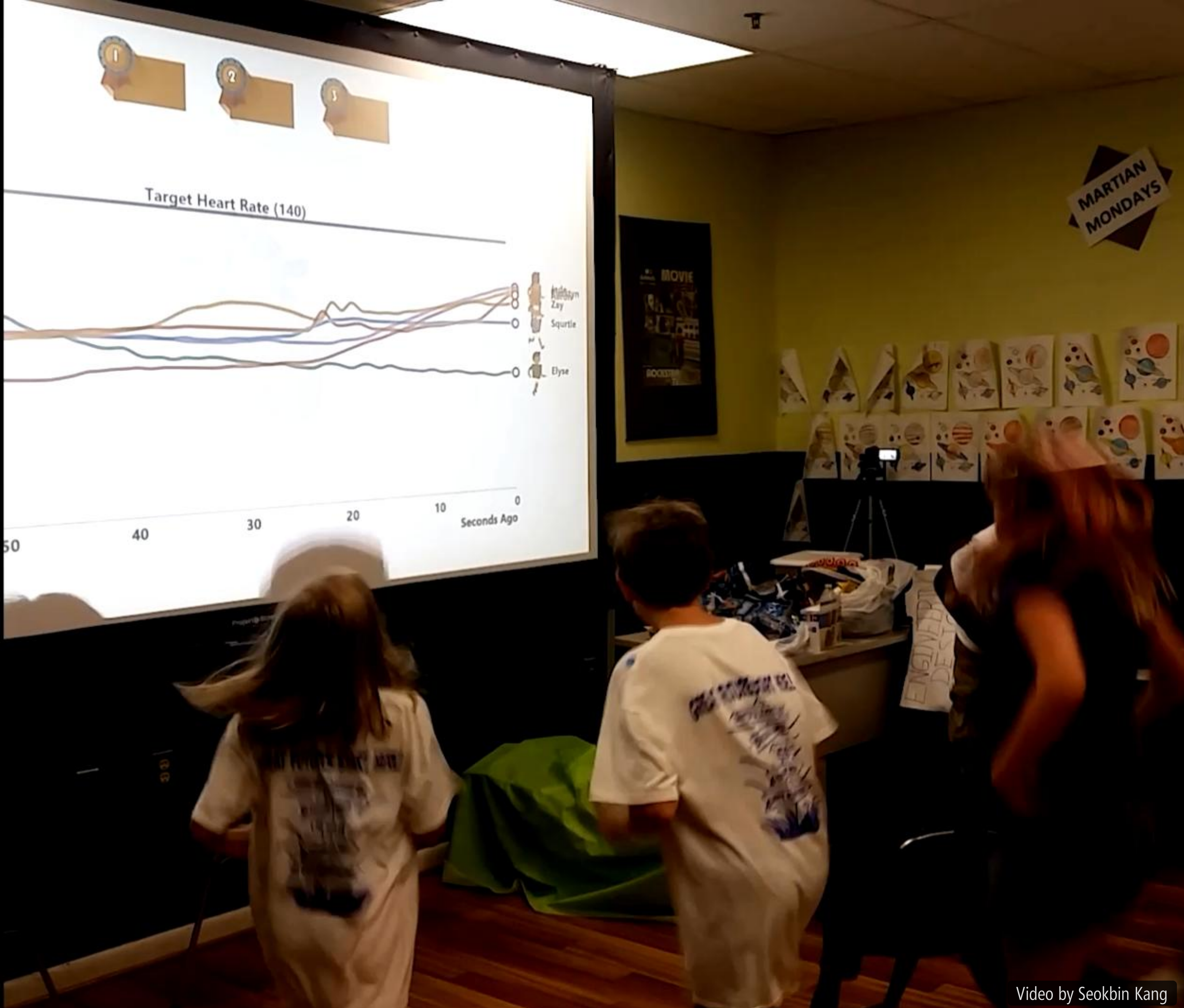
Moving Graphs

Social comparison

Hypothesis testing

Basic statistics

Kang *et al.,* IDC’17; Clegg, CHI’17; Byrne, ICLS’18



Video by Seokbin Kang

UNEXPECTED FINDING

How Does It Work?

STEM EDUCATION

MAKERWEAR

MAJEED KAZEMITABAAR

LIANG HE

IDC’15, CHI’16 Best Poster, CHI’17 Best Paper

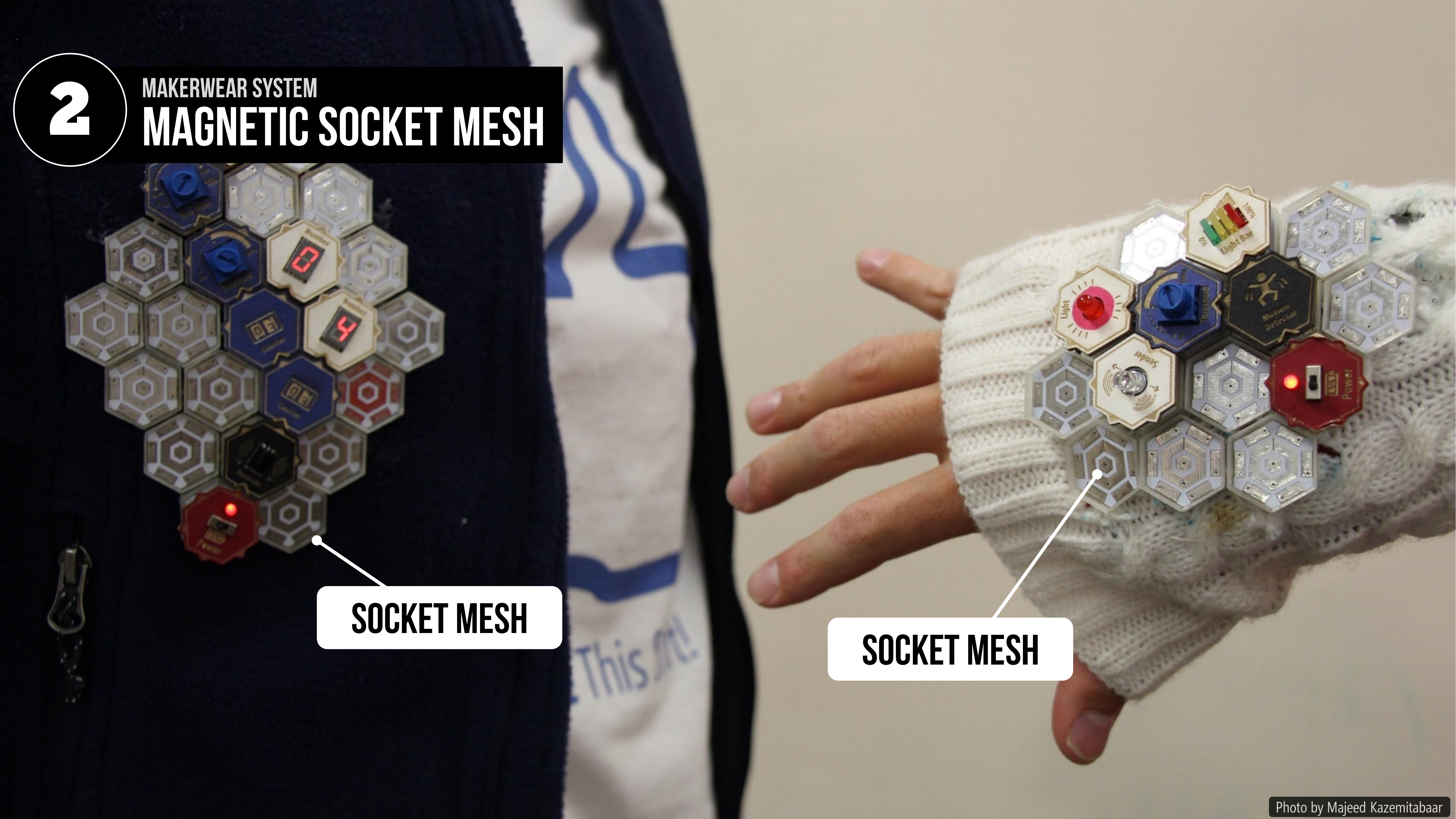
How can we…

enable young children to build their own interactive wearables?

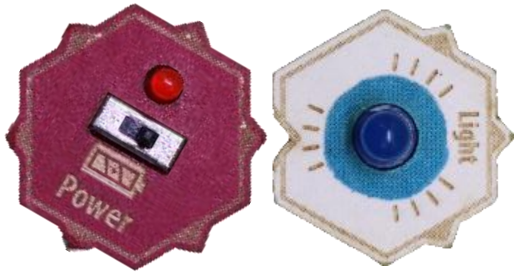
Photo by Majeed Kazemitabaar

1 MAKERWEAR SYSTEM
TANGIBLE MODULES

Photo by Majeed Kazemitabaar


2
MAKERWEAR SYSTEM
MAGNETIC SOCKET MESH
SOCKET MESH
SOCKET MESH
Photo by Majeed Kazemitabaar


Power


Power
Light


Power
Motion Detector
Light

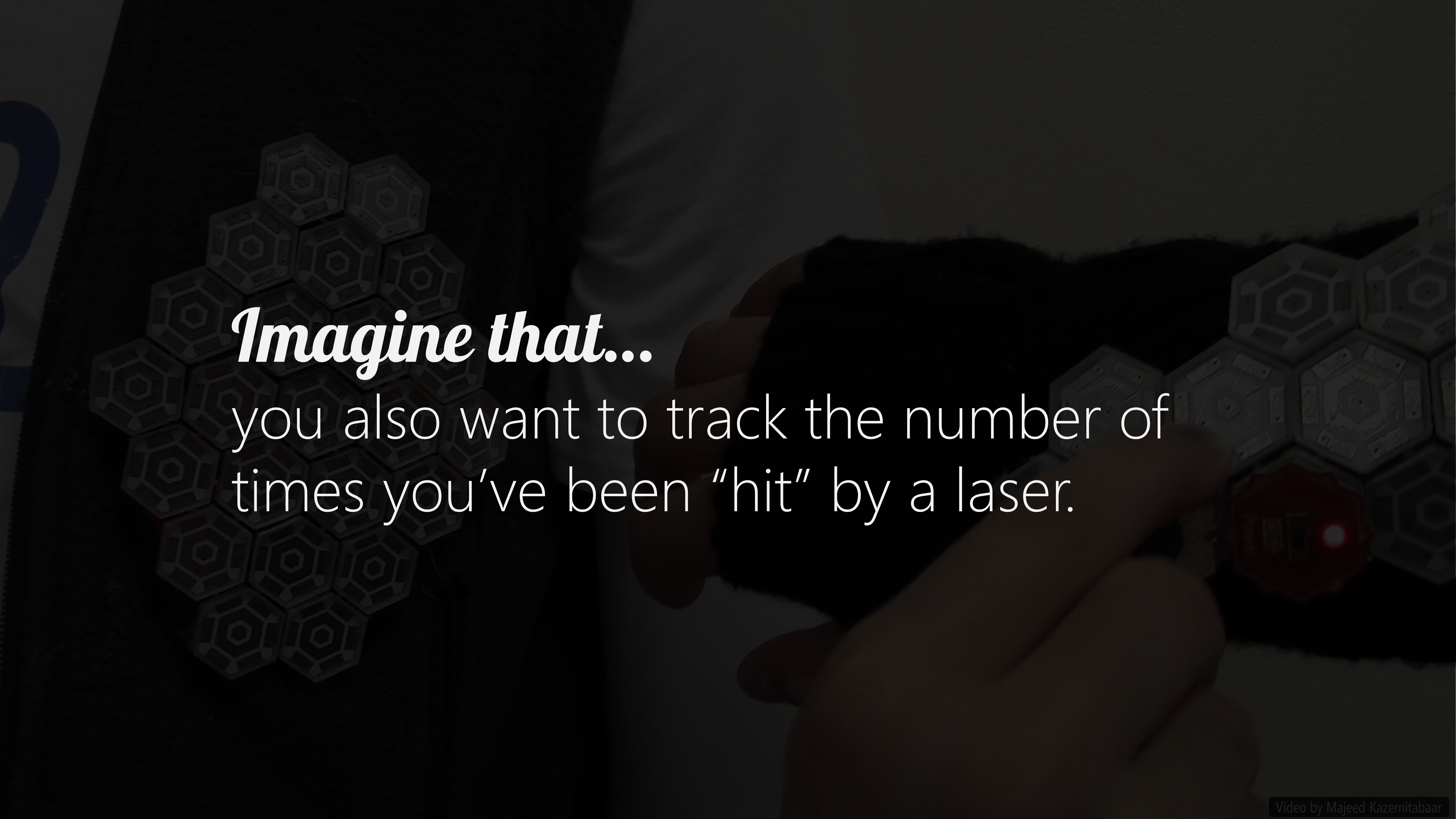
MAKERWEAR EXAMPLES

"MOTION-REACTIVE CLOTHES"

Motion-reactive clothes!


MAKERWEAR
“LASER TAG ARMBAND”
Video by Majeed Kazemitabaar


MAKERWEAR EXAMPLES
“LASER TAG ARMBAND”
Video by Majeed Kazemitabaar


Imagine that…
you also want to track the number of
times you've been "hit" by a laser.
Video by Majeed Kazemitabaar

Video by Majeed Kazemitabaar

Video by Majeed Kazemitabaar

MAKERWEAR

OVERALL

Highly engaged in making

Wide variety of designs

Applied computational thinking


MAKERWEAR
“MAGIC POKÉMON”
Age 9
Photo by Jon E. Froehlich


Video by Jon E. Froehlich


MAKERWEAR
“SMART LACROSSE STICK”
KEEP
GOING
GOING
Age 9


BAD
AD'S
SUPERMAN
LOVES STEM
KEEP
GOING

STEM EDUCATION

EVALUATIONS (N=240)

TEACHER INTERVIEWS

AFTER-SCHOOL PROGRAMS

CAMPS / WORKSHOPS

ELEMENTARY SCHOOLS

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**
5. **Believe in yourself**, believe in your work
6. The **people matter** the most
7. Engage and serve **community**

Makeability Lab Handbook

By Professor Jon Froehlich and lab members
Allen School of Computer Science and Engineering
University of Washington

Welcome to the Makeability Lab! 👋 We are so happy that you're here. Let's do great things together!

This handbook is intended to establish lab principles, values, and expectations. When you join our group (woohoo!), you are expected to read it. If you're just considering the Makeability Lab, awesome! This document should help you understand *who* we are and *whether* our lab is a good match for your personality and interests.

The handbook is a working document. We value your comments, suggested edits, and constructive criticisms. As with the lab itself, this handbook is ours—we get to define who we are and what we want to be. This is both a collective opportunity and a collective responsibility. Being part of a lab, pursuing a PhD, and having a healthy advisor-advisee relationship requires significant work and investment.

If something is unclear, it's likely confusing to others too—so, please ask questions and/or suggest edits so we can collectively improve the handbook.

This handbook is a start and not an end—and hopefully will provoke self-reflection and opportunities for dialogue between us. Please also see our list of Resources, the Allen School Graduate Student Handbook, and the PhD Process webpage.

Let's do it!

Core Values

The following Makeability values represent who we are and continually strive to be. They help define and unify us.

Mutual respect and support. The Makeability Lab is founded on mutual respect, trust, and support. We respect and support one another through our words and actions. If someone makes you uncomfortable, please let me know immediately. If I am the source of discomfort, I would hope that you could approach me—either in the moment or afterwards. If you don't feel comfortable reaching out to me, you can involve our grad advising staff. Alternatively, you could fill out this anonymous Makeability Lab feedback form or a similar feedback form run by the Allen School.

Trust. Trust allows us to take risks, be vulnerable, and cooperate more efficiently[4]. It is foundational to any relationship—personal or professional. We must trust each other and our labmates. A challenge for all of us, however, is that trust is *earned* through interaction, experience, and observation. Let us invest in our relationships, be patient, and earn this trust.

Elevate others. How can you make others better as a result of your presence? In the Makeability Lab, we try to elevate others, not diminish them. Your presence in the lab should lift us higher. For example, show interest in other's work and well being, be constructive and kind in your critiques, volunteer to help review paper drafts, talks, and scholarship applications.

Community engagement. Our research is driven by the needs of people, communities, and society. Our intention should always be to *work with* and *contribute* to these communities.

Togetherness. Research and graduate school can feel insular. But we are in this together. Seek help. Offer help. Be there for one another. My most fulfilling and exciting collaborations in graduate school were with fellow students—working closely together, learning from one another, and challenging each other to do great work and be better.

Psychological safety. We engender and nurture a psychologically safe environment. All members are free to speak up, to try and fail, to be who they are. This does not mean that we must all agree or provide unequivocal praise but that people feel supported in taking risks and speaking up.

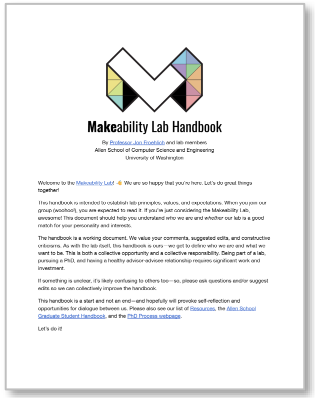
Culture of excellence. You are part of one of the top HCI research institutions in the world. In all parts of our work, we strive for excellence and hold ourselves to the highest standards, while acknowledging that, in some cases, perfection is the enemy of done.

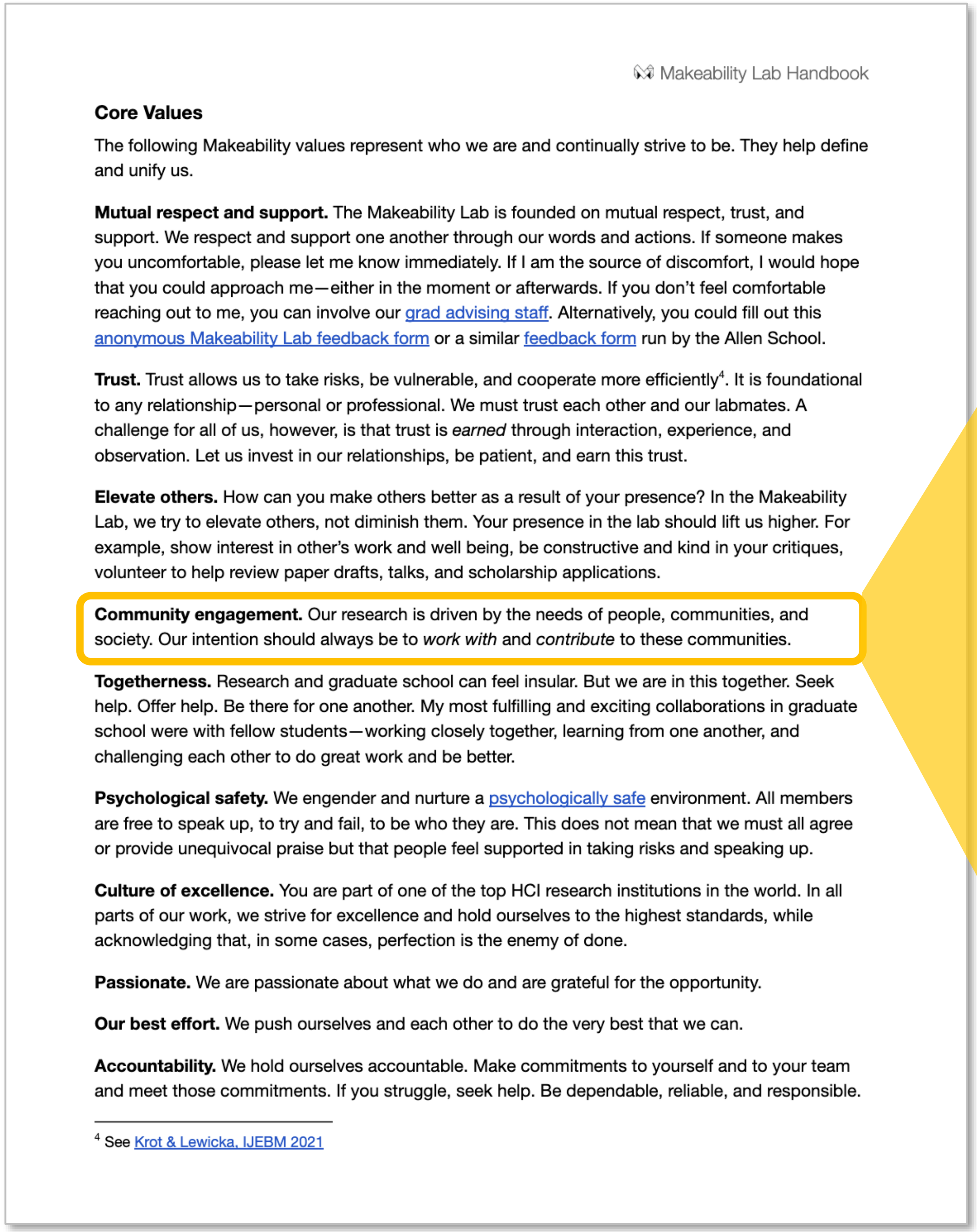
Passionate. We are passionate about what we do and are grateful for the opportunity.

Our best effort. We push ourselves and each other to do the very best that we can.

Accountability. We hold ourselves accountable. Make commitments to yourself and to your team and meet those commitments. If you struggle, seek help. Be dependable, reliable, and responsible.

[4] See Krot & Lewicka, IJEBM 2021





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---

[4] See Krot & Lewicka, IJEBM 2021

"**Community engagement.** Our research is driven by the needs of people, communities, and society. Our intention should always be to *work with* and *contribute* to these communities. "

STEM EDUCATION

PARTNERSHIPS

KID MUSEUM

BOYS & GIRLS CLUBS

futuremakers

KIDS MAKE THINGS BETTER.COM

CYC Center for Young Children

PGCPS

Great By Choice

Prince George's County
Public School System

WE ARE CASA

CASA

SOMOS CASA

UNIVERSITY OF MARYLAND 18 56

COLLEGE OF EDUCATION

STEM Masters in Education Program

University of Maryland Kidsteam

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**
5. **Believe in yourself**, in your vision
6. The **people matter** the most
7. Engage and serve **community**

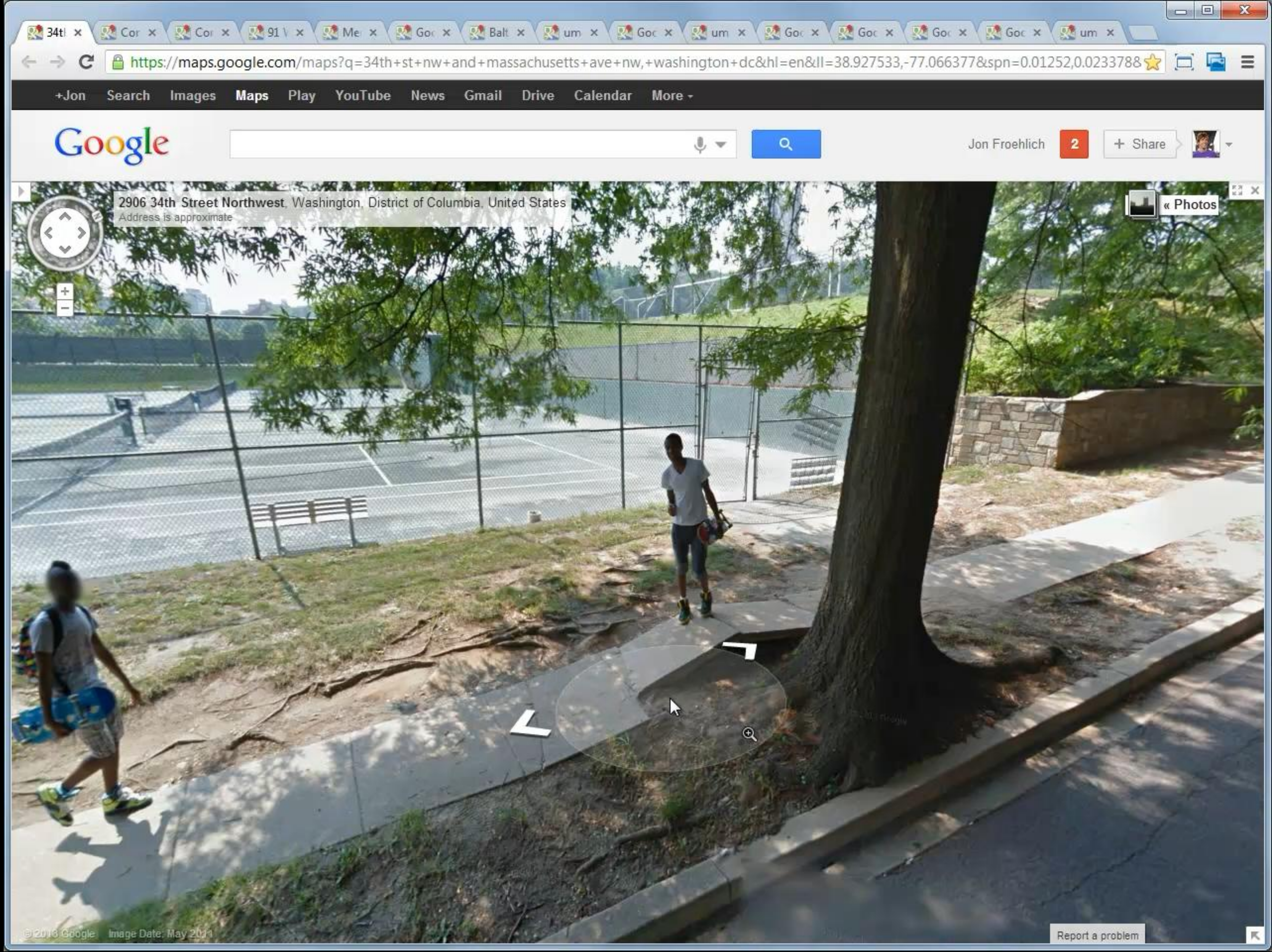
PROJECTSIDEWALK.ORG

UMD 2012

STARTING AS A PROFESSOR

UMD 2012

CAN WE USE STREET VIEW TO FIND & MAP INACCESSIBLE AREAS OF THE WORLD?



How do **sidewalk barriers** impact **human mobility**?

INTERVIEWS & WORKSHOPS WITH 150 STAKEHOLDERS

Combining Crowdsourcing and Google Street
Identify Street-level Accessibility Problem

Kotaro Hara, Victoria Le, Jon E. Froehlich
Human-Computer Interaction Lab (HCIL)
Computer Science Department, University of Maryland, College Park

Improving Public Transit Accessibility for Blind Riders by Crowdsourcing Bus Stop Landmark Locations with Google Street View

Kotaro Hara[1], Shiri Azenkot[2], Megan Campbell[2], Cynthia L. Bennett[2], Vicki Le[1], Sean Pannella[1], Robert Moore[1], Kelly Minckler[2], Rochelle H. Ng[2], Jon E. Froehlich[1]
[1]Makeability Lab | HCIL
[2]DUB Group
Computer Science and Engineering

The Design of Assistive Location-based Technologies for People with Ambulatory Disabilities: A Formative Study

Kotaro Hara, Christine Chan, Jon E. Froehlich
Makeability Lab | Human-Computer Interaction Lab (HCIL)
Computer Science Department, University of Maryland, College Park
{kotaro, jonf}@cs.umd.edu; chan2017@umd.edu

never realized sidewalks were a big deal": A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk

Chu Li, University of Washington, USA
Katrina Ma, University of Washington, USA, ma.katrina91@gmail.com
Michael Saugstad, University of Washington, USA, saugstad@cs.washington.edu
Kie Fujii, Medicine, USA, kie.fujii@hmhn.org
Molly Delaney, University of Illinois at Chicago, USA, mdelan9@uic.edu
Yochai Eisenberg, University of Illinois at Chicago, USA, yeisen2@uic.edu
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Judy L. Shanley, Easterseals, USA, jshanley@easterseals.com
Devon Snyder, University of Illinois at Chicago, USA, dsnyde8@uic.edu

Urban Accessibility as a Socio-Political Problem: A Multi-Stakeholder Analysis

MANASWI SAHA, University of Washington
DEVANSHI CHAUHAN, University of Washington

disabilities — MDPI

Article

Multiple-Stakeholder Perspectives on Accessibility Data and the Use of Socio-Technical Tools to Improve Sidewalk Accessibility

Delphine Labbé [1], Yochai Eisenberg [1,*], Devon Snyder [1], Judy Shanley [2], Joy M. Hammel [1,3] and Jon E. Froehlich [4]

1 Department of Disability and Human Development, University of Illinois-Chicago, Chicago, IL 60608, USA; dlabbe@uic.edu (D.L.); dsnyde8@uic.edu (D.S.); hammel@uic.edu (J.M.H.)
2 Easterseals, Chicago, IL 60604, USA; jshanley@easterseals.com
3 Occupational Therapy Department, University of Illinois-Chicago, Chicago, IL 60608, USA
4 Paul G. Allen School of Computer Science & Engineering, University of Washington, Seattle, WA 98195, USA; jonf@cs.washington.edu
* Correspondence: yeisen2@uic.edu

Abstract: For people with disabilities, accessible pedestrian infrastructure can support independence,

Source: Rooted in Rights, https://youtu.be/NRh-4Y3aNeo


THE PROBLEM IS
NOT JUST A LACK
OF ACCESSIBLE
INFRASTRUCTURE
A LACK OF DATA

Google Faculty Research Award, 2012

Combining Crowdsourcing and Computer Vision for Street-level Accessibility

PI: Jon Froehlich (HCI), Co-PI: David Jacobs (Computer Vision)
Department of Computer Science, University of Maryland, College Park
{ jonf, djacobs }@cs.umd.edu
Google Sponsors: Peng Dai (daipeng@google.com) and Sacha Arnoud (sacha@google.com)

(a) Object in Path (b) No Curb Ramp (c) Surface Problem (d) Prematurely Ending Sidewalk

Figure 1: In this proposal, we combine crowdsourcing and computer vision to semi-automatically locate, identify, and assess accessibility problems in city streets, sidewalks, and building facades in online map imagery. The images above show crowd annotations from preliminary experiments on Mechanical Turk where untrained "turkers" were asked to find, label, and rate the severity of accessibility obstacles in Google Street View (GSV) images.

1 Introduction

According to the most recent US Census (2010), roughly 30.6 million adults have physical disabilities that affect their ambulatory activities [8]. Of these, nearly half report using an assistive aid such as a wheelchair (3.6 million) or a cane, crutches, or walker (11.6 million) [8]. Despite comprehensive civil rights legislation for Americans with disabilities (*e.g.*, [1]), many city streets, sidewalks, and businesses in the US remain inaccessible [6,7]. The problem is not just that sidewalk accessibility fundamentally affects *where* and *how* people travel in cities but also that there are few, if any, mechanisms to determine accessible areas of a city *a priori*. Indeed, in a recent report, the National Council on Disability noted that they could not find comprehensive information on the "degree to which sidewalks are accessible" across the US [6]. **In this proposal, we describe new, scalable methods for collecting data on street-level accessibility including streets, sidewalks, and building facades by combining crowdsourcing and computer vision (*e.g.*, Figure 1).** Our overarching vision is to transform the way information about street-level accessibility is collected, visualized, and accessed.

Google Faculty Research Award, 2012

Combining Crowdsourcing and Computer Vision for Street-level Accessibility

PI: Jon Froehlich (HCI), Co-PI: David Jacobs (Computer Vision)
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To support the viability of our proposal, we have conducted three preliminary studies. First, because finding, labeling, and assessing the severity of sidewalk accessibility problems in streetscape imagery is a subjective and potentially ambiguous task, we investigated its feasibility with six motivated and diligent labelers: three members of the research team and three wheelchair users. Results showed the labeling approach is reliable, with high intra- and inter-labeler agreement, and allowed us to establish baseline understandings of performance (*i.e.,* what does "good" labeling performance look like for this task) [5]. Second, we piloted a range of labeling interfaces and examined the effect of three interfaces on task performance [2]. Third, we performed preliminary experiments using a manually curated database of 229 Google Street View (GSV) images, demonstrating that *untrained* crowd workers on Mechanical Turk (turkers) could correctly determine the presence of accessibility problems with 81% accuracy. With simple quality control methods, this accuracy increased to 93% [5].

2 Research Plan

Building off this initial momentum, our proposal describes two phases of work: **(i) the development of scalable, map-based techniques and labeling tools** to acquire large amounts of data on street-level accessibility, which will be deployed initially on online labor markets such as Mechanical Turk; **(ii) the integration and use of computer vision algorithms** to further scale our data collection methods by directing the efforts of human labelers to scenes that are likely to contain problems. Though beyond the scope of this proposal, we ultimately plan to deploy these data collection techniques more broadly via a publically accessible website, and to utilize the data and techniques to enable new types of accessible-aware navigation tools.; For example, *RouteAssist* (Figure 2) will personalize route suggestions based on a user's reported mobility level.

2.1 Crowdsourcing Streetscape Labeling

Our labeling work will focus on interfaces and experiments for practical, scalable collection of street-level accessibility data.

Improving labeling scalability: Our current prototype labeling system relies on a manually curated database of images selected by the research team. This was sufficient to demonstrate feasibility but ignored important practical aspects such as locating the GSV camera in geographic space and selecting an optimal viewpoint. These challenges clearly need to be solved

NSF Medium Grant, 2012

HCC: Medium: Combining Crowdsourcing and Computer Vision for Street-level Accessibility

(a) Object in Path (b) No Curb Ramp (c) Surface Problem (d) Prematurely Ending Sidewalk

Figure 1: In this proposal, we outline a research agenda that combines crowdsourcing, online map imagery, and computer vision to semi-automatically locate, identify, and assess accessibility problems in city streets, sidewalks, and building facades. The images above show crowd annotations from preliminary experiments on Mechanical Turk where untrained "turkers" were asked to find, label, and rate the severity of sidewalk accessibility obstacles in Google Street View (GSV) images.

1 Introduction

According to the most recent US Census (2010), roughly 30.6 million adults have physical disabilities that affect their ambulatory activities [128]. Of these, nearly half report using an assistive aid such as a wheelchair (3.6 million) or a cane, crutches, or walker (11.6 million) [128]. Despite comprehensive civil rights legislation for Americans with disabilities (e.g., [9,75]), many city streets, sidewalks, and businesses in the US remain inaccessible [90,96,120]. The problem is not just that sidewalk accessibility fundamentally affects *where* and *how* people travel in cities but also that there are few, if any, mechanisms to determine accessible areas of a city *a priori*. Indeed, in a recent report, the National Council on Disability noted that they could not find comprehensive information on the "degree to which sidewalks are accessible" across the US [96]. In this proposal, we describe new scalable methods for collecting data on street-level accessibility including streets, sidewalks, and building facades (*e.g.,* Figure 1) and a set of new accessible-aware map-based tools to take advantage of this data (*e.g.,* Figure 2). Our overarching vision is to transform the way in which information is collected and visualized about street-level accessibility.

The lack of street-level accessibility information can have a significant negative impact on the independence and mobility of citizens [99,120]. For example, in our own initial formative interviews with wheelchair users, we uncovered a prevailing view about navigating to new areas of a city: "I usually don't go where I don't know [about accessible routes]" (Participant C, congenital polyneuropathy). Although maintenance issues such as buckled or cracked sidewalks can pose significant accessibility challenges so too do larger, more permanent infrastructural issues such as utility poles or fire hydrants directly in sidewalk paths or the lack of curb ramps at intersections or sidewalks (see Figure 1). These issues are significant. In a precedent-setting court case in 1993, the court ruled that the "lack of curb cuts is a primary obstacle to the smooth integration of those with disabilities into the commerce of daily life" and that "without curb cuts, people with ambulatory disabilities simply cannot navigate the city" [75].

Sidewalk and street accessibility problems become even more significant in light of the unprecedented growth of the senior (65+) population in the US [97] and, commensurately, the number of people in the US with some level of impairment that affects their mobility. According to the 2010 US Census, nearly *half* of the US population with some form of ambulatory limitation is 65 or older (15.2 million) [128]. Because the attenuated reflexes and physical limitations of older adults might prohibit them from driving automobiles, they are more likely to rely on public transit or walking than other adults [57]. In this way, inaccessible public rights-of-way have cascading effects—they do not only impede trips to local areas but can also prevent access to and from public transit stops (*e.g.,* subway stations), further restricting a person's radius of travel [128].

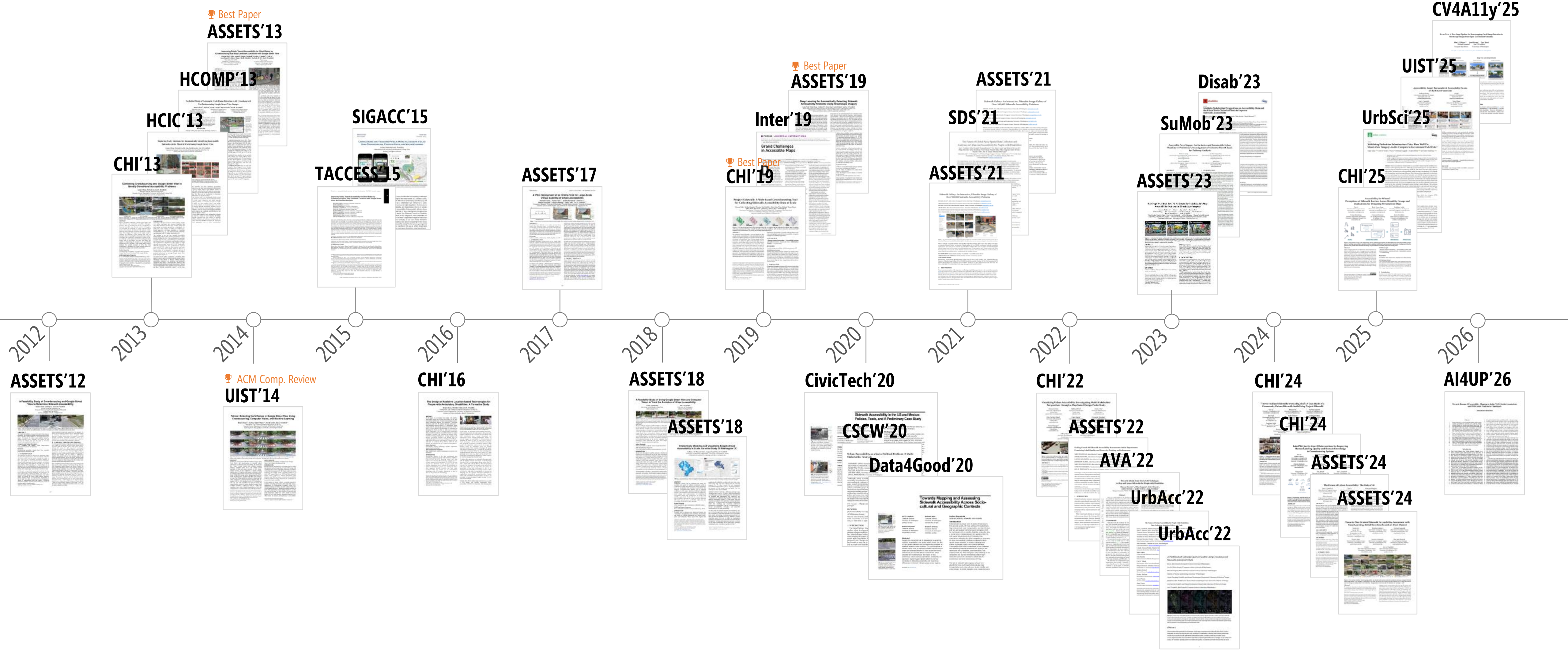
1

This is a good idea but **not** a tenure-level idea.

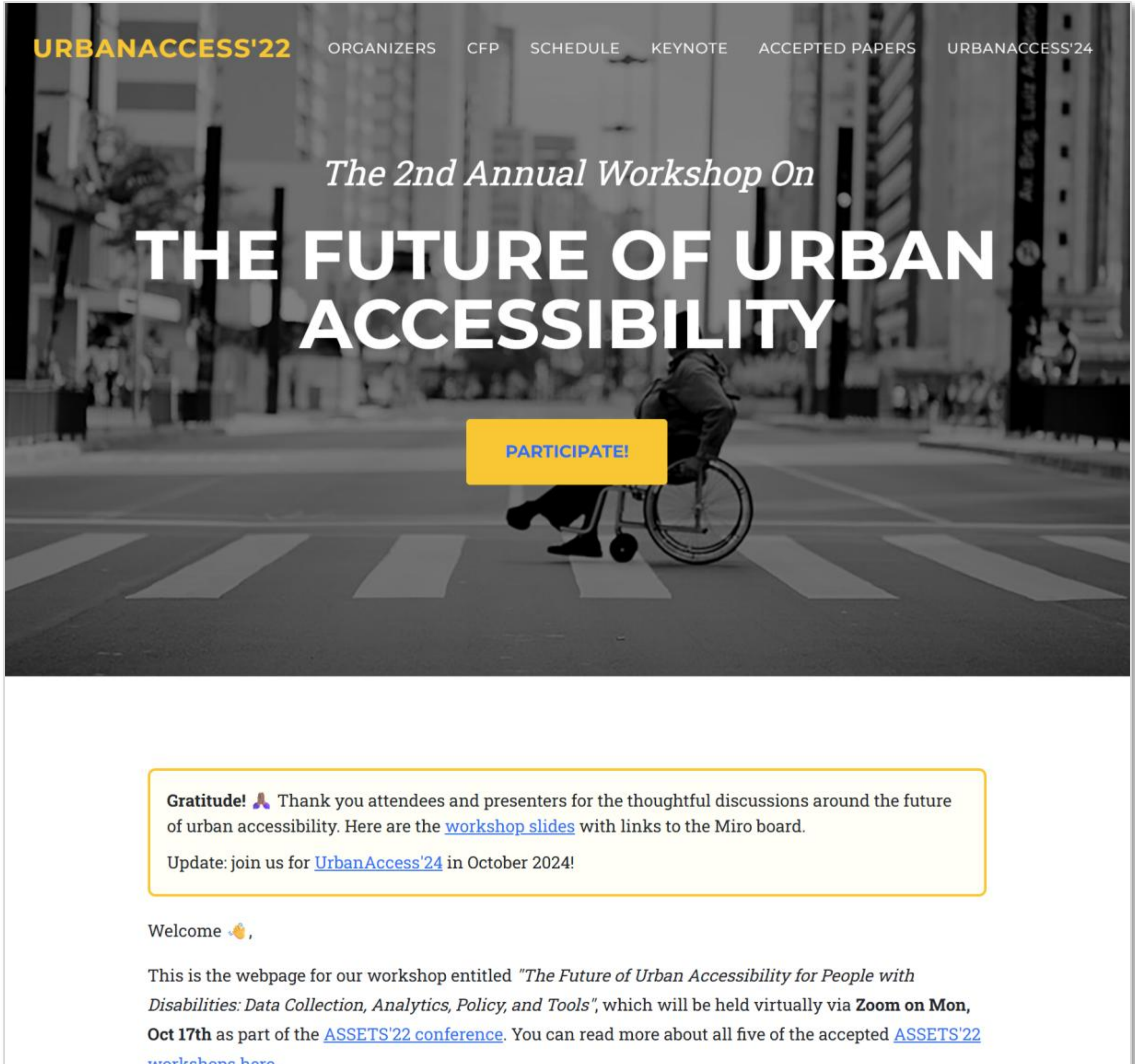
-SENIOR FACULTY

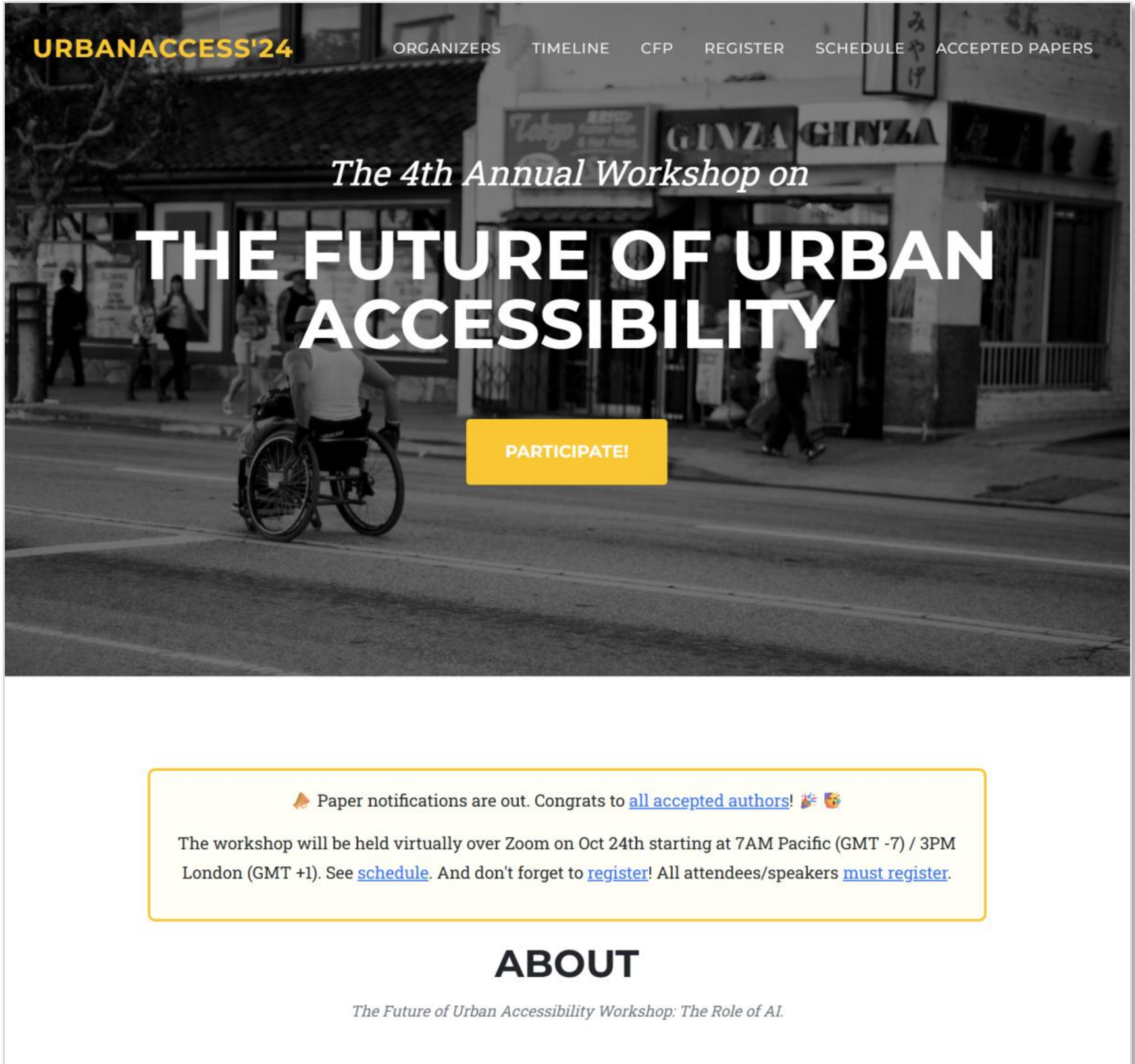
URBAN ACCESSIBILITY

RESEARCH



FOUR INTERNATIONAL WORKSHOPS

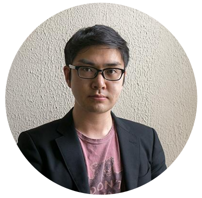




TRY IT!

PROJECT SIDEWALK

http://projectsidewalk.org



Kotaro Hara
UMD CS PhD'16

Manaswi Saha
UW CSE PhD'22

Mikey Saugstad
UMD CS MS'18
UW CSE

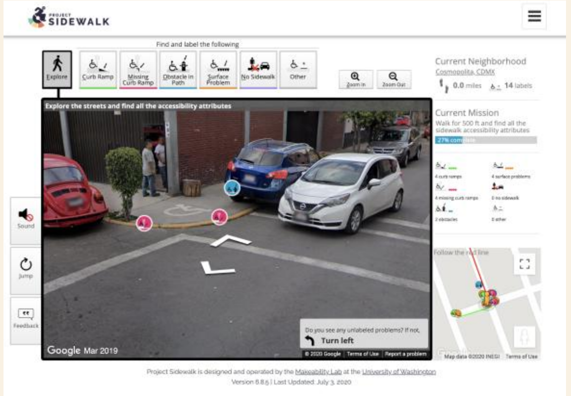
Chu Li
UW CSE PhD

Yochai Eisenberg
UIC Professor
Disability & Human Development

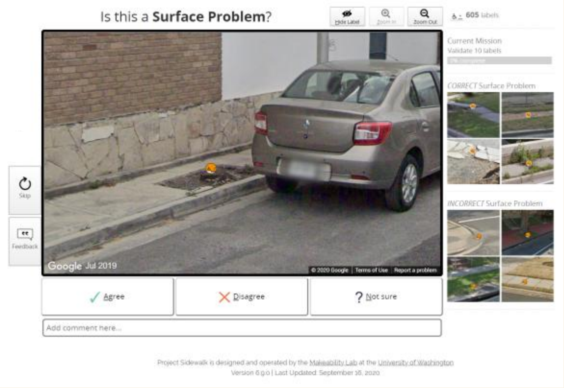
ONLINE MAP IMAGERY

+

REMOTE CROWDSOURCING INTERFACES



Labeling missions



Validation missions

HUMAN LABELS

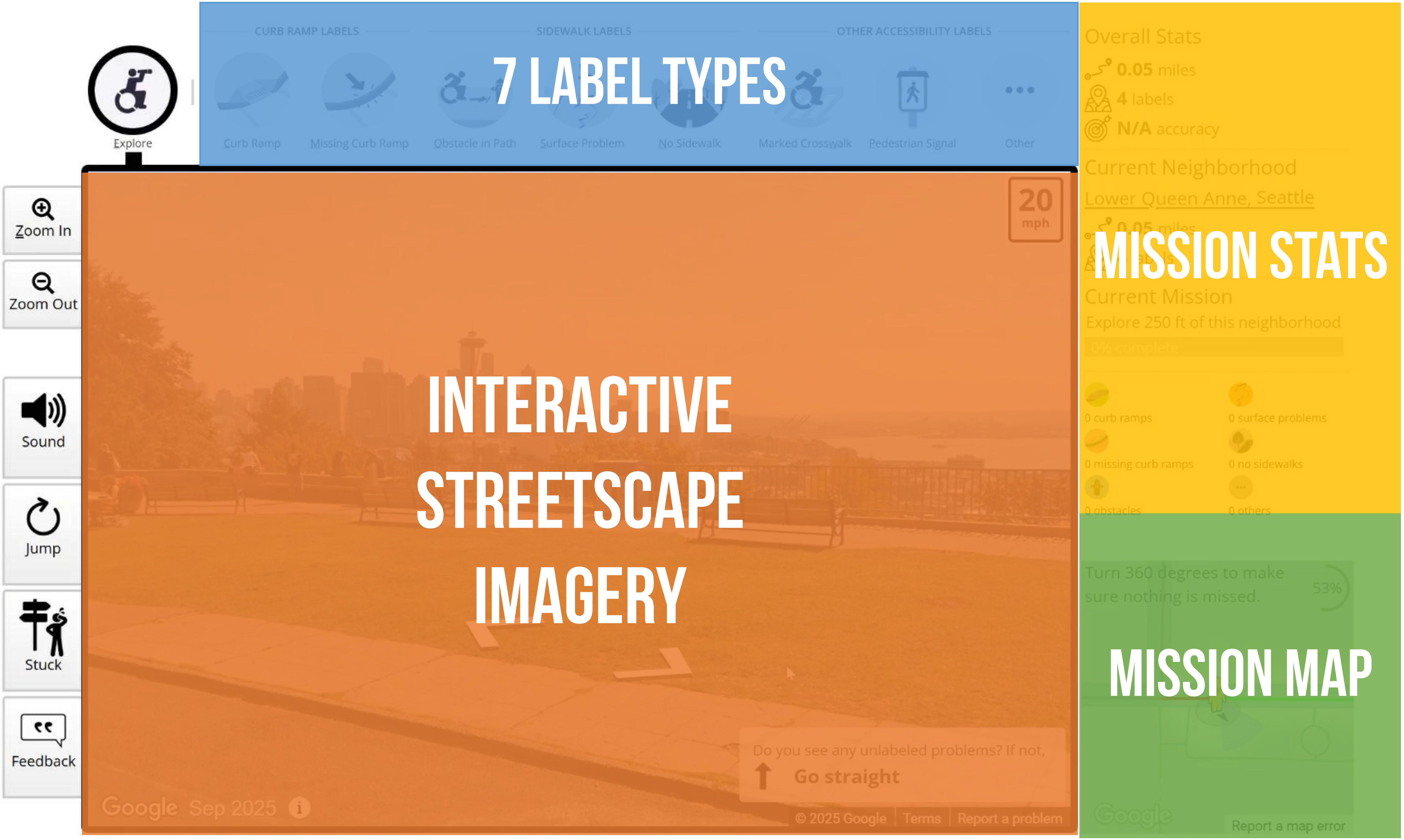
MACHINE LEARNING

PROJECT SIDEWALK
HTTP://PROJECTSIDEWALK.IO

MAP, ASSESS, & VISUALIZE EVERY SIDEWALK IN THE

W RLD

PROJECTSIDEWALK.ORG


7 LABEL TYPES
CURB RAMP LABELS
SIDEWALK LABELS
OTHER ACCESSIBILITY LABELS
Explore
Curb Ramp
Missing Curb Ramp
Obstacle in Path
Surface Problem
No Sidewalk
Marked Crosswalk
Pedestrian Signal
Other
Zoom In
Zoom Out
Sound
Jump
Stuck
Feedback
INTERACTIVE STREETSCAPE IMAGERY
Do you see any unlabeled problems? If not,
Go straight
Google Sep 2025
© 2025 Google
Terms
Report a problem
Overall Stats
0.05 miles
4 labels
N/A accuracy
Current Neighborhood
Lower Queen Anne, Seattle
MISSION STATS
Current Mission
Explore 250 ft of this neighborhood
0 curb ramps
0 surface problems
0 missing curb ramps
0 no sidewalks
0 obstacles
0 others
Turn 360 degrees to make sure nothing is missed.
53%
MISSION MAP
Report a map error

Best Paper
ASSETS'13
HCOMP'13
HCIC'13
CHI'13
SIGACC'15
TACCESS'15
ASSETS'17
Best Paper
ASSETS'19
Inter'19
Best Paper
CHI'19
ASSETS'21
SDS'21
ASSETS'21
Disab'23
SuMob'23
ASSETS'23
CV4A11y'25
UIST'25
UrbSci'25
CHI'25
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2026
ASSETS'12
ACM Comp. Review
UIST'14
CHI'16
ASSETS'18
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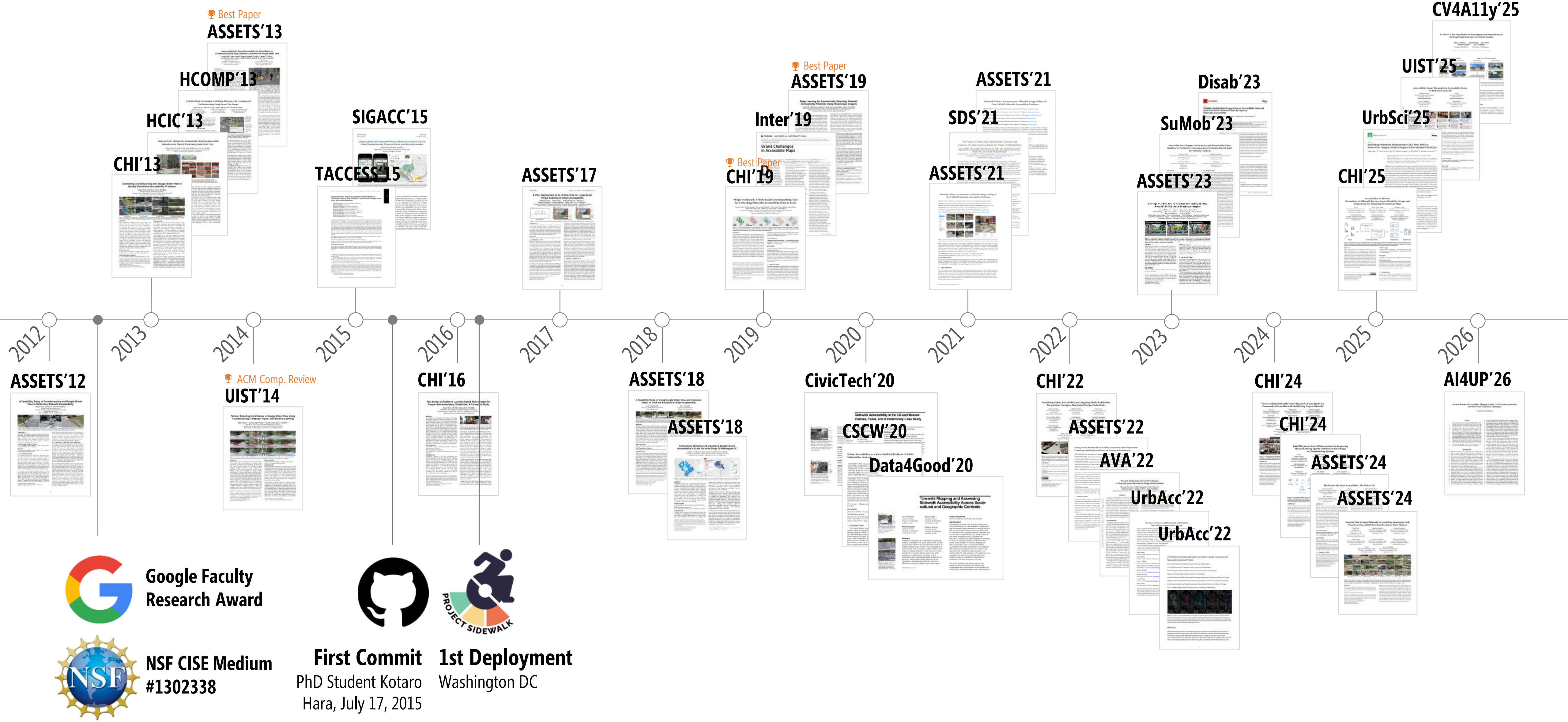
CSCW'20
Data4Good'20
CHI'22
ASSETS'22
AVA'22
UrbAcc'22
UrbAcc'22
CHI'24
CHI'24
ASSETS'24
ASSETS'24
AI4UP'26
Google Faculty
Research Award
NSF CISE Medium
#1302338

It’s good research but **don’t spend your time** on **open sourcing** and **deploying**. It’s not worth the effort & **won’t be** recognized by academia.

-SENIOR FACULTY



Best Paper
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HCOMP'13
HCIC'13
CHI'13
SIGACC'15
TACCESS'15
ASSETS'17
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Inter'19
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SDS'21
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Disab'23
SuMob'23
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CHI'22
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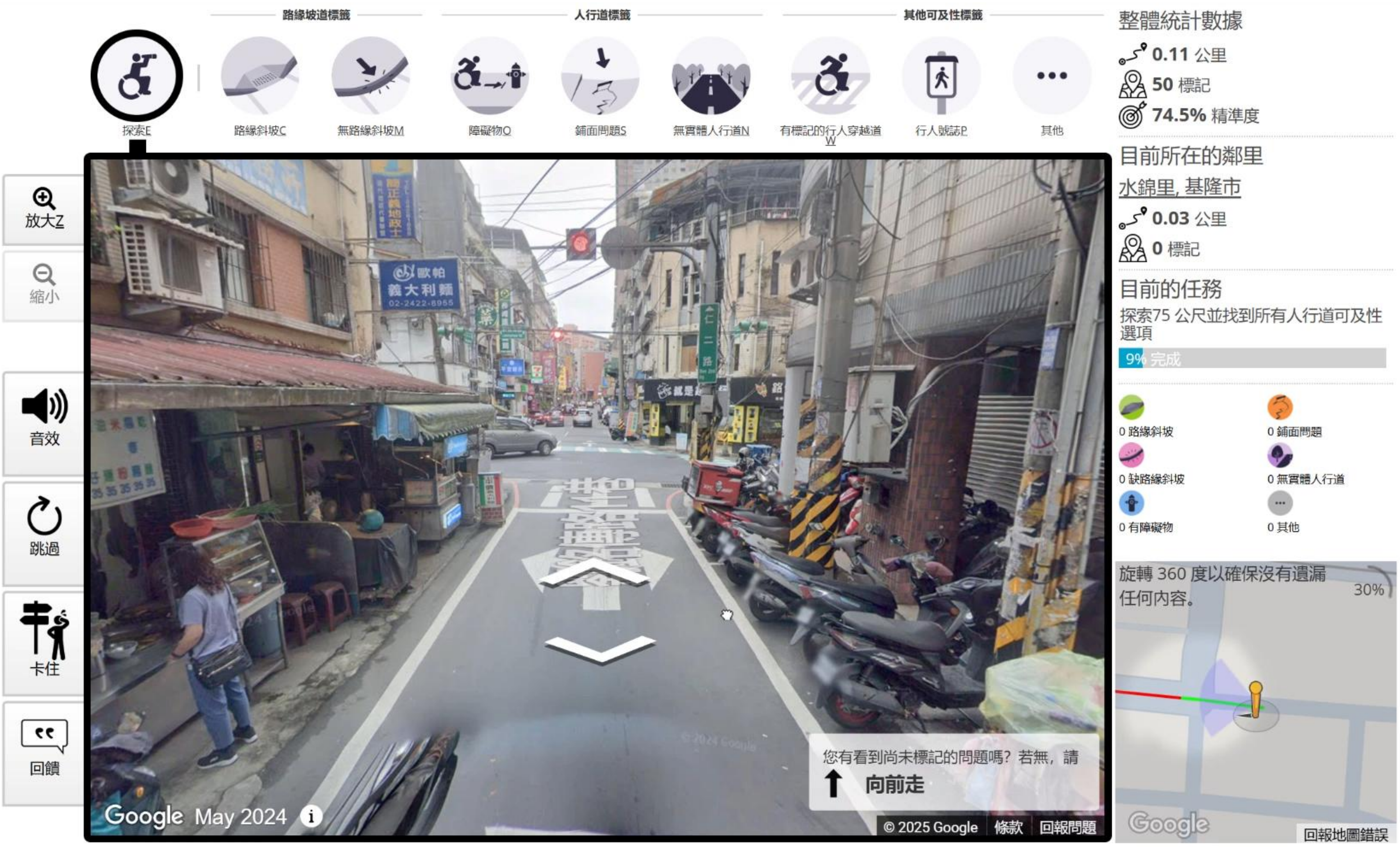
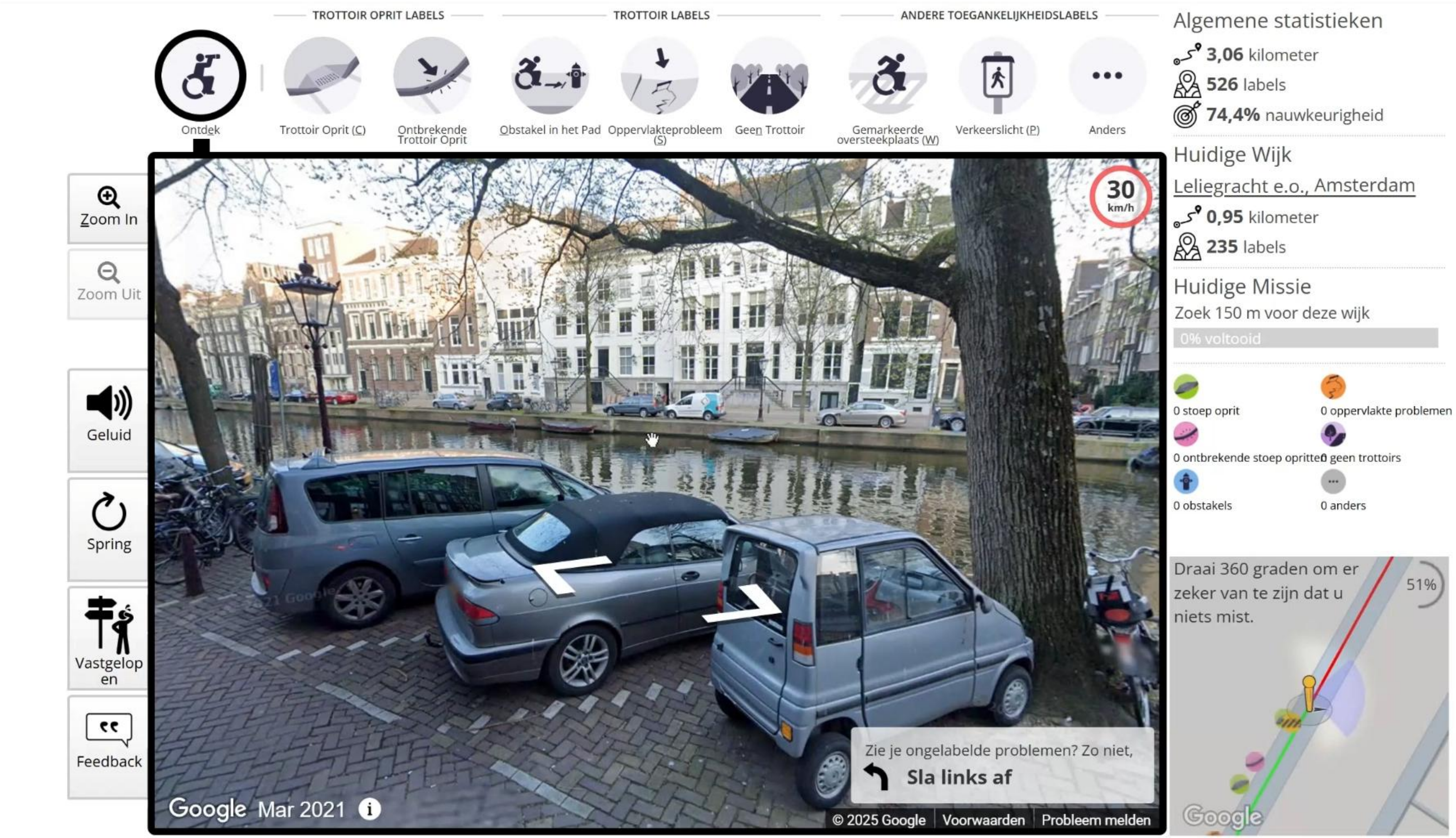
UrbAcc'22
UrbAcc'22
CHI'24
CHI'24
ASSETS'24
ASSETS'24
AI4UP'26
Google Faculty
Research Award
NSF CISE Medium
#1302338
First Commit
PhD Student Kotaro
Hara, July 17, 2015
PROJECT SIDEWALK
1st Deployment
Washington DC

PROJECT SIDEWALK

50 CITIES, 12 COUNTRIES, 6 LANGUAGES

Deployments	Streets Explored	Labels	Validations
50 Cities	20,500 km	1.5 million	1.8 million


路緣坡道標籤
人行道標籤
其他可及性標籤
探索E
路緣斜坡C
無路緣斜坡M
障礙物O
鋪面問題S
無實體人行道N
有標記的行人穿越道W
行人號誌P
其他
整體統計數據
0.11 公里
50 標記
74.5% 精準度
目前所在的鄰里
水錦里, 基隆市
0.03 公里
0 標記
目前的任務
探索75 公尺並找到所有人行道可及性選項
9% 完成
0 路緣斜坡
0 鋪面問題
0 缺路緣斜坡
0 無實體人行道
0 有障礙物
0 其他
旋轉 360 度以確保沒有遺漏任何內容。
30%
放大Z
縮小
音效
跳過
卡住
回饋
您有看到尚未標記的問題嗎？若無，請
向前走
Google May 2024
© 2025 Google
條款
回報問題
回報地圖錯誤


TROTTOIR OPRIT LABELS
TROTTOIR LABELS
ANDERE TOEGANKELIJKHEIDSLABELS
Ontdek
Trottoir Oprit (C)
Ontbrekende Trottoir Oprit
Obstakel in het Pad
Oppervlakteprobleem (S)
Geen Trottoir
Gemarkeerde oversteekplaats (W)
Verkeerslicht (P)
Anders
Algemene statistieken
3,06 kilometer
526 labels
74,4% nauwkeurigheid
Huidige Wijk
Leliegracht e.o., Amsterdam
0,95 kilometer
235 labels
Huidige Missie
Zoek 150 m voor deze wijk
0% voltooid
0 stoep oprit
0 oppervlakte problemen
0 ontbrekende stoep opritten
0 geen trottoirs
0 obstakels
0 anders
Zoom In
Zoom Uit
Geluid
Spring
Vastgelopen
Feedback
30 km/h
Zie je ongelabelde problemen? Zo niet,
Sla links af
Google Mar 2021
© 2025 Google
Voorwaarden
Probleem melden
Draai 360 graden om er zeker van te zijn dat u niets mist.
51%
Google

World Enabled

Ciudad Fácil

WPI

Worcester Polytechnic Institute 1865

Plaksha University

Access Living

Cities for All — Global Campaign on Inclusive and Accessible Cities

City of Mendota, Illinois — The World's Greatest Little City — Home of the National Sweet Corn Festival

City of St. Louis

Oradell Girl Scouts

Hackensack Meridian School of Medicine

CREATE

AIMCIL — Achieving Independence and Mobility Center for Independent Living

Liga Peatonal

scistarter — People-powered science

El Colegio de Michoacán

Universidad del Azuay

Active Transportation Alliance

Open Columbus

Chicago Metropolitan Agency for Planning

Greater Fort Wayne Inc. — Metro Chamber Alliance

trailnet — Streets for All

Universidad Autónoma de Sinaloa

Metropolitan Planning Council — shaping a more equitable, sustainable and prosperous Chicago region since 1934

SFU Simon Fraser University

Bike PGH!

Universidad de Monterrey — Homo Hominis in Ministerio Perficitur

WSDOT

City of Amsterdam

San Pedro Garza García — Gobierno Municipal

City of Burnaby

City of Newberg

USP Universidade de São Paulo

Progress Center for independent living

Universidad Nacional Autónoma de México — Por mi raza hablará el espíritu

amsterdam intelligence

Regional Transportation Authority (rta)

Pacific NW Transportation Consortium — PACTRANS Region 10

Bellevue School District

UW Disability & D/deaf Cultural Center

Chicago Metropolitan Agency for Planning

University of South Carolina

UIC University of Illinois Chicago

Universität Zürich UZH

Metropolitan Mayors Caucus

Vitruvius — give it strength, make it useful, deliver it beautifully

WindSwell Foundation

Disability Rights Washington

Teaneck High School

公民幫推 People Nudge

Denny International Middle School

UF University of Florida — College of Health and Human Performance

Tecnológico de Monterrey

Civic Innovation Lab

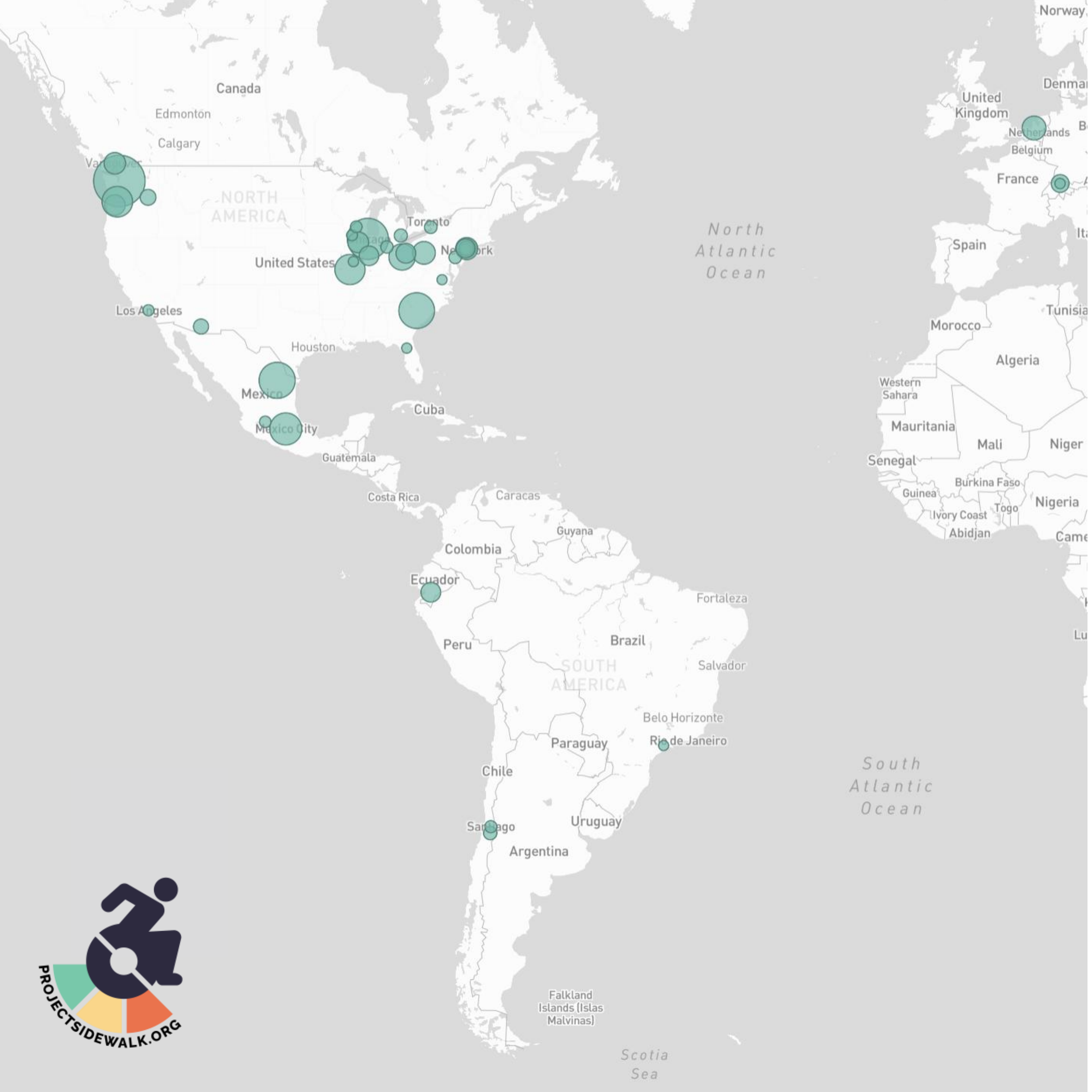
Great Lakes ADA Center — A Member of the ADA National Network

MS™

WHAT’S THE **IMPACT?**

PROJECT SIDEWALK

TRANSLATIONAL IMPACT



Informing Policy

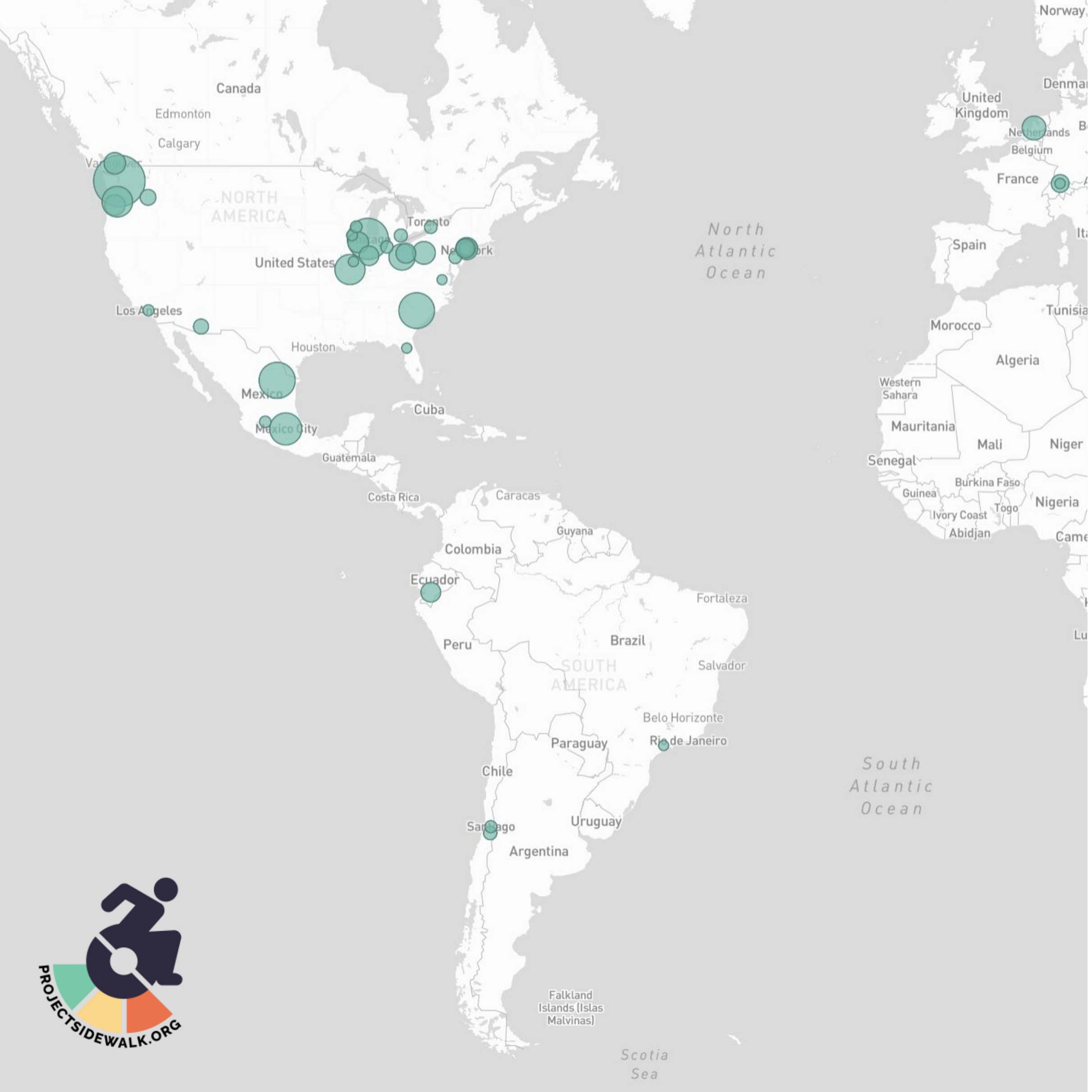
Urban Planning

Service Learning

Research Engine

PROJECT SIDEWALK

TRANSLATIONAL IMPACT



Informing Policy

Urban Planning

Service Learning

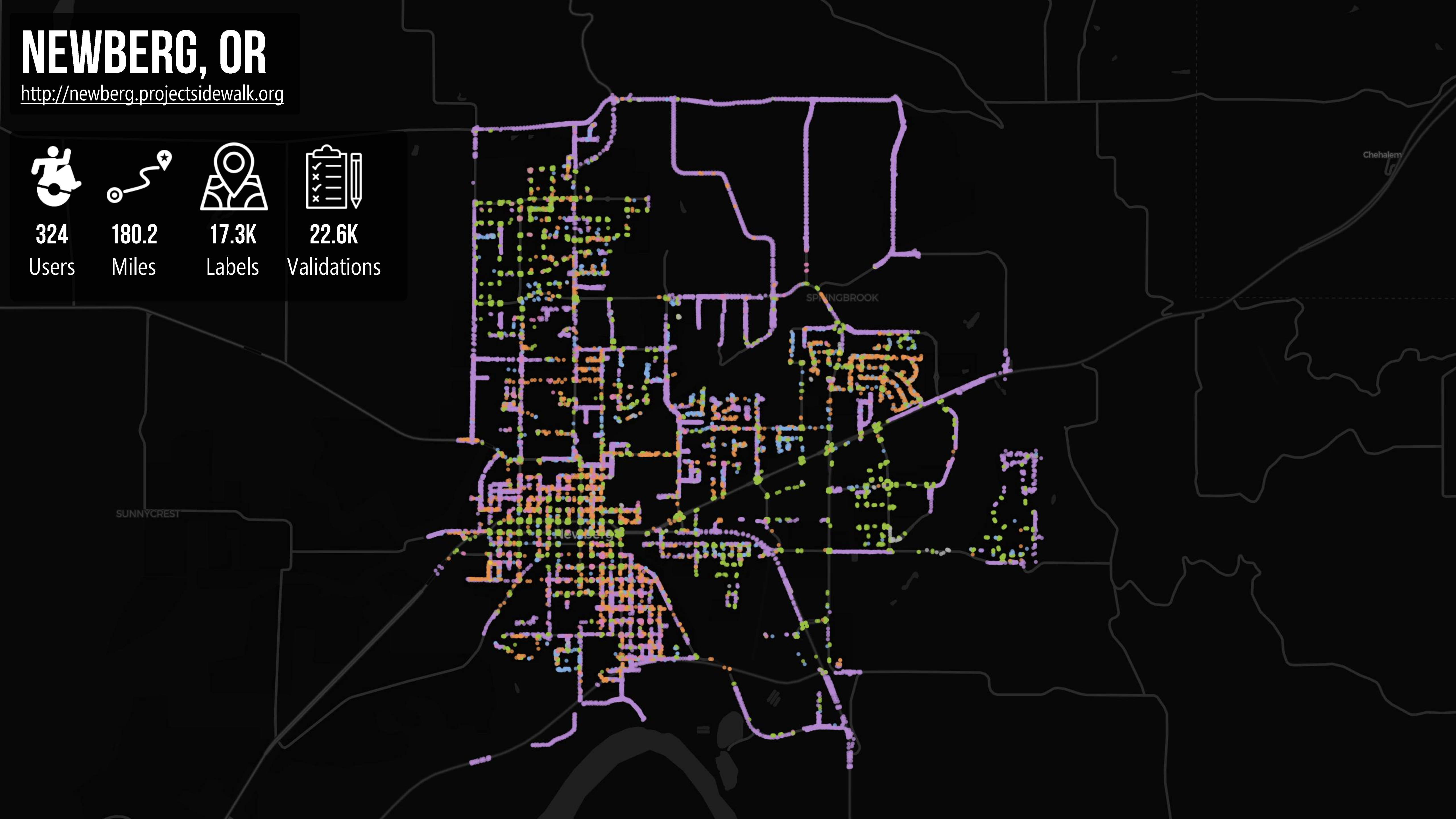
Research Engine


NEWBERG, OREGON
Disability Advocates
Local Community
City of Newberg
Public Works Office
Canada
Edmonton
Calgary
North Atlantic Ocean
Colombia
Ecuador
Peru
Brazil
Chile
Argentina
South Atlantic Ocean
Iceland
Sweden
Finland
Norway
Russia
United Kingdom
France
Spain
Italy
Poland
Ukraine
Kazakhstan
Mongolia
China
India
Japan
Africa
Indian Ocean
Indonesia
Philippines
Australia
New Zealand

NEWBERG, OR

http://newberg.projectsidewalk.org

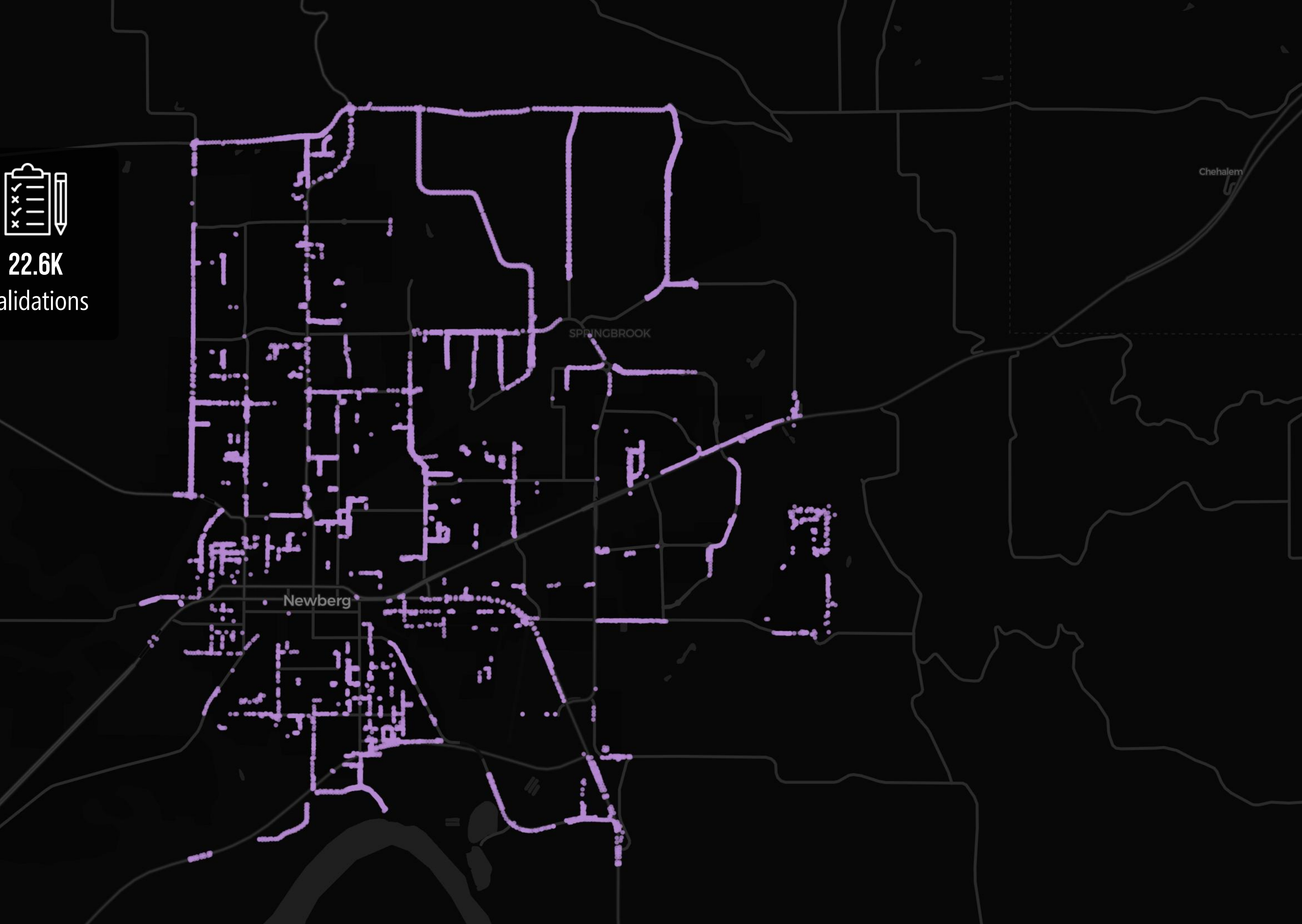
324	180.2	17.3K	22.6K
Users	Miles	Labels	Validations



NEWBERG, OR

http://newberg.projectsidewalk.org

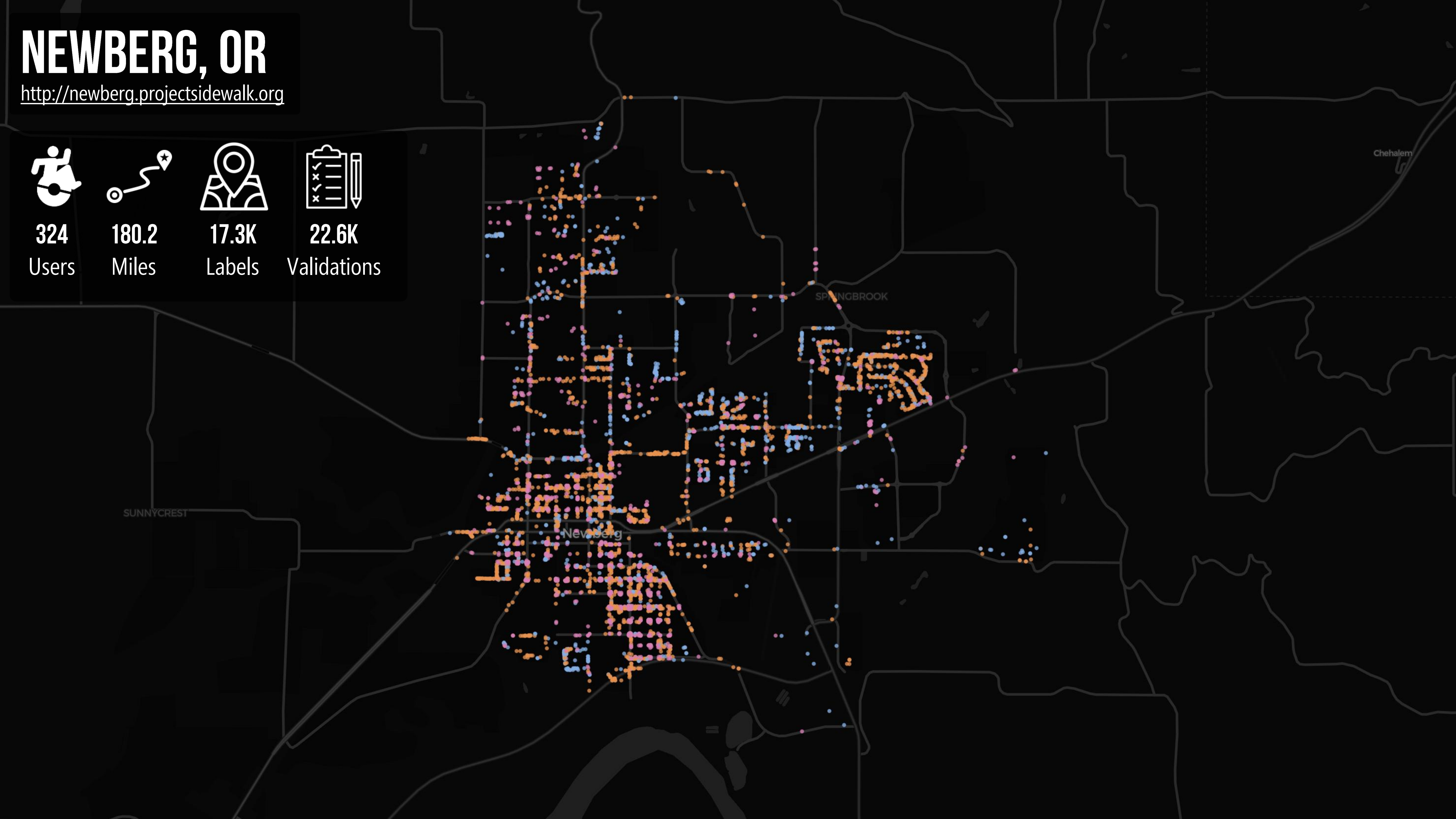
324	180.2	17.3K	22.6K
Users	Miles	Labels	Validations



NEWBERG, OR

http://newberg.projectsidewalk.org

324	180.2	17.3K	22.6K
Users	Miles	Labels	Validations



City of Newberg

SIDEWALK REPAIR PROGRAM

RESIDENTIAL GRANT AND LOAN APPLICATION PACKET

Sidewalks are for Everybody

Sidewalks make the entire community accessible,
are required under the Federal ADA regulations,
and enhance your home's value and curb appeal.

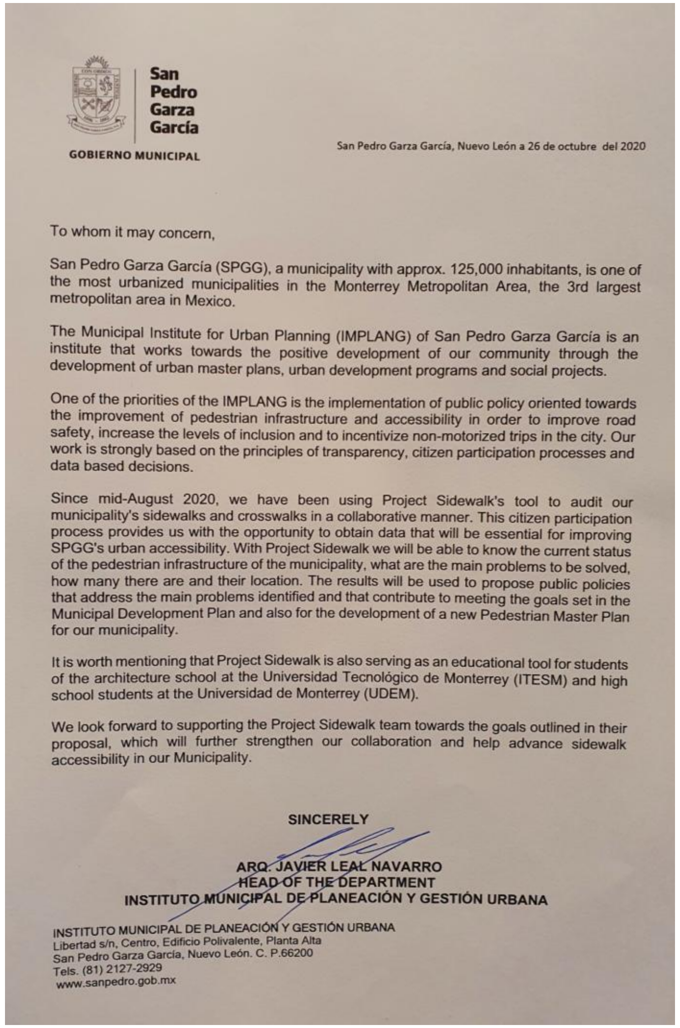
City Engineer's Office: Email: sidewalkrepairprogram@newbergoregon.gov | 503.537.1273 | PO Box 970

Newberg City Hall | 414 E. First Street | Newberg, OR 97132 | (503) 538-9421 | M-F 8:30-4:30PM


SAN PEDRO, MX
LIGA PEATONAL
LigaPeatonal.org
Local University
Local Community

PROJECT SIDEWALK MEXICO

SAN PEDRO, MX



San Pedro Garza García

GOBIERNO MUNICIPAL

San Pedro Garza García, Nuevo León a 26 de octubre del 2020

To whom it may concern,

San Pedro Garza García (SPGG), a municipality with approx. 125,000 inhabitants, is one of the most urbanized municipalities in the Monterrey Metropolitan Area, the 3rd largest metropolitan area in Mexico.

The Municipal Institute for Urban Planning (IMPLANG) of San Pedro Garza García is an institute that works towards the positive development of our community through the development of urban master plans, urban development programs and social projects.

One of the priorities of the IMPLANG is the implementation of public policy oriented towards the improvement of pedestrian infrastructure and accessibility in order to improve road safety, increase the levels of inclusion and to incentivize non-motorized trips in the city. Our work is strongly based on the principles of transparency, citizen participation processes and data based decisions.

Since mid-August 2020, we have been using Project Sidewalk's tool to audit our municipality's sidewalks and crosswalks in a collaborative manner. This citizen participation process provides us with the opportunity to obtain data that will be essential for improving SPGG's urban accessibility. With Project Sidewalk we will be able to know the current status of the pedestrian infrastructure of the municipality, what are the main problems to be solved, how many there are and their location. The results will be used to propose public policies that address the main problems identified and that contribute to meeting the goals set in the Municipal Development Plan and also for the development of a new Pedestrian Master Plan for our municipality.

It is worth mentioning that Project Sidewalk is also serving as an educational tool for students of the architecture school at the Universidad Tecnológico de Monterrey (ITESM) and high school students at the Universidad de Monterrey (UDEM).

We look forward to supporting the Project Sidewalk team towards the goals outlined in their proposal, which will further strengthen our collaboration and help advance sidewalk accessibility in our Municipality.

SINCERELY

ARQ. JAVIER LEAL NAVARRO
HEAD OF THE DEPARTMENT
INSTITUTO MUNICIPAL DE PLANEACIÓN Y GESTIÓN URBANA

INSTITUTO MUNICIPAL DE PLANEACIÓN Y GESTIÓN URBANA
Libertad s/n, Centro, Edificio Polivalente, Planta Alta
San Pedro Garza García, Nuevo León. C. P.66200
Tels. (81) 2127-2929
www.sanpedro.gob.mx

"Project Sidewalk provides us with data that is **essential to improving San Pedro's urban accessibility**. With Project Sidewalk, we **know the main problems** to be solved, how many problems there are, and their location… The results will be used to inform a **new Pedestrian Master Plan** for our municipality.

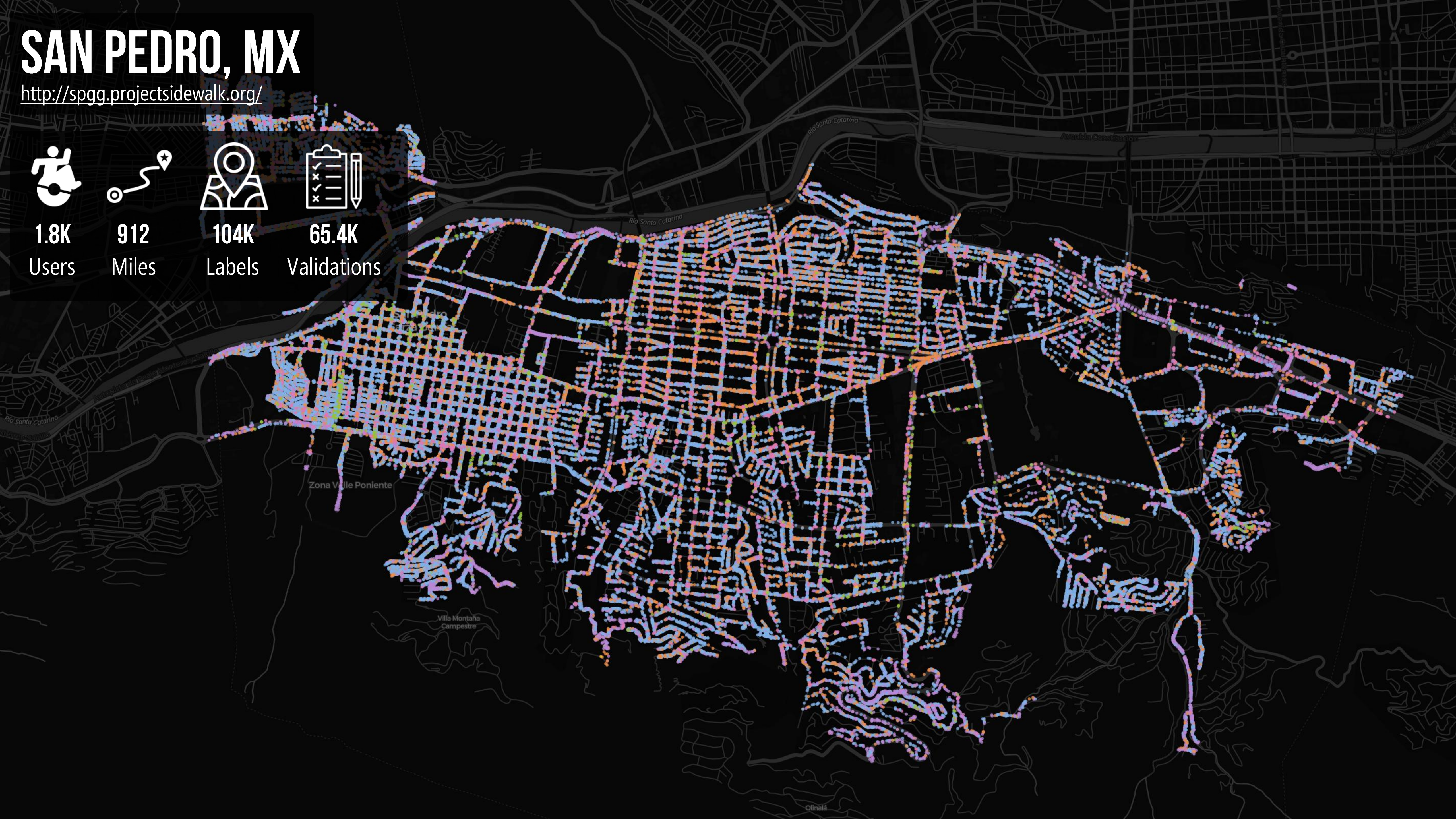
San Pedro Garza García

GOBIERNO MUNICIPAL

SAN PEDRO, MX

http://spgg.projectsidewalk.org/

1.8K	912	104K	65.4K
Users	Miles	Labels	Validations



SAN PEDRO, MX

http://spgg.projectsidewalk.org/

1.8K	912	104K	65.4K
Users	Miles	Labels	Validations

ONU-HABITAT
POR UN MEJOR FUTURO URBANO

ENFOQUE ACTIVISTA

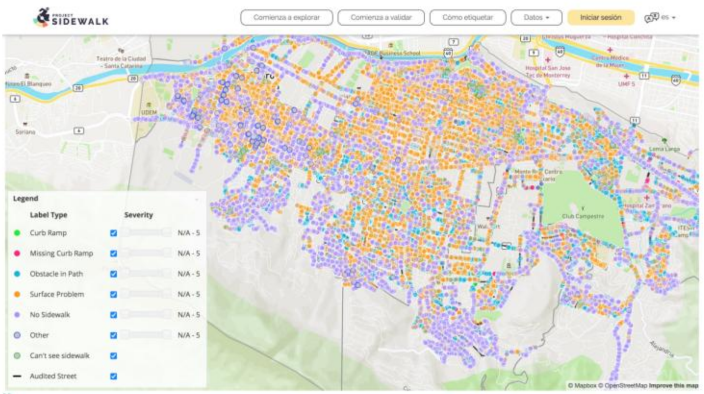
E

EvaluANDO: del activismo peatonal a la colaboración comunitaria para el registro de obstáculos en las banquetas

Escrito por
Claudina de Gyves y Ana Rodríguez

Ubicación
San Pedro Garza García, México

Palabras clave
activismo peatonal, movilidad sostenible, infraestructura peatonal, participación remota



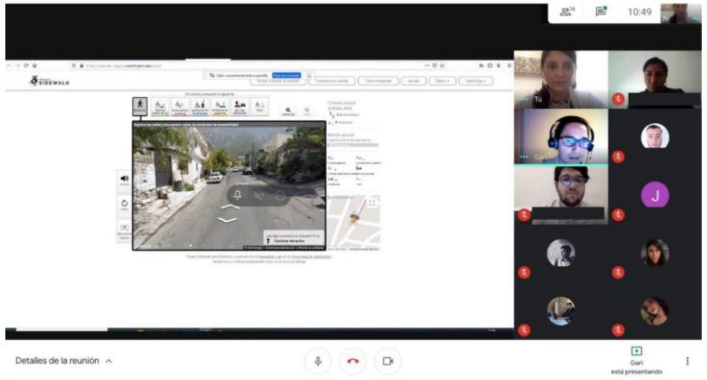
>>
Fotografía 2. Mapa de etiquetas en Project Sidewalk

Fuente: Liga Peatonal (2021).

La vinculación fue posible gracias a que ya había un historial de activismo peatonal en la metrópoli y el acercamiento no fue solo con la Liga Peatonal como ONG, sino de la mano de Makeability Lab, un actor técnico-académico que mostró disposición a contextualizar su plataforma a las necesidades de las calles mexicanas. Aunado a este proceso, la situación por la COVID-19 detonó una serie de intervenciones en el espacio público por parte del municipio de San Pedro Garza García, enfocadas en promover la movilidad sostenible, destacando las ciclovías emergentes y la aceleración de otros proyectos en el espacio público que estaban en puerta. Todo esto generó un escenario adecuado para la colaboración de EvaluANDO SPGG, en la que todos los actores involucrados estaban conscientes de la importancia de contar con información precisa sobre las condiciones de las calles en el municipio.

Recientemente, en mayo de 2021, tras 9 meses de trabajo y con la participación de 1099 personas se lograron cubrir los 570.2 km de vialidades que tiene el municipio de SPGG y se generaron 105 117 etiquetas (Makeability Lab, 2021) en un ejercicio inédito a nivel nacional de participación ciudadana para ubicar los obstáculos de movilidad peatonal.

El caso de EvaluANDO SPGG destaca no solo por haber completado el mapeo del municipio y ser resultado de una colaboración multisectorial entre gobierno local, sociedad civil y academia, sino porque los resultados son ahora insumos valiosos del municipio para la creación de nuevos planes y proyectos. Los planes en proceso de elaboración, tanto de movilidad activa como de seguridad vial, con los resultados de EvaluANDO, ayudarán a identificar estrategias aterrizadas a la realidad y fomentar una mayor participación ciudadana, al involucrar a la población desde su diagnóstico y permitir la descarga de los datos generados en formato editable.



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Fotografía 4. Mapatón San Pedro Garza García

Fuente: Liga Peatonal (2020).

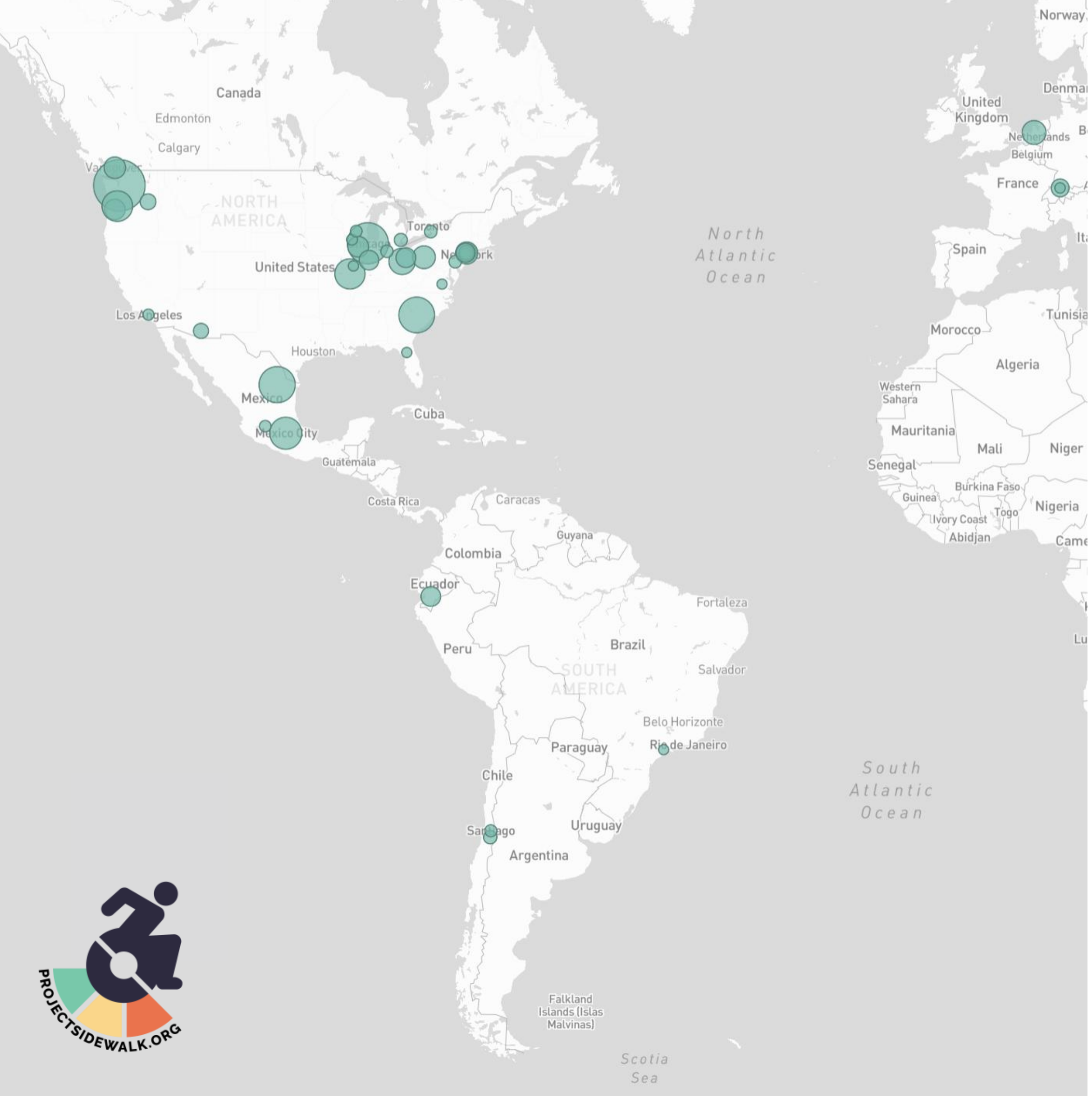
En el proceso de levantamiento de información, Liga Peatonal trató de complementar el trabajo asincrónico e individual con cuatro eventos donde varias personas se conectaban de manera simultánea a probar la herramienta y resolver dudas sobre su funcionamiento. Se convocó a dos sesiones dirigidas a las personas ciudadanas del municipio, con el nombre de Mapatones, y otras dos orientadas a estudiantes universitarios, en formato de talleres en los que se les introducía al tema de movilidad peatonal y donde se generaron propuestas para atender los problemas principales.

Si bien este proceso ha permitido el involucramiento de adolescentes y jóvenes en el análisis crítico de su entorno urbano, todavía presenta oportunidades de mejora en la inclusión de personas que no tienen acceso a dispositivos de internet. Ante esta situación, sería conveniente explorar el ejercicio analógico del mapeo en sitio con herramientas impresas y más con el fin de fortalecer la convivencia vecinal y promover la organización, que con la precisión del levantamiento. En estos escenarios de atención a la población en condición de vulnerabilidad, tal vez destaquen otros elementos a mapear no tan relacionados con ser un obstáculo en las banquetas, sino ya más encaminados a una ausencia de infraestructura como la misma pavimentación de las calles, las banquetas o la falta de conectividad con otros sectores.

Además, en las reflexiones en torno al uso de la herramienta y las necesidades para el diagnóstico urbano incluyente, se identificó como área de oportunidad un mapeo con perspectiva de género, que pudiera incluir no solamente obstáculos en los trayectos identificados, sino también situaciones y elementos propios de la infraestructura que provocan una sensación de inseguridad, pero que no representan como tal un obstáculo, como sí lo hacen los muros ciegos, la falta de luminarias, los recovecos o terrenos baldíos.

PROJECT SIDEWALK

TRANSLATIONAL IMPACT



Informing Policy

Urban Planning

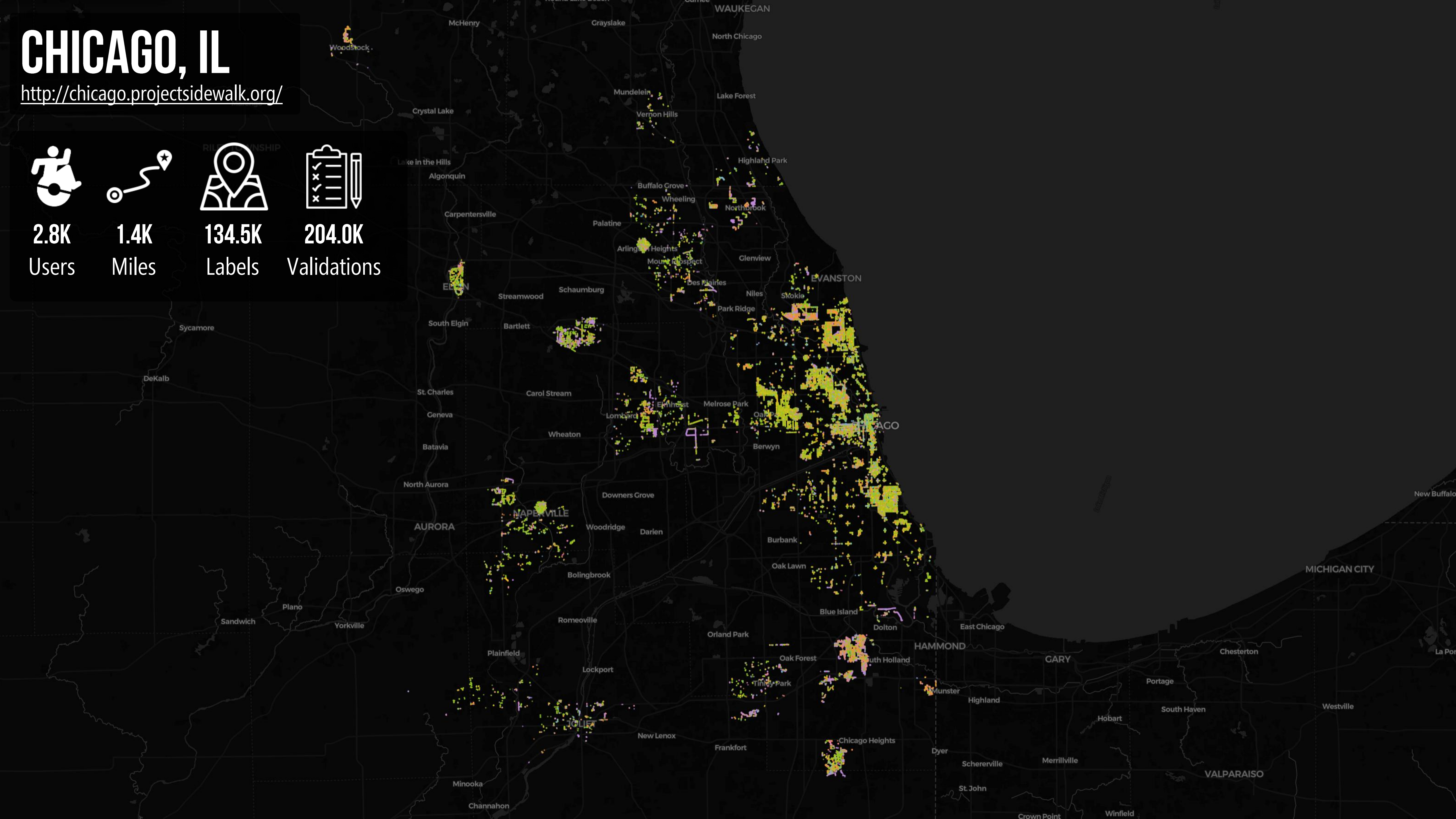
Service Learning

Research Engine

CHICAGO, IL

http://chicago.projectsidewalk.org/

2.8K	1.4K	134.5K	204.0K
Users	Miles	Labels	Validations



“Project Sidewalk helped us **make better decisions** in how to **prioritize our $1.5m infrastructure spending** as well as alert appropriate **city departments** to **high-priority accessibility issues.**”

- ALISON MURPHY

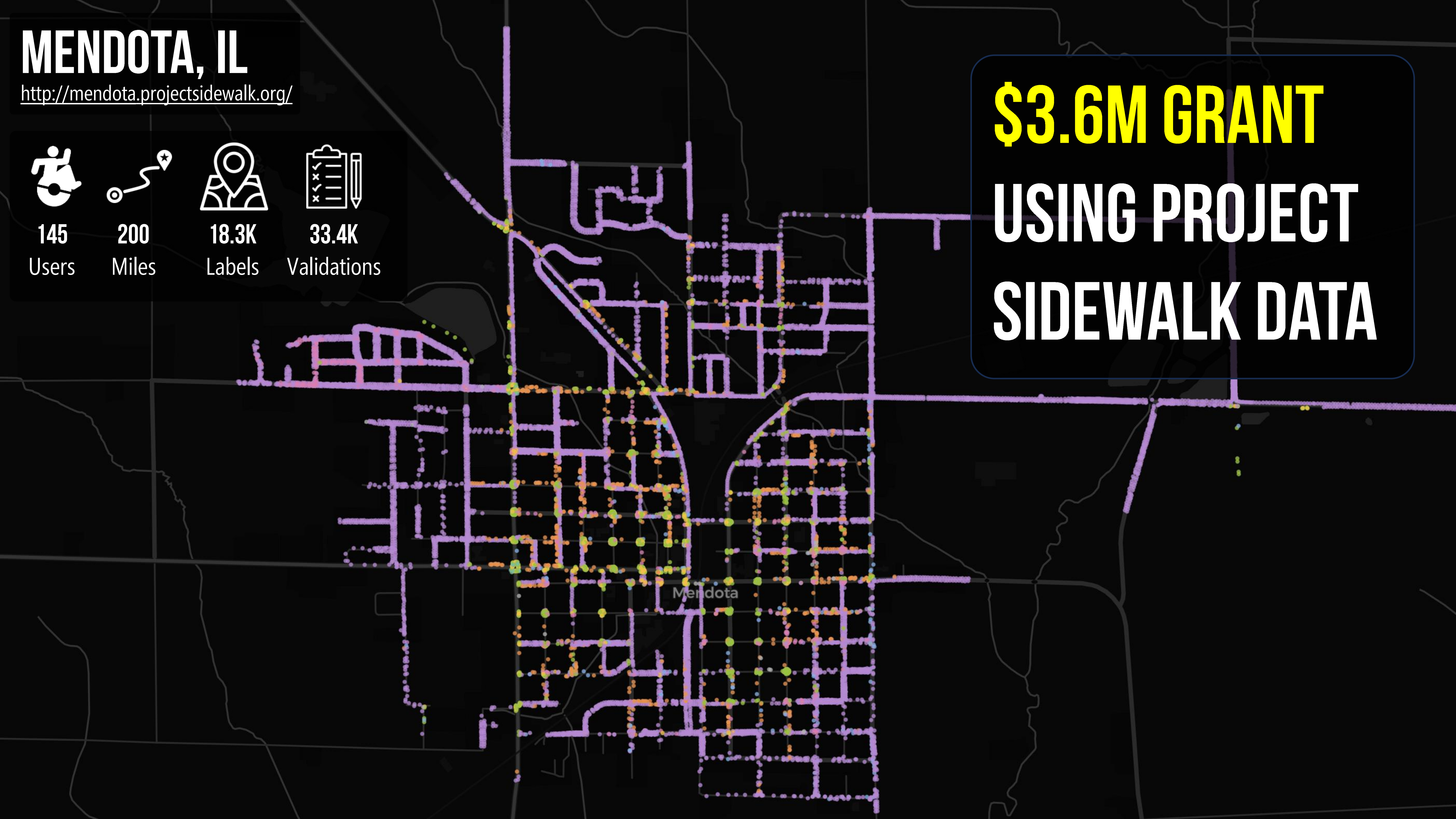
Director of Communications & Development
40th Ward of Chicago

MENDOTA, IL

http://mendota.projectsidewalk.org/

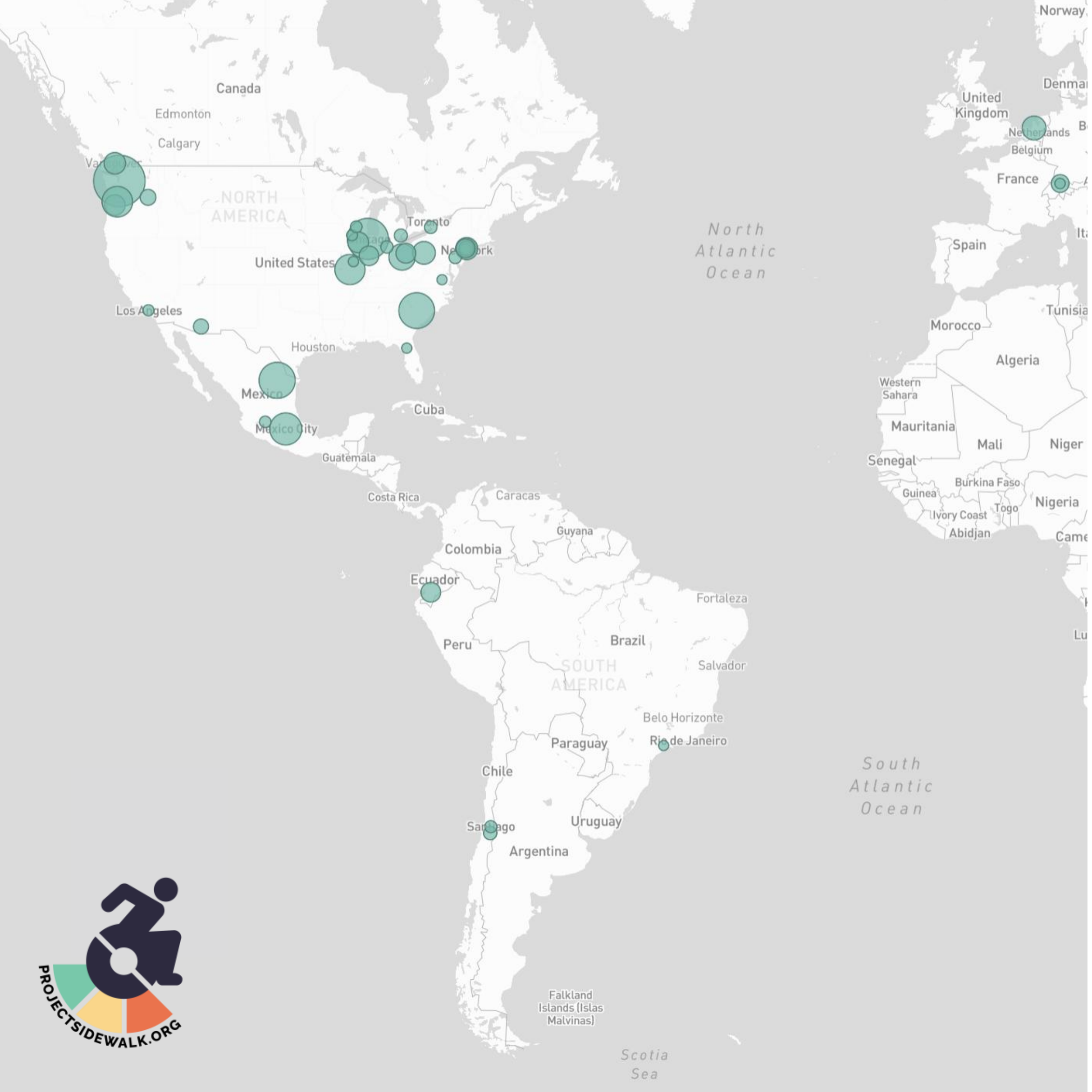
145	200	18.3K	33.4K
Users	Miles	Labels	Validations

$3.6M GRANT USING PROJECT SIDEWALK DATA



PROJECT SIDEWALK

TRANSLATIONAL IMPACT



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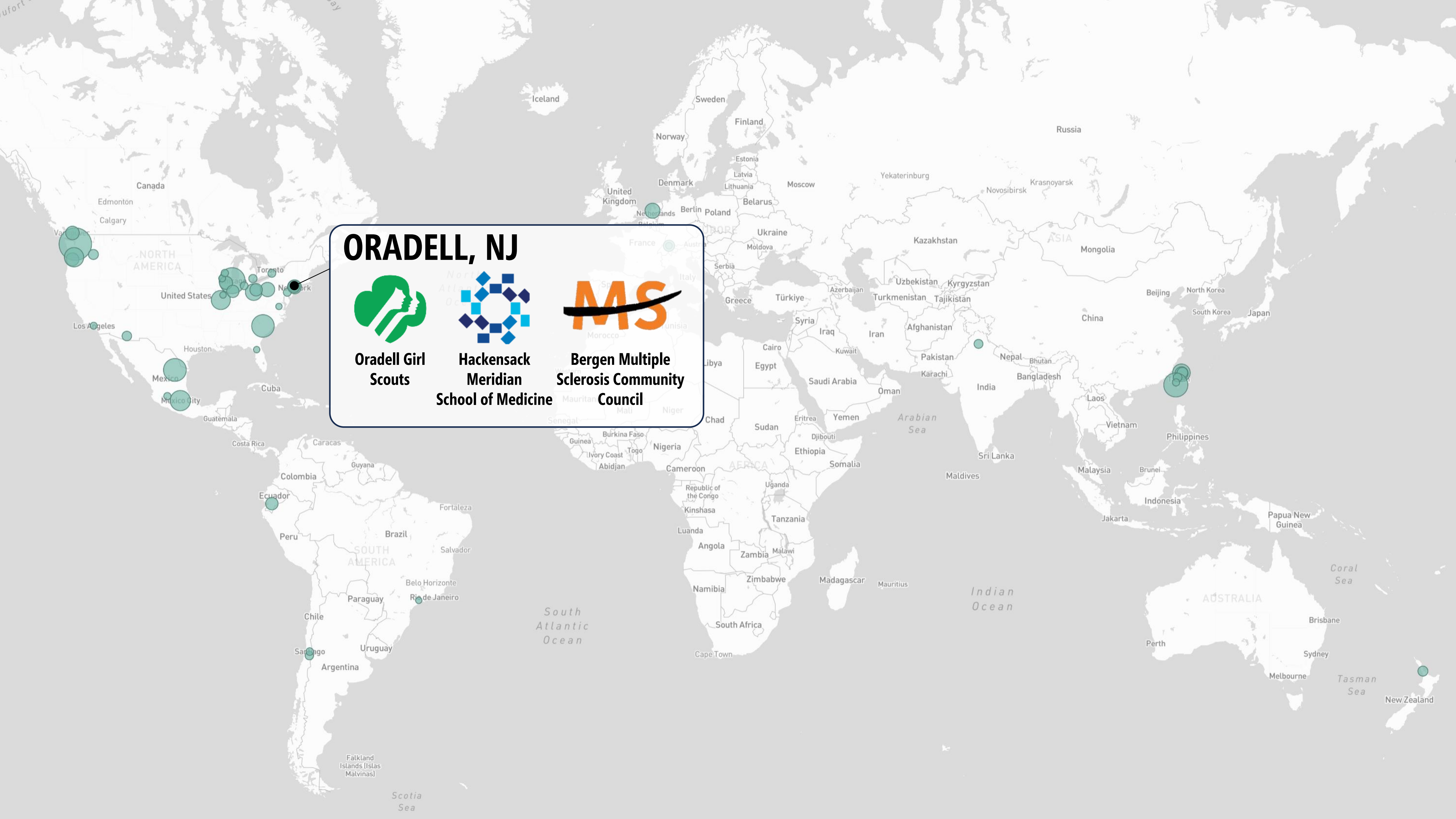
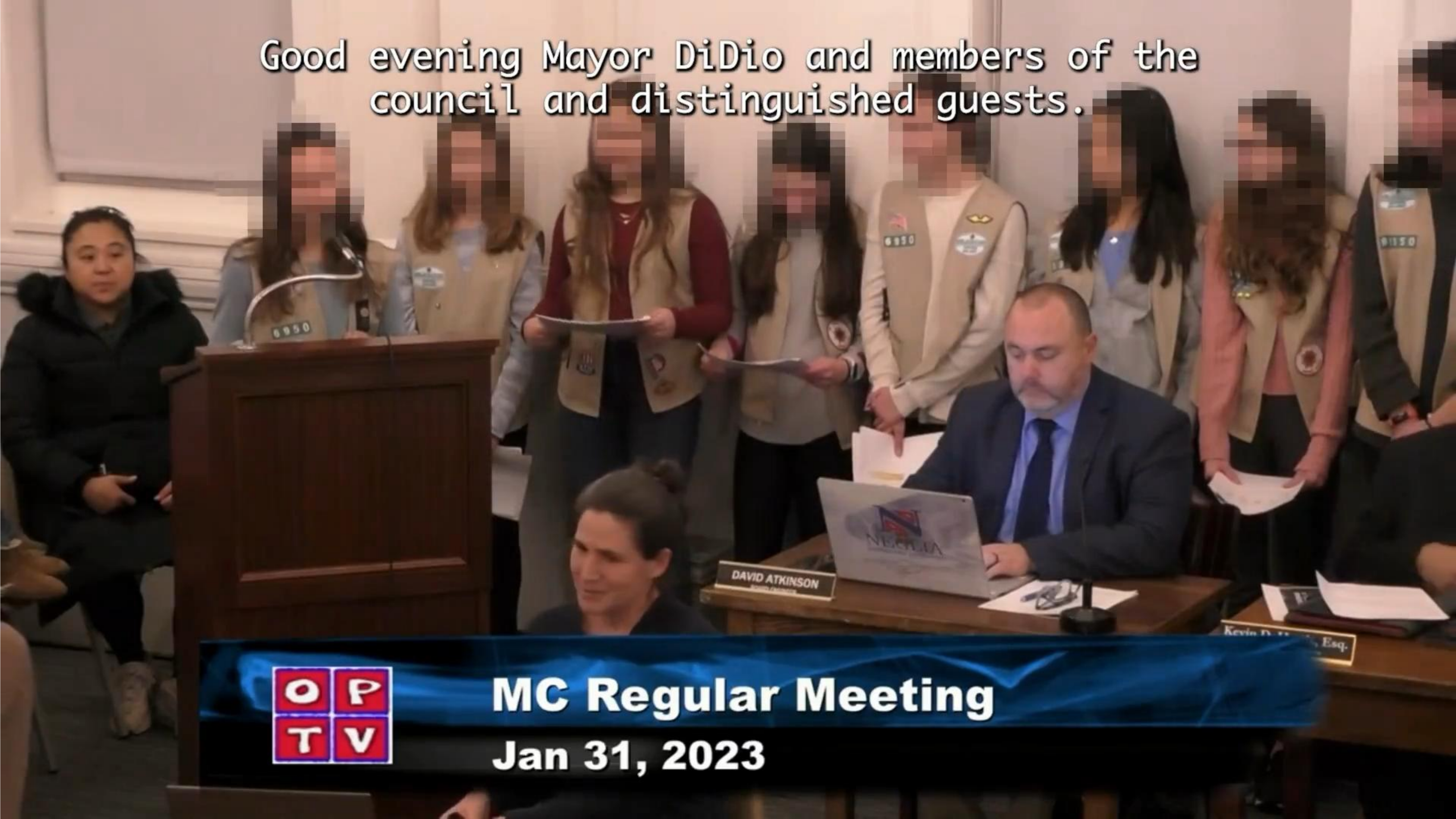
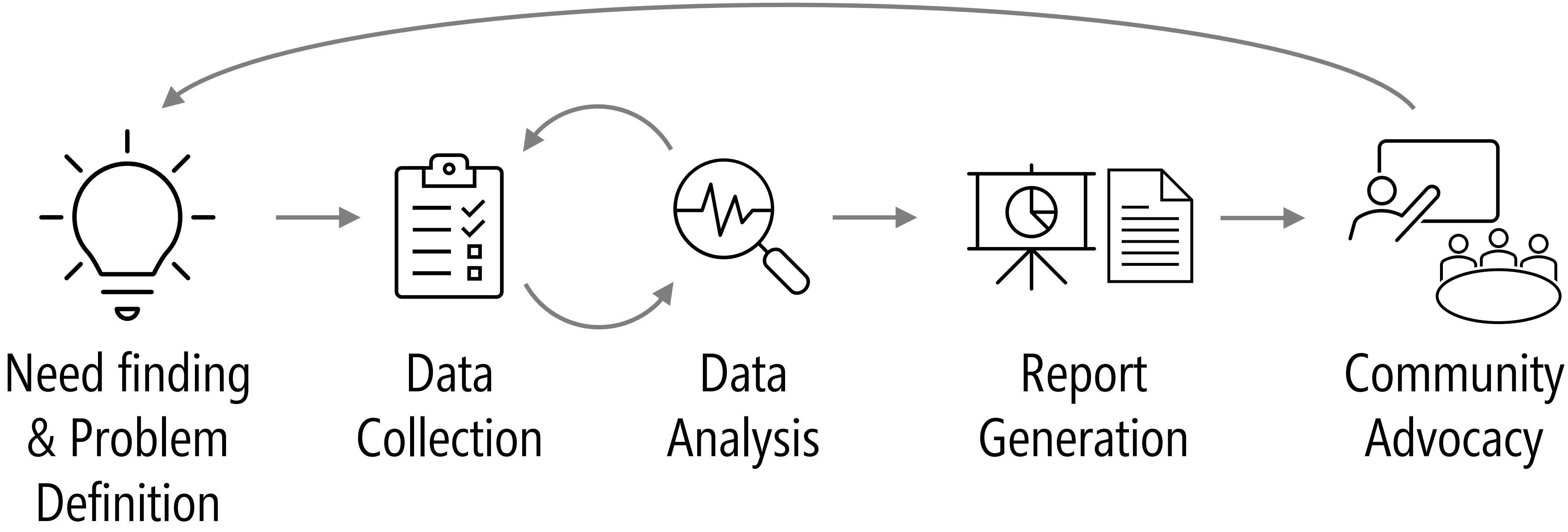
HOW CAN PROJECT SIDEWALK BE A PLATFORM FOR LEARNING WHILE ALSO PROVIDING VALUABLE DATA?


ORADELL, NJ
Oradell Girl Scouts
Hackensack Meridian School of Medicine
Bergen Multiple Sclerosis Community Council


Good evening Mayor DiDio and members of the council and distinguished guests.
DAVID ATKINSON
OP
TV
MC Regular Meeting
Jan 31, 2023

PROJECT SIDEWALK

SERVICE LEARNING

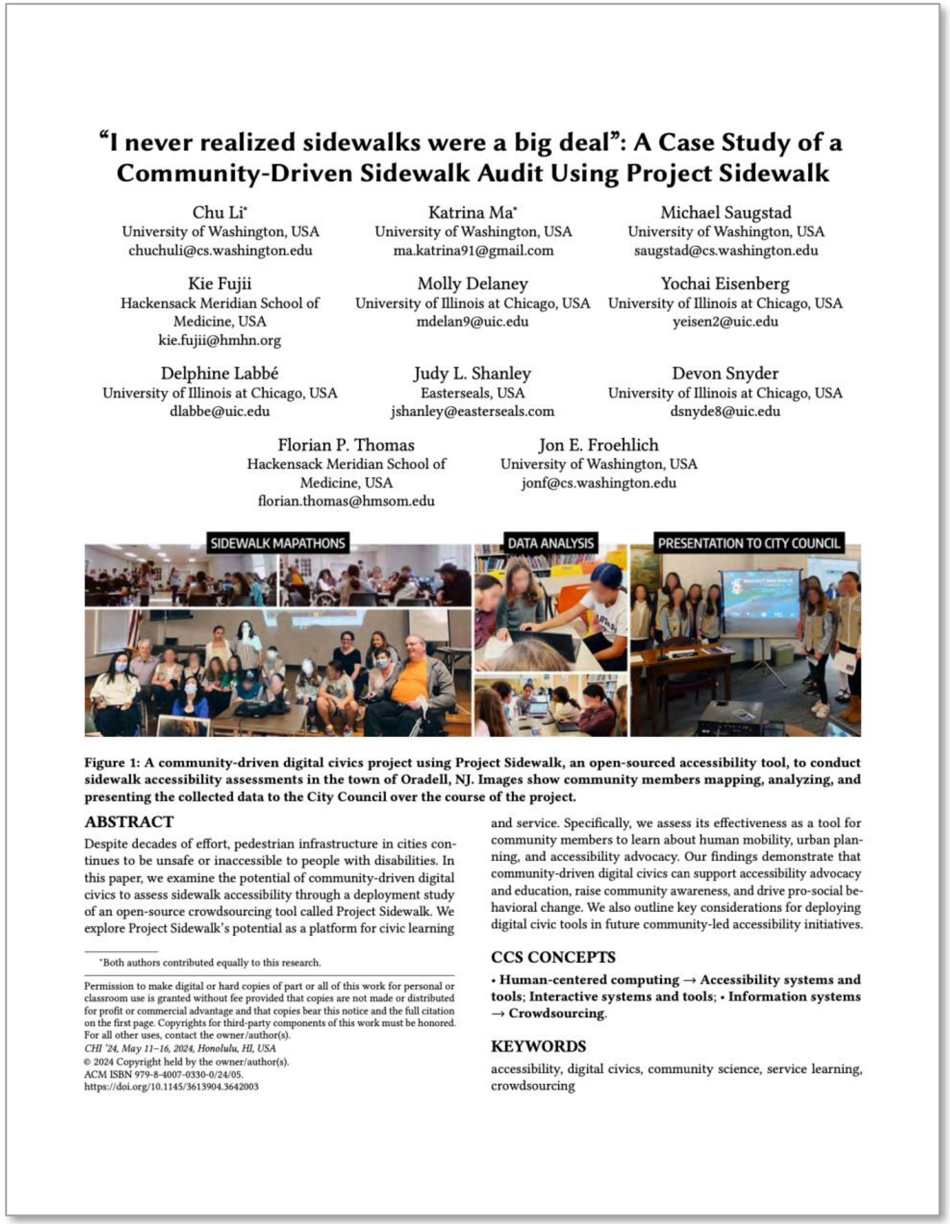


Li, C., *et al.* “I never realized sidewalks were a big deal”: A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk. CHI 2024

CHI'24

Li, Ma, Saugstad *et al.*
"I never realized sidewalks were a big deal": A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk

CHU LI



"I never realized sidewalks were a big deal": A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk

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SIDEWALK MAPATHONS
DATA ANALYSIS
PRESENTATION TO CITY COUNCIL

Figure 1: A community-driven digital civics project using Project Sidewalk, an open-sourced accessibility tool, to conduct sidewalk accessibility assessments in the town of Oradell, NJ. Images show community members mapping, analyzing, and presenting the collected data to the City Council over the course of the project.

ABSTRACT

Despite decades of effort, pedestrian infrastructure in cities continues to be unsafe or inaccessible to people with disabilities. In this paper, we examine the potential of community-driven digital civics to assess sidewalk accessibility through a deployment study of an open-source crowdsourcing tool called Project Sidewalk. We explore Project Sidewalk's potential as a platform for civic learning and service. Specifically, we assess its effectiveness as a tool for community members to learn about human mobility, urban planning, and accessibility advocacy. Our findings demonstrate that community-driven digital civics can support accessibility advocacy and education, raise community awareness, and drive pro-social behavioral change. We also outline key considerations for deploying digital civic tools in future community-led accessibility initiatives.

*Both authors contributed equally to this research.

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05.
https://doi.org/10.1145/3613904.3642003

CCS CONCEPTS

• **Human-centered computing → Accessibility systems and tools; Interactive systems and tools;** • **Information systems → Crowdsourcing.**

KEYWORDS

accessibility, digital civics, community science, service learning, crowdsourcing

Figure 5: Timeline showing dates of partnership formations and key project events in the Oradell Sidewalk Project.

Hackensack Meridian School of Medicine), and a local *Girl Scouts* troop.[2]

3.2.2 In-person Field Audits. In September 2021, the advocacy group and the Scouts held several meetings to generate ideas on how to improve Oradell's urban accessibility for people with disabilities. They first discussed topics such as what constitutes an "*accessibility issue*" and general impressions of Oradell's accessibility levels across neighborhoods, and then decided on conducting in-person field audits to document accessibility barriers. From October to November 2021, advocacy group representatives and the Scouts took photographs of accessibility issues around their neighborhood, including barriers such as missing curb ramps, uneven surfaces, walkway obstructions (*e.g.*, utility poles, overgrown greenery), and obstructed entrances to municipal buildings (*e.g.*, library, post office, town hall). They identified ~30 issues with a location, picture, and description across ~1 miles of sidewalks (Figure 7).

In early November, an advocacy group member (P3 in Table 1) discovered Project Sidewalk online and initiated a meeting to discuss adopting this new approach for identifying accessibility issues. With the Project Sidewalk team's support, they decided to deploy and use this web tool in Oradell (https://oradell.projectsidewalk.org/).

3.2.3 Assessing Oradell with Project Sidewalk. After obtaining geographic neighborhood boundary data, Project Sidewalk was set up and deployed in Oradell in April 2022. Initial tests and contributions were from the advocacy group and Project Sidewalk team. To broaden community involvement and provide additional training, the organizers planned and held two mapathons and began advertising campaigns within their communities. Figure 9 shows a temporal plot of label and validation contributions over time.

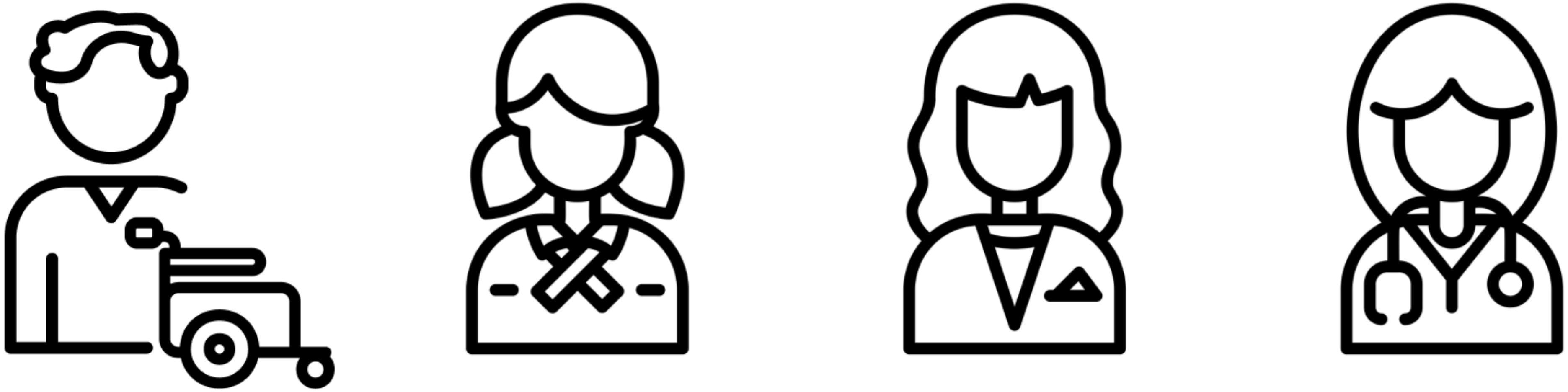
First mapathon. The first mapathon was on April 22, 2022 at the administration building of the local government (Oradall Borough Hall). The event was organized by the local Scout troop leaders, representatives from the National Multiple Sclerosis Society, and students and faculty from Hackensack Medical. The mapathon's goal was to familiarize participants with Project Sidewalk, motivate contributions, and advance understanding of how the built environment can affect people with disabilities.

Figure 6: (A) Diagram showing the deeply intertwined interactions between stakeholders in the Oradell Sidewalk Project, including the local medical center (Hackensack Meridian), MS (Multiple Sclerosis) group, and Girl Scouts troop who started the initiative, then engaged with Project Sidewalk and their research team to assess all sidewalks in Oradell, NJ. (B) Image from the initial City Council meeting in March 2022. (C) Image from the first Scouts meeting with local advocates in September 2021.

Figure 7: Examples of sidewalk accessibility issues photographed by advocacy group representatives and Scout members during in-person audits in their neighborhoods.

[2]Girl Scouts is a youth organization for girls in the United States with a mission to "*build girls of courage, confidence, and character, who make the world a better place*" through activities such as camping, community service, and practical skill-building like first aid [87].

POST-HOC INTERVIEWS IN ORADELL (N=19)



Disability Advocates

Girl Scouts

Parents

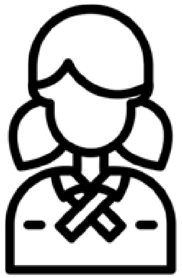
Medical Professionals

Li, C., *et al*. "I never realized sidewalks were a big deal": A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk. CHI 2024

Before Project Sidewalk**, I never realized how important curb ramps** are for people with disabilities…

- GIRL SCOUT (GS4)

Post-study interview

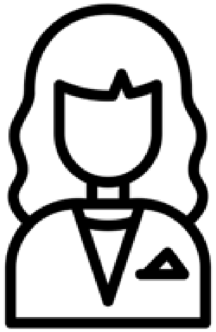


Li, C., *et al*. "I never realized sidewalks were a big deal": A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk. CHI 2024

Now when they walk down the street and see something [inaccessible], they quickly notice and say **“This is wrong!”**

- PARENT

Post-study interview

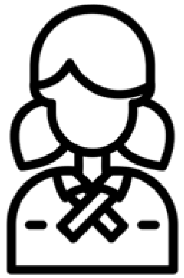


Li, C., *et al*. “I never realized sidewalks were a big deal”: A Case Study of a Community-Driven Sidewalk Audit Using Project Sidewalk. CHI 2024

This experience gave me a new perspective that I can use **to help change the world**.

- GIRL SCOUT (GS7)

Post-study interview



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PROJECT SIDEWALK

TRANSLATIONAL IMPACT

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Universidad Nacional Autónoma de México

Plaksha University

University of South Carolina

University of Zurich UZH

SFU Simon Fraser University

USP Universidade de São Paulo

SMU

UIC University of Illinois Chicago

WPI

Universiteit van Amsterdam

UF University of Florida College of Health and Human Performance

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Service Learning

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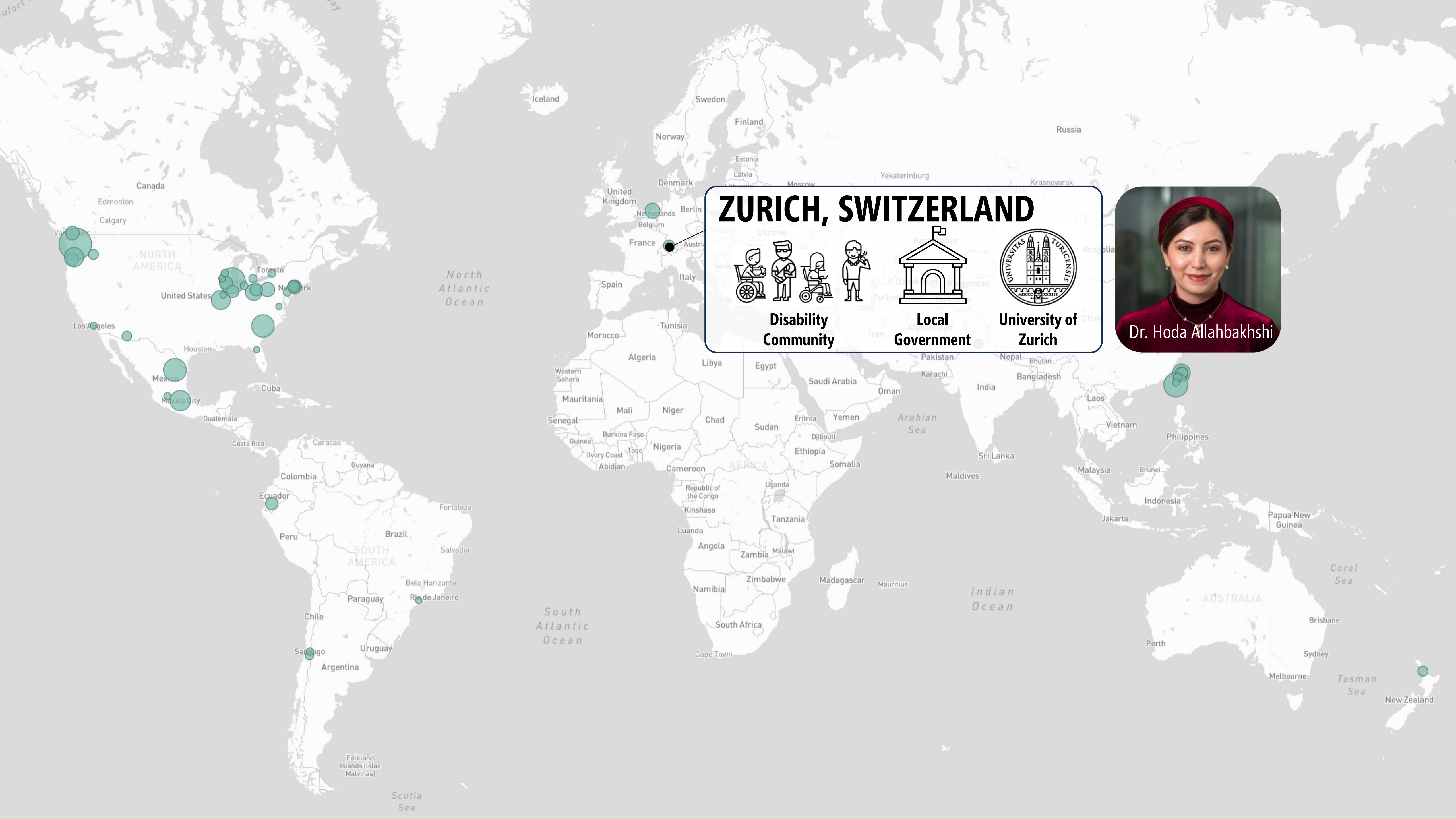
ZURICH, SWITZERLAND
Disability Community
Local Government
University of Zurich
UNIVERSITAS TURICENSIS
MDCCCXXXIII
Iceland
Sweden
Finland
Norway
Russia
Estonia
Latvia
Denmark
United Kingdom
Netherlands
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Costa Rica
North Atlantic Ocean
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Tunisia
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Mali
Niger
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Sudan
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Guinea
Burkina Faso
Ivory Coast
Abidjan
Togo
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Cameroon
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Eritrea
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Ethiopia
Somalia
Yemen
Saudi Arabia
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Iran
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Bhutan
Bangladesh
India
Arabian Sea
Sri Lanka
Maldives
Laos
Vietnam
Philippines
Malaysia
Brunei
Indonesia
Jakarta
Papua New Guinea
Caracas
Guyana
Colombia
Ecuador
Peru
Brazil
Fortaleza
Salvador
SOUTH AMERICA
Belo Horizonte
Rio de Janeiro
Paraguay
Chile
Santiago
Uruguay
Argentina
Falkland Islands (Islas Malvinas)
Scotia Sea
South Atlantic Ocean
Republic of the Congo
Uganda
Kinshasa
Tanzania
Luanda
Angola
Zambia
Malawi
Zimbabwe
Namibia
Madagascar
Mauritius
South Africa
Cape Town
Indian Ocean
Coral Sea
AUSTRALIA
Brisbane
Perth
Sydney
Melbourne
Tasman Sea
New Zealand
Dr. Hoda Allahbakhshi

UNIVERSITY OF ZURICH

URBAN SCIENCE RESEARCH WITH PROJECT SIDEWALK

Navigation Challenges in Urban Areas for Persons with Mobility Restrictions

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Annina Ardüser ✉
Department of Geography, University of Zurich, Switzerland

Abstract

The Sustainable Development Goals (SDGs) promote making the world better for everyone, with a focus on creating cities that are inclusive and sustainable, as outlined in SDG 11. Spatial accessibility plays a pivotal role in fostering age-friendly and inclusive urban environments. However, there is still a lack of complete data on accessibility essential for providing mobility services to individuals with restricted mobility, mainly due to the high costs. While some participatory initiatives like OpenStreetMap (OSM) have made progress in this area, there is still a significant gap in data about sidewalk accessibility.

To address this gap, we used a citizen science approach to gather information and improve our understanding of sidewalk accessibility in District 1 of Zurich. Eighteen individuals from diverse population groups took part in our study. Using the Project Sidewalk web tool (PRSW), participants collected sidewalk features like curb ramps and surface problems by virtually inspecting street view images.

In this paper, we present preliminary results derived from participatory data collection. The findings show the variances in accessibility labels concerning their frequency, spatial distribution, and severity levels attributed by participants. Furthermore, we provide insights into the accuracy of the data, verified through validation by experts in geographical knowledge using PRSW.

Our approach allowed for broader participation and diverse perspectives in collecting sidewalk accessibility data. We believe that the provided dataset has the potential to address unanswered questions about spatial accessibility. For instance, the distribution of accessibility within specific population groups or across a city can be explored. This information can help policymakers develop interventions that tackle accessibility inequalities and ensure equitable access, especially for those with mobility impairments.

2012 ACM Subject Classification Social and professional topics

Keywords and phrases Navigation, Mobility-restrictions, Inclusive mobility, Spatial accessibility, Citizen science

Digital Object Identifier 10.4230/LIPIcs.COSIT.2024.22

Category Short Paper

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[1] corresponding author

16th International Conference on Spatial Information Theory (COSIT 2024).
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LIPICS Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Towards an Inclusive Urban Environment: A Participatory Approach for Collecting Spatial Accessibility Data in Zurich

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Digital Society Initiative, University of Zürich, Switzerland
Department of Geography, University of Zürich, Switzerland

Abstract

The unprecedented rate of urbanization, along with the increase in the aging and disabled populations, bring about an increasing demand for public services and an inclusive urban environment that allows easy access to those facilities. Spatial Accessibility is a measure to assess how inclusive a city is and how easily public facilities can be reached from a specific location through movement in physical space or built environment.

A detailed geodata source of accessibility features is needed for reliable spatial accessibility assessment, such as sidewalk width, surface type, and incline. However, such data are not readily available due to the huge implication costs. Remote crowdsourcing data collection using Street View Imagery, so-called 'virtual audits' have been introduced as a valid, cost-efficient tool for accessibility data enrichment at scales compared to conventional methods because it enables involving more participants, saving more time by avoiding field visits and covering a larger area.

Therefore, in our pilot project, ZuriACT: Zurich Accessible CiTy, with the help of digital tools that allow for virtual inspections and measurements of accessibility features, we want to contribute to collecting and enriching accessibility information in the city of Zurich embedded in a citizen science project that will have both scientific and social impacts.

With the help of additional accessibility data produced in this project, the issues of an inclusive urban environment can be demonstrated by mapping the potential spatial inequalities in access to public facilities for disabled or restricted people in terms of mobility. Thus, this project provides helpful insight into implementing policy interventions for overcoming accessibility biases to ensure equitable services, particularly for people with disabilities, and contributes to creating an inclusive and sustainable urban environment. It goes without saying that an inclusive city is beneficial and impacts the quality of life of not only the population groups mentioned above but also the society at large.

2012 ACM Subject Classification Social and professional topics

Keywords and phrases Spatial accessibility, virtual audits, digital tools, mobility disability, citizen science, inclusive city, Zurich

Digital Object Identifier 10.4230/LIPIcs.GIScience.2023.13

Category Short Paper

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1 Introduction

It is projected that by 2050, about 70 percent of the world's population will live in urban environments, 15 percent of them will live with disabilities [10]. Moreover, the prediction shows that by 2050, the number of older people will reach 2 billion worldwide [12]. The unprecedented rate of urbanization, along with the increase in the aging and disabled populations, bring about an increasing demand for public services and access to those facilities. Depending on the infrastructure and design, the urban environment and physical

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LIPICS Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

AGILE: GIScience Series, 6, 23, 2025. https://doi.org/10.5194/agile-giss-6-23-2025
Proceedings of the 28th AGILE Conference on Geographic Information Science, 10–13 June 2025.
Eds.: Auriol Degbelo, Serena Coetzee, Carsten Keßler, Monika Sester, Sabine Timpf, Lars Bernard
This contribution underwent peer review based on a full paper submission.

AGILE Association of Geographic Information Laboratories in Europe

Developing enriched pedestrian networks using accessibility features

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Abstract. Accessibility studies often focus on the general population, overlooking individual differences in mobility capacities and the role of external factors. Microscale street elements such as stairs, high kerbs, and sidewalk cracks can significantly impact urban mobility for individuals with restricted movement capacities. This study introduces a workflow to integrate different detailed accessibility information, such as barriers and facilitators for pedestrian mobility, with sidewalk data to create an enriched pedestrian network. Using this network, we evaluate each segment by computing an impedance score to quantify accessibility. Furthermore, we demonstrate how the network can be tailored to individual mobility needs and highlight its potential as a decision-making tool for urban planners and civil engineers to identify and prioritise targeted interventions for vulnerable populations.

Submission Type. Analysis

BoK Concepts. [AM11] Network analysis, [AM11-7] Accessibility modelling, [AM5-3] Spatial cluster analysis

Keywords. Spatial accessibility, Microscale elements, Mobility restriction, Pedestrian networks, Urban environment

1 Introduction

Ensuring equitable and adequate access for all to public facilities in urban areas is an essential target included in various Sustainable Development Goals such as 10 and 11 (United Nations, 2022). This is especially important since by 2050 it is projected that approximately two-thirds of the world's population is expected to reside in urban areas (United Nations, 2019), and currently 16% of the global population worldwide is believed to live with some sort of disability (World Health Organisation, 2022).

Spatial accessibility refers to how easily destinations, such as public facilities, can be reached through movement in physical space (Allahbakhshi, 2023). It is highly context-dependent and influenced by various factors (Lid & Solvang, 2016), including microscale street elements such as poles, stairs, cobblestones, kerb ramps, or pedestrian signals. These elements can either restrict or facilitate pedestrian movement, significantly impacting access to certain areas and services (Hammel et al., 2015) and contributing to social exclusion (Svensson, 2010).

Physical barriers are especially important for individuals with mobility restrictions, as they can increase perceived distance (Vale et al., 2016), reduce the number of available opportunities (Achuthan et al., 2010) and force individuals to stay at home or in familiar places (Mao & Chen, 2022). Additionally, as individuals have different mobility needs, the impact of these elements varies (Georgescu et al., 2024). For example, a high kerb may be a barrier for a wheelchair user but can serve as a facilitator, marking the edge of the sidewalk, for a visually impaired individual. Therefore, such elements become vital in assessing spatial accessibility.

However, despite their significance, research on microscale elements and their impact on individuals with varying mobility capacities remains limited. Most of these studies rely on field visits to collect data on the various accessibility features that affect pedestrian movement. These features are then recorded in spatial databases, where each element is linked to its corresponding

1 of 8

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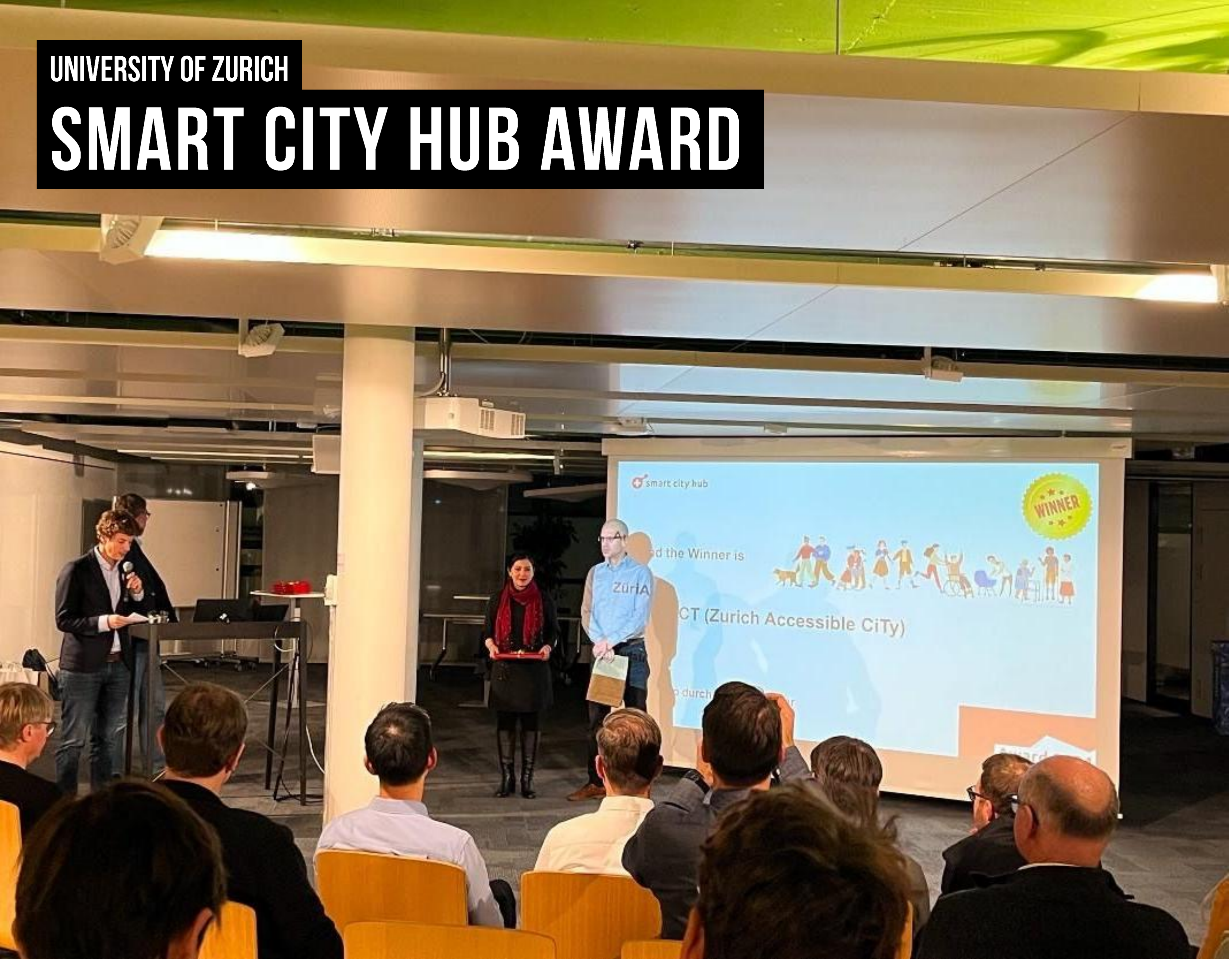
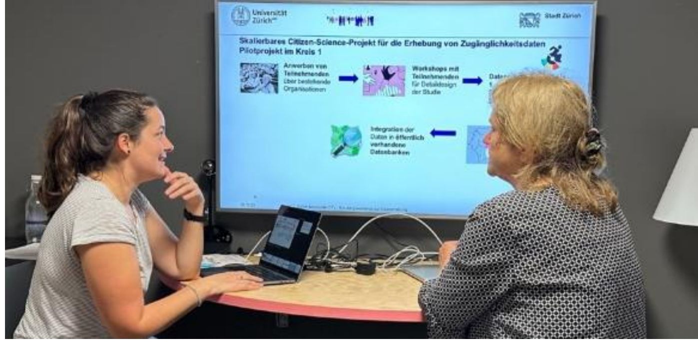
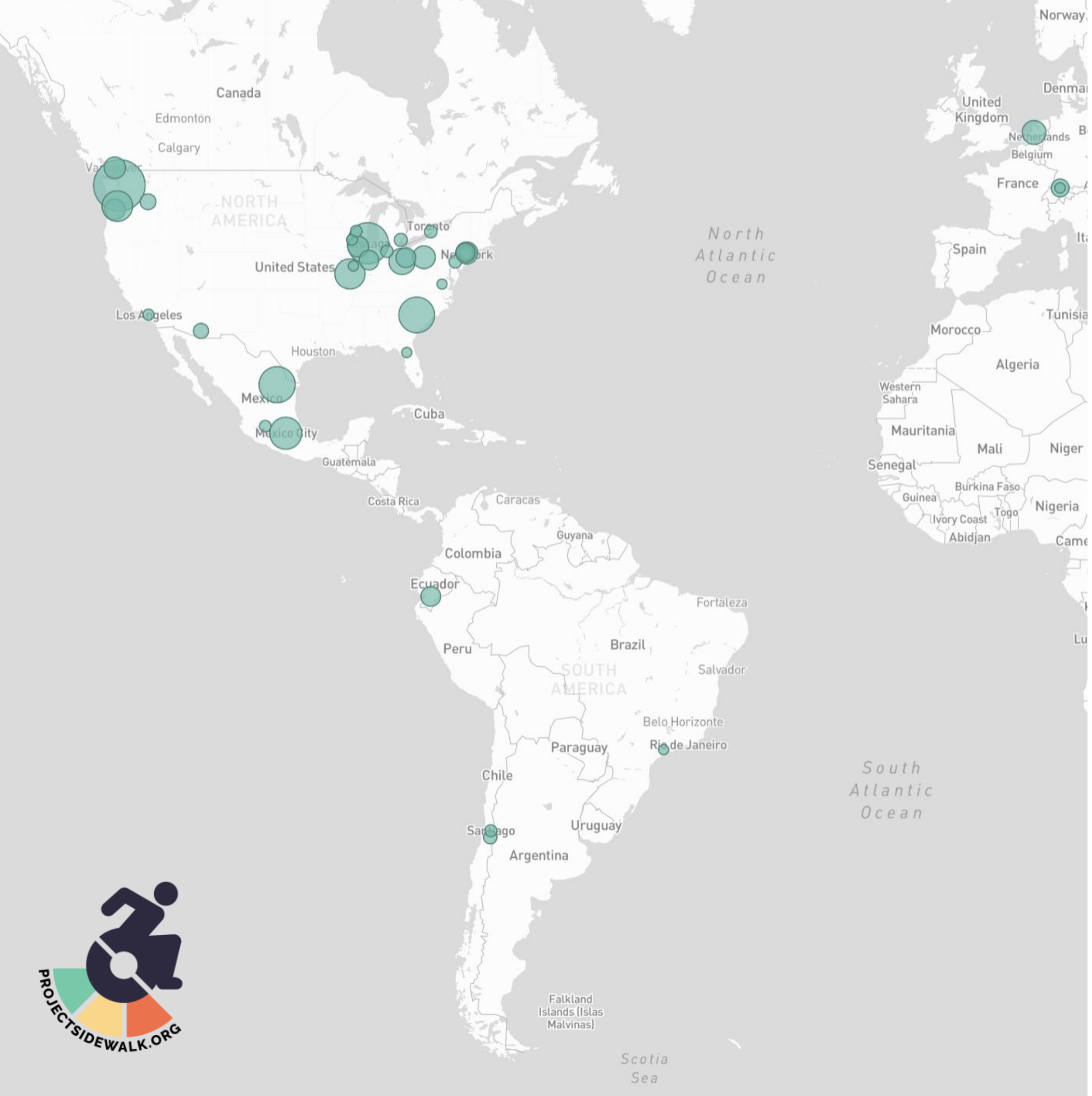




PROJECT SIDEWALK

TRANSLATIONAL IMPACT



Informing Policy

Urban Planning

Service Learning

Research Engine

SEVEN LESSONS LEARNED

1. Always **another mountain**
2. **Choose** your mountains carefully
3. **Persistence** is key
4. Know & use your **leverage points**
5. **Believe in yourself**, in your vision
6. The **people matter** the most
7. Engage and serve **community**

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PROJECT
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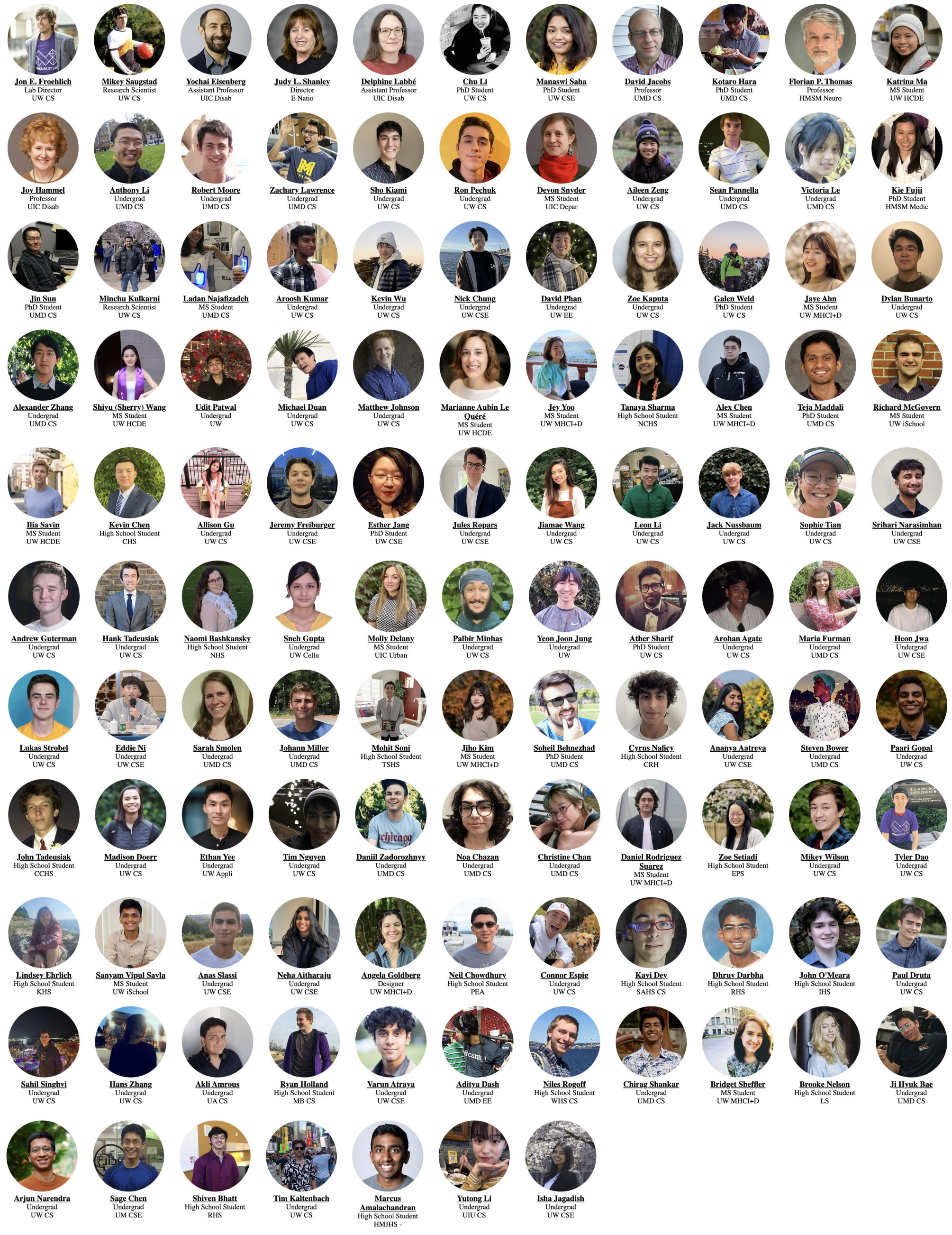
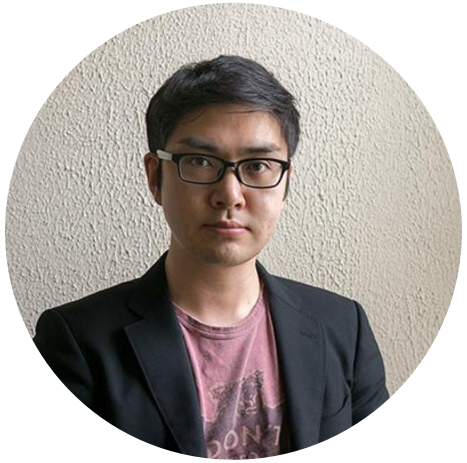
BUILT BY STUDENTS, FACULTY, & OUR COMMUNITY PARTNERS





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2017-present

Mikey Saugstad
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Liang He


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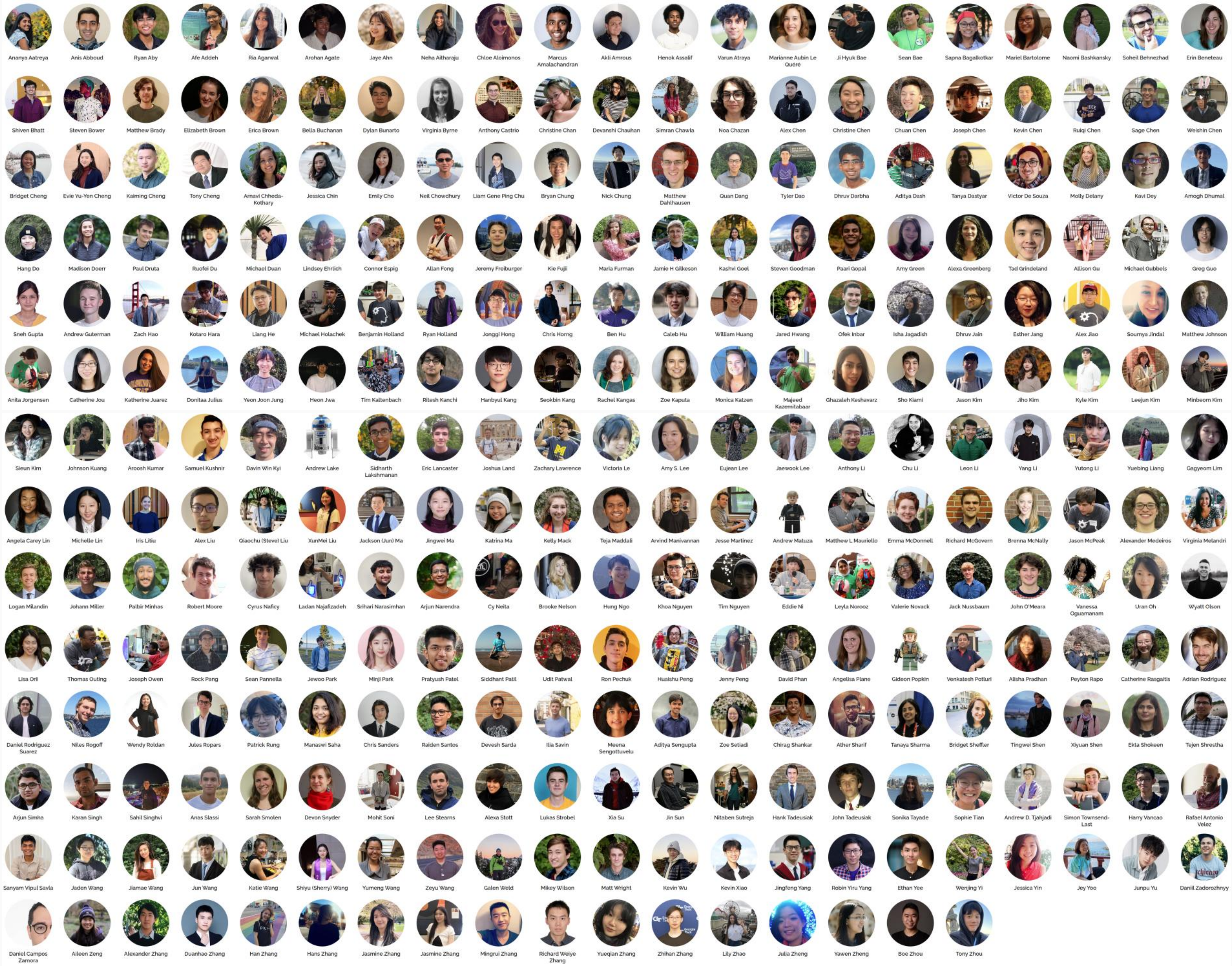

SEVEN LESSONS LEARNED

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6. The **people matter** the most
7. Engage and serve **community**

2024 ACM SIGCHI Societal Impact Award

External

[redacted]

Tue, Feb 20, 2024, 3:24 PM

to me

Dear Jon,

I regret to inform you that you that your nomination was not selected for the 2024 ACM SIGCHI Societal Impact Award. The pool and caliber of the nominations for this award was extremely strong.
interest in the Societal Impact Award and hope that you will consider submitting

2025 ACM SIGCHI Societal Impact Award

External

[redacted]

to me

Tue, Feb 25, 2025, 1:43 PM

Dear Jon,

We regret to inform you that you that your nomination was not selected for the 2024 ACM SIGCHI Societal Impact Award. The pool and caliber of the nominations for this award was extremely strong. We appreciate your interest in the Societal Impact Award and hope that you will consider submitting nominations in the future.

Sincerely,
The SIGCHI Societal Impact Award Committee

2024 ACM SIGCHI Societal Impact Award External

Tue, Feb 20, 2024, 3:24 PM

2025 ACM SIGCHI Societal Impact Award External

2026 ACM SIGCHI Societal Impact Award External

Elizabeth M Gerber <egerber@northwestern.edu> Sun, Jan 25, 3:12 PM

to jonf@cs.uw.edu, Kentaro

Dear Jon,

I am pleased to let you know that you will receive the ACM SIGCHI Societal Impact Award at CHI 2026. You have earned this award for the novelty and depth of your research, efforts in scaling the work for direct impact on society, and leadership in our field.

We hope you will celebrate with friends and close colleagues, but ask that you not share widely until ACM SIGCHI announces all the award winners for 2026.

Kentaro Toyama, ACM SIGCHI Awards Chair, will follow up with more details regarding the honorarium, talk, and travel details.

Congratulations again for your incredible work! Please let me know if you have any questions.

Sincerely,

Liz and the ACM SIGCHI Societal Impact Award Committee


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