Interaction Dynamics for Crowdsourced Obstacle Data

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Kevin Curtin, Manzhu Yu

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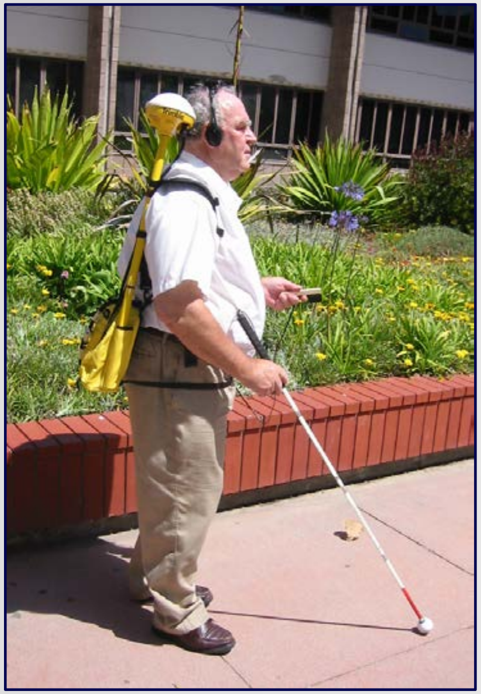
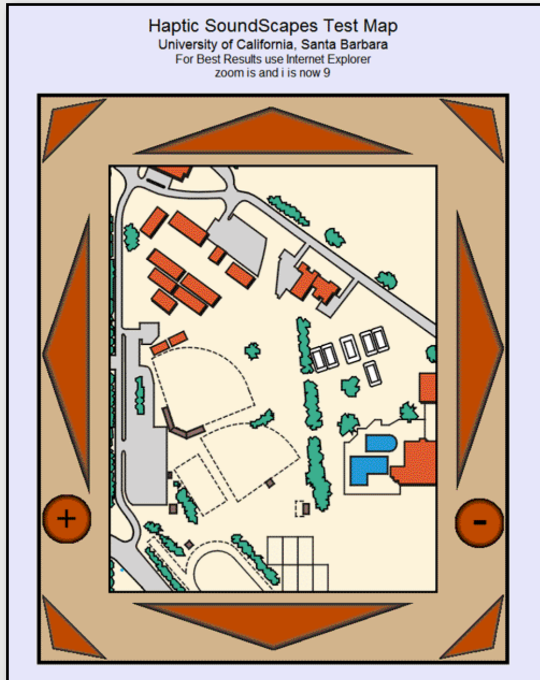
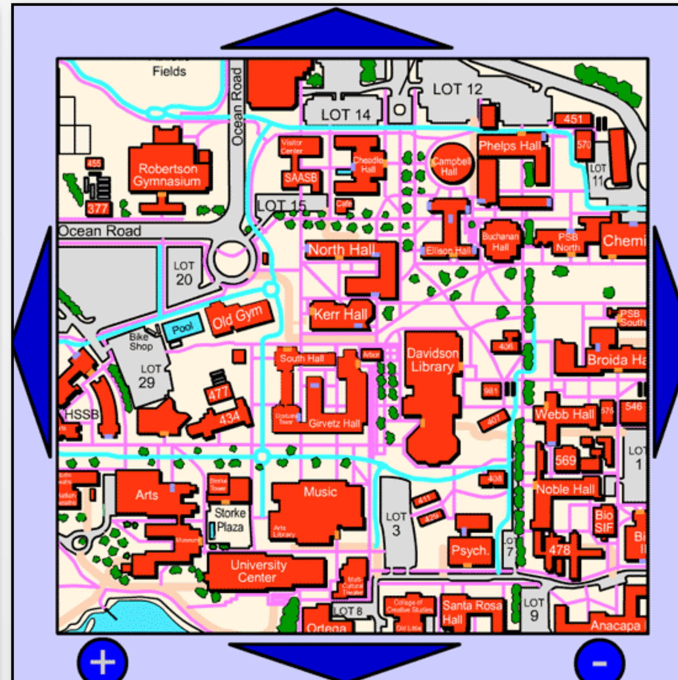
Funding: USACE/ERDC, BAA #AA-10-4733, Contract #W9132V-11-P-0011

Motivations

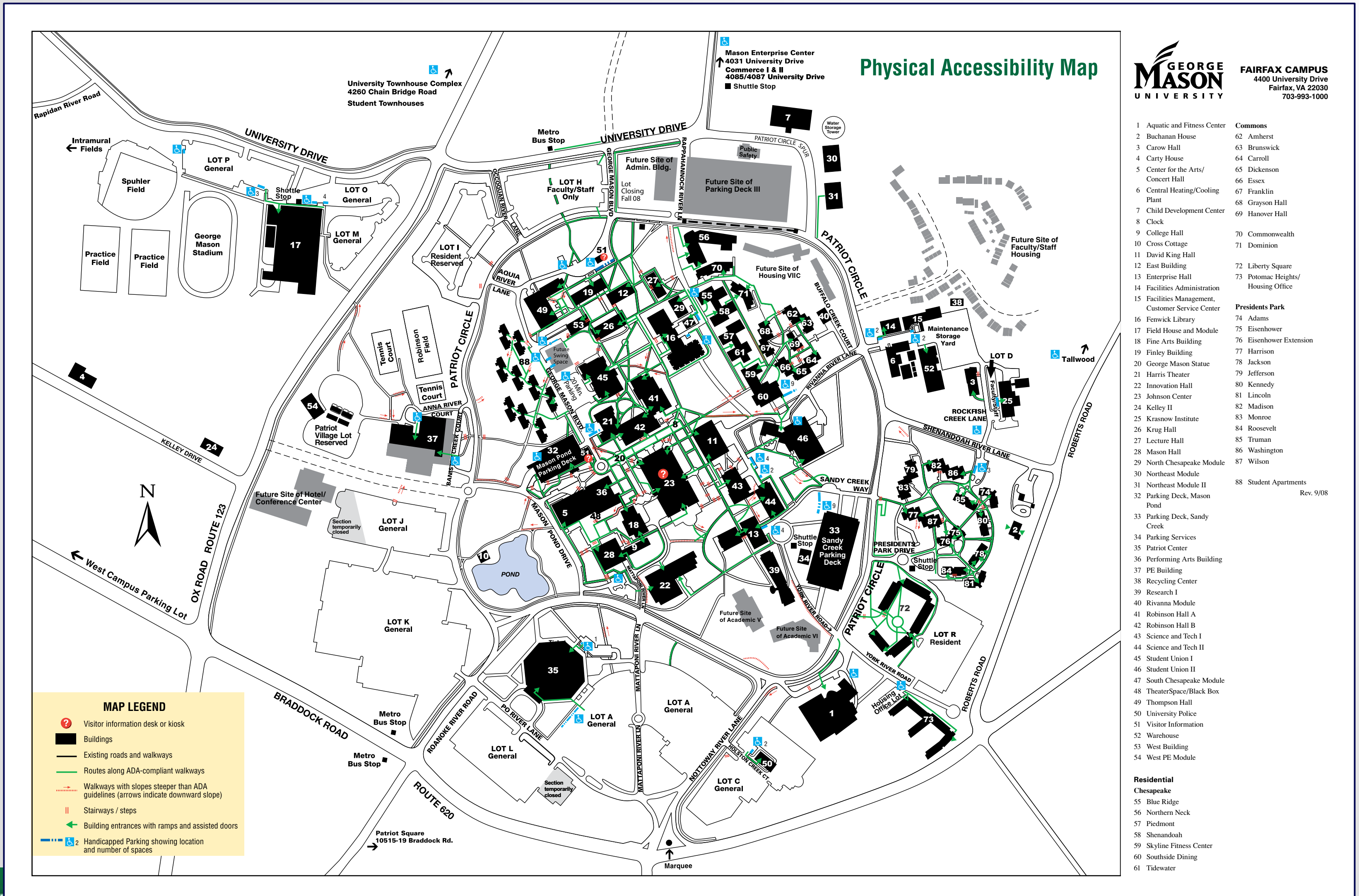






- Barriers: Print and Movement
- Wayfinding and Accessibility
- Non-visual mapping interfaces
- Rice et al. (2005), Golledge et al. (2005, 2006)

Non-accessible accessibility



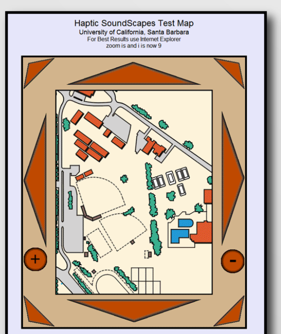
Navigation Obstacles

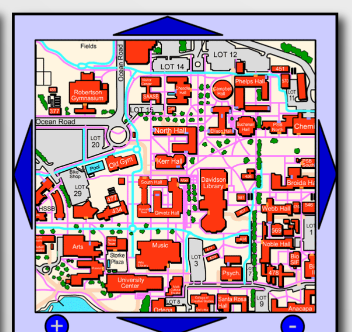
Navigation Obstacles

Navigation Obstacles

Summary

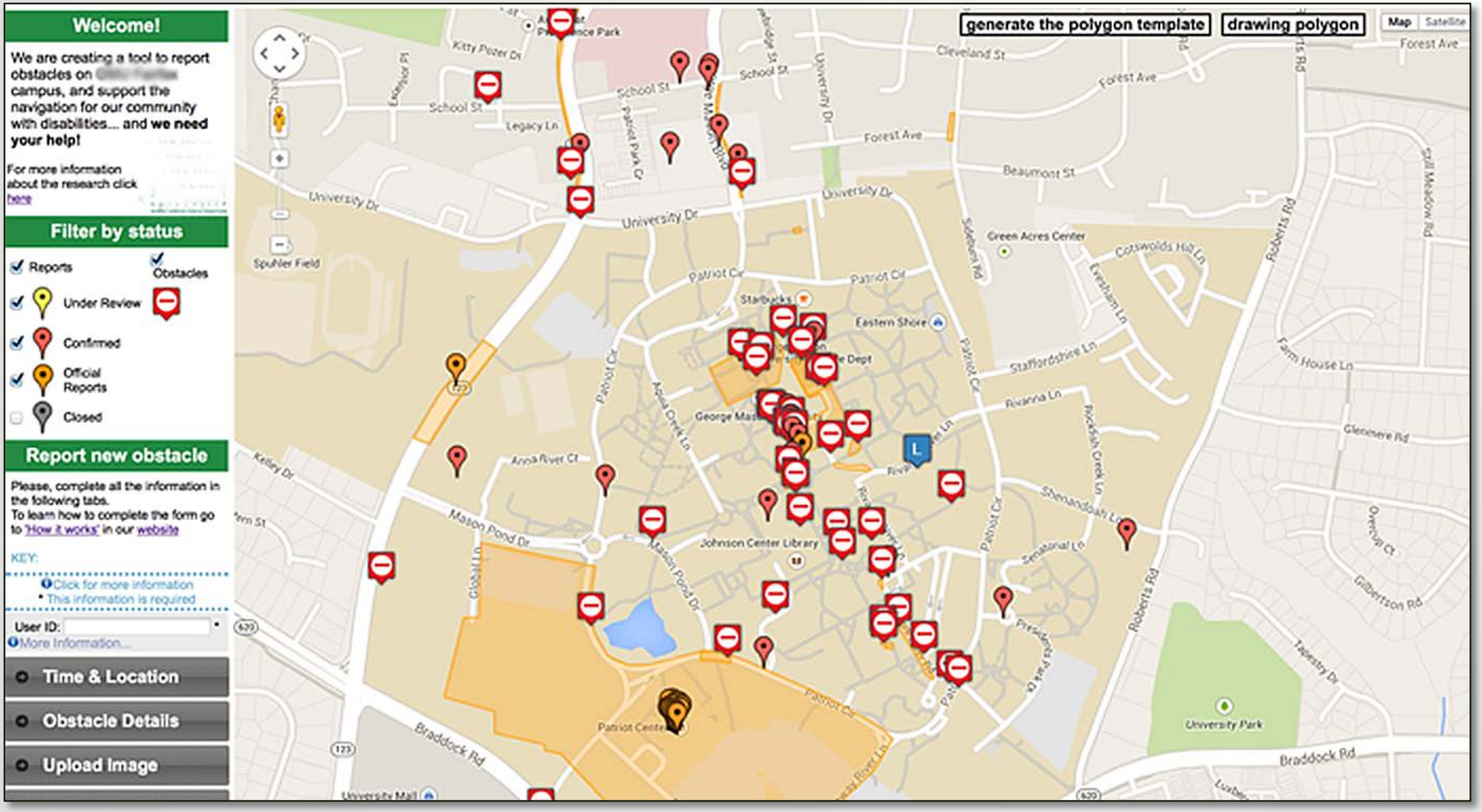
- **Accessibility** facilitates equity, participation, access to public space, transit, employment
- **Geoaccessibility** uses maps, geospatial information, and GIS to understand obstacles and enhance access
- **Key:** high-quality, high-resolution geospatial data and real-time updates
- **Challenges:** Modes of communication, infrastructure, interaction dynamics



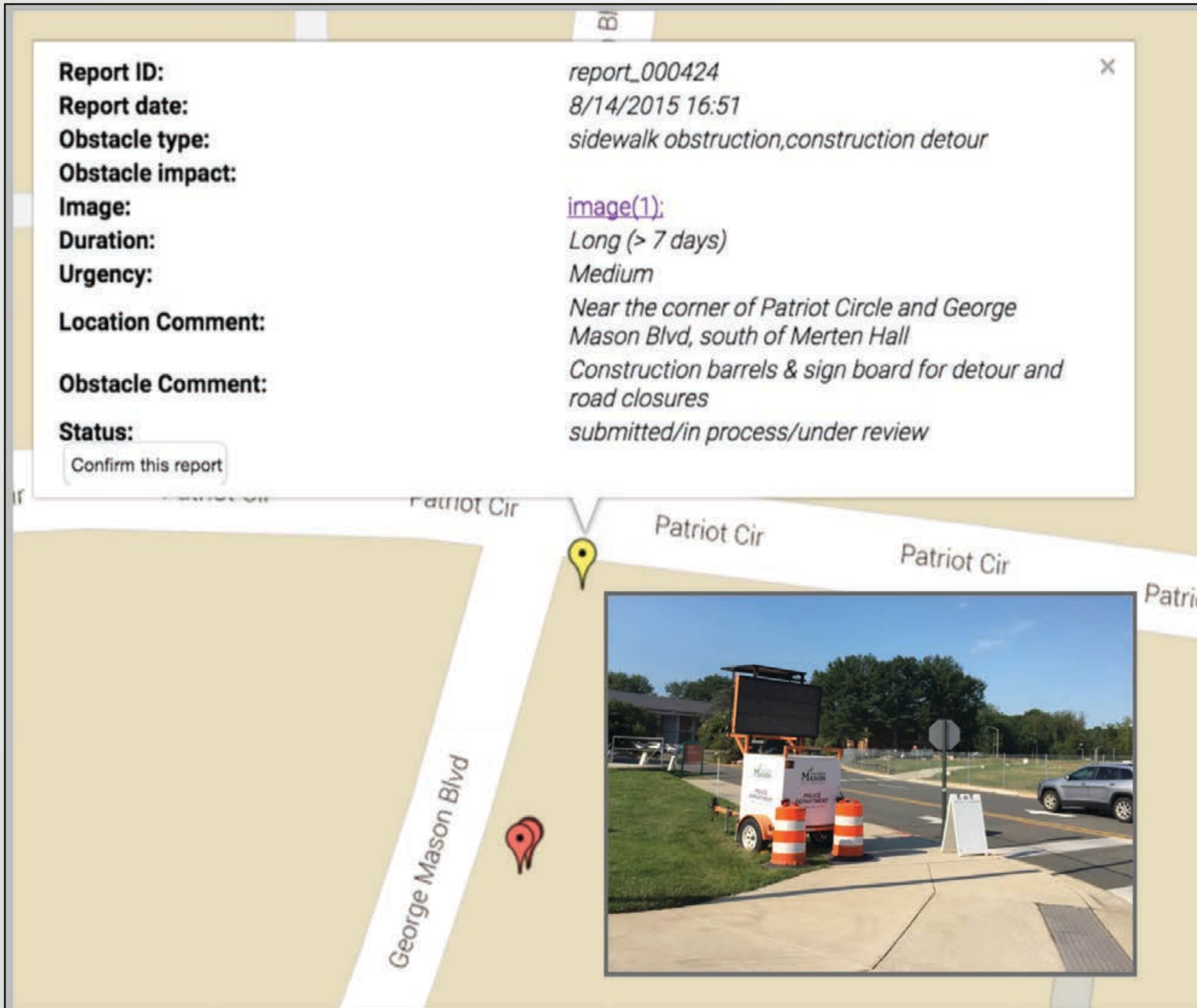


GEOCROWDSOURCED DATA COLLECTION

Obstacle Reporting Systems

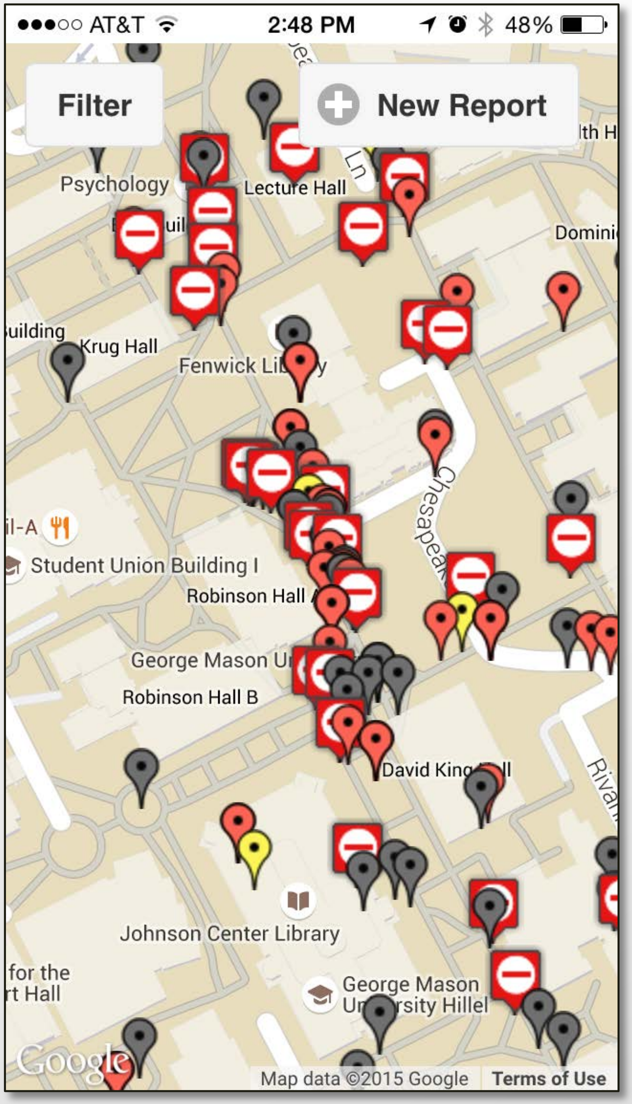


GMU Geocrowdsourcing Testbed: Obstacle Report



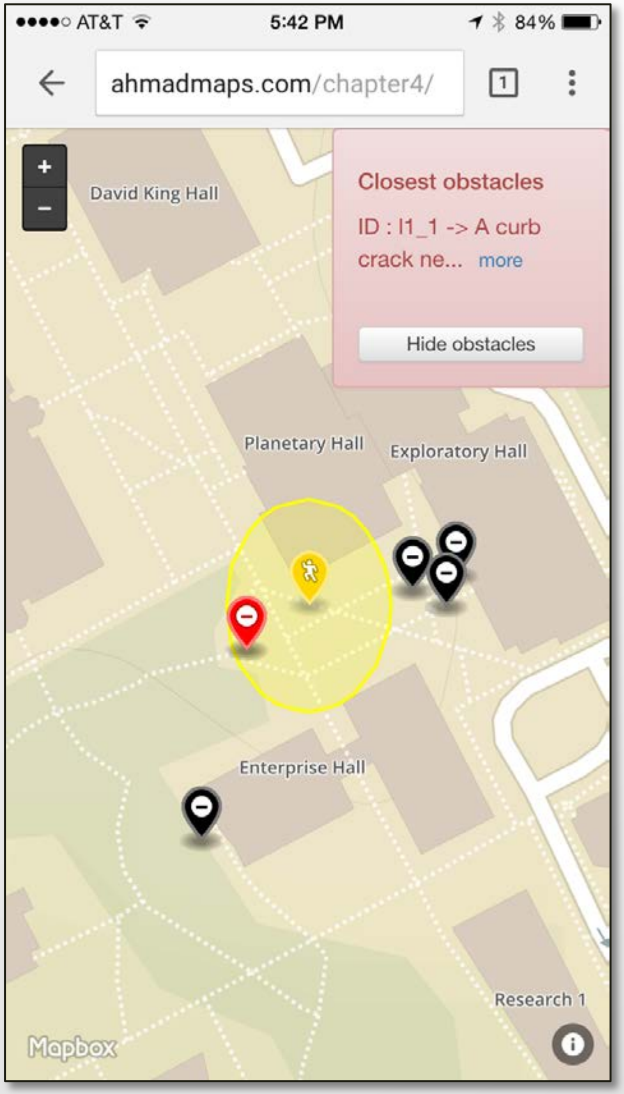
Mobile Web Application (v.1)

- Web application
- Google Maps, Sencha Touch
- Purpose: data collection

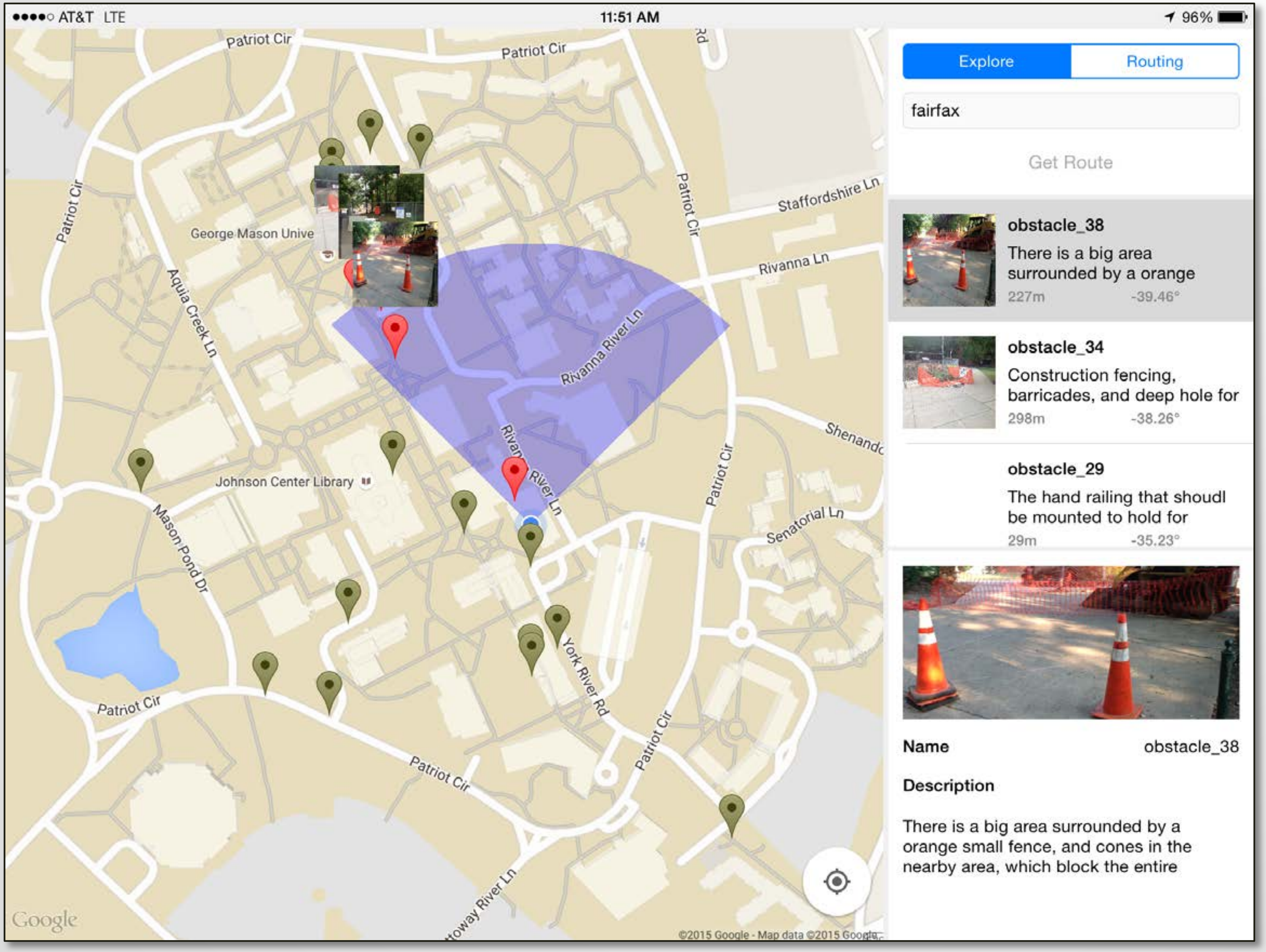


Mobile Web Application

- V.2
- Turf, Mapbox
- Primary: Obstacle interaction with movement
- Latency issues

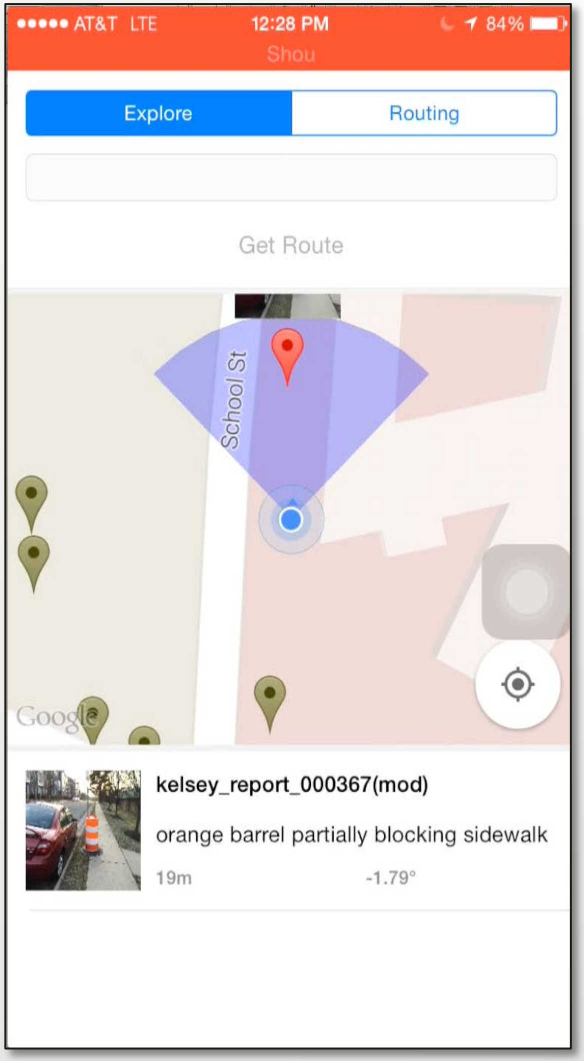


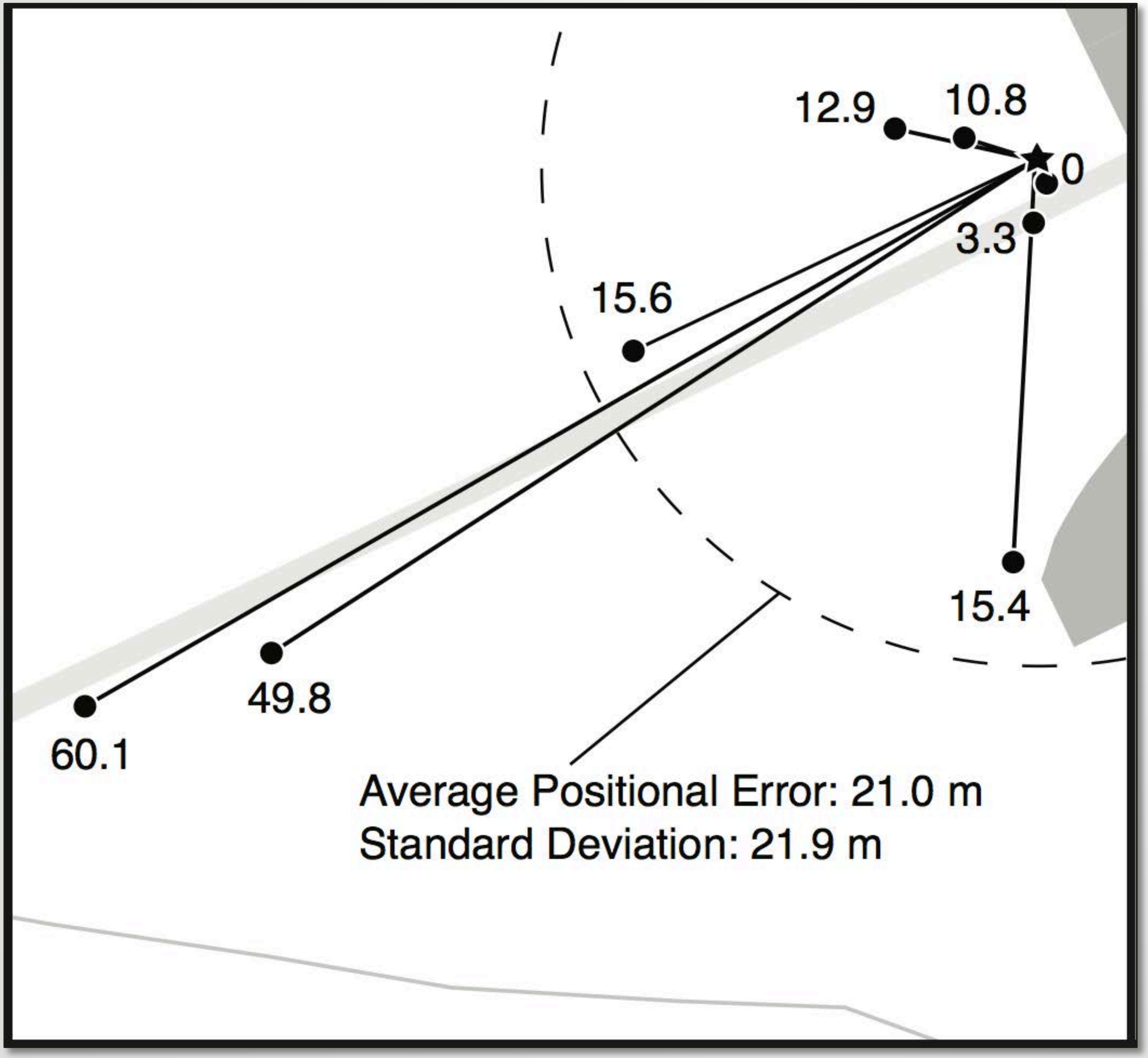
Native Mobile Application (v.1, iPad)



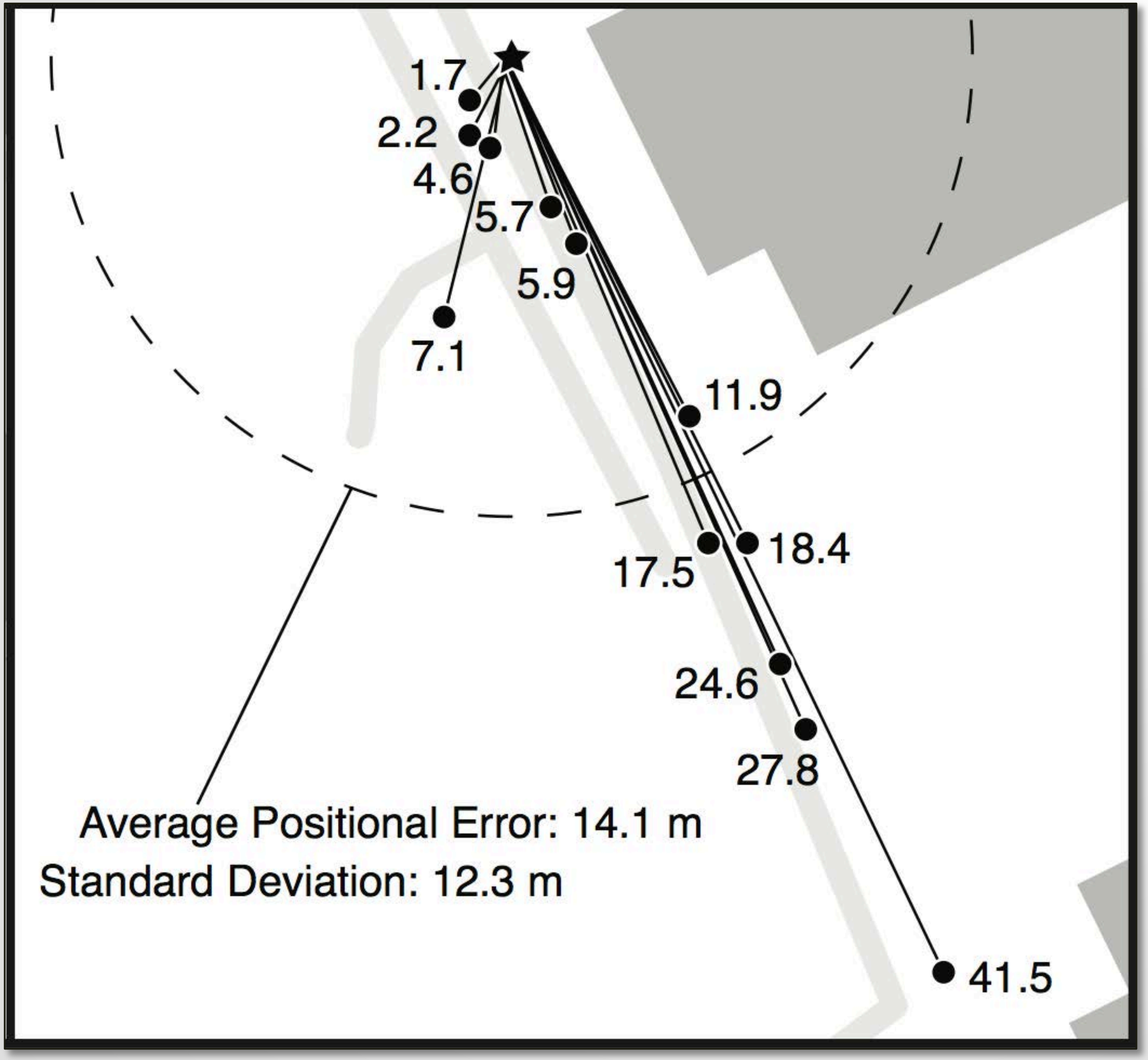
Native Mobile Application

- Swift for iOS
- Responsive
- Modes: Explore/Routing
- Chimes/cues
- 100 ft. interaction buffer
- Stable trajectory/compass





12.9
10.8
0
3.3
15.6
15.4
49.8
60.1
Average Positional Error: 21.0 m
Standard Deviation: 21.9 m


1.7
2.2
4.6
5.7
5.9
7.1
11.9
17.5
18.4
24.6
27.8
41.5
Average Positional Error: 14.1 m
Standard Deviation: 12.3 m

QUALITY ASSESSMENT

Quality Assessment of Geocrowdsourced Data

Elements of Spatial Data quality (Guptill and Morrison 1995, Veregin 1999)

Positional Accuracy	Attribute Accuracy	Completeness	Logical Consistency	Semantic Accuracy	Temporal Accuracy	Lineage	Usage

Quality Assessment Studies:

- National Map Accuracy Standards, NSSDA, GIS
- Haklay (2010), **Girres and Touya (2010)**: Horizontal Positional Accuracy of OSM data is +/-6 meters [“Haklay Distance”]
- Goodchild & Li (2012) Quality Assessment methods for VGI
- Camponovo & Freundschuh (2014): Accuracy of attributes, categorization
- Good review: Senaratne et al. (2018)

Quality Assessment of Geocrowdsourced Data

Elements of spatial data quality (Guptill and Morrison 1995, Veregin 1999)

Positional Accuracy	Attribute Accuracy	Completeness	Logical Consistency	Semantic Accuracy	Temporal Accuracy	Lineage	Usage

Goodchild and Li (2012) Three methods of assessing VGI data quality:

Social Approach

Project researchers field check and moderate crowdsourced data

Crowdsourced Approach

Based on Linus' Law; if enough people contribute, errors will be corrected (Haklay et al. 2010)

Geographic Approach

Crowdsourced data is compared to official data and known geographic phenomena

Our approach: Social moderation → hybrid crowdsourcing

Obstacle Report Attributes

Report Attribute	Format	Categories	Required
Date & Time of Observation	Selected from calendar, or typed to fit MM/DD/YYYY HH:MM format		Y
Location (X,Y)	Click-drag of locator icon (web), or GPS-coordinates from device (mobile)		Y
Location (text)	Text box		N
Obstacle Type	Selection menu	sidewalk obstruction, construction detour, entrance/exit problem, poor surface condition, crowd/event, other	Y
Obstacle Description	Text box		N
Duration	Drop-down menu	Short (<1 day), Medium (1-7 days), Long (>7 days)	Y
Urgency	Drop-down menu	Low, Medium, High	Y
Image	Image upload		N

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Quality Assessment Variables

Quality Assessment Variables	Score	Rank	Weight (%)
QA: Moderator Quality Score	1-5	1	20
QA: Location (X,Y)	0-1	2	17
QA: Image Quality	0,1,2,3	3	15
QA: Urgency	0,1,2	4	12
QA: Obstacle type	0,1,2	5	11
QA: Duration	0,1,2	6	10
QA: Temporal Consistency	0,1	7	6
QA: Location text	0,1	8	5
QA: Completeness	0-100% scaled to 0-1	9	4
			100

Index Image

Obstacle Image Detail

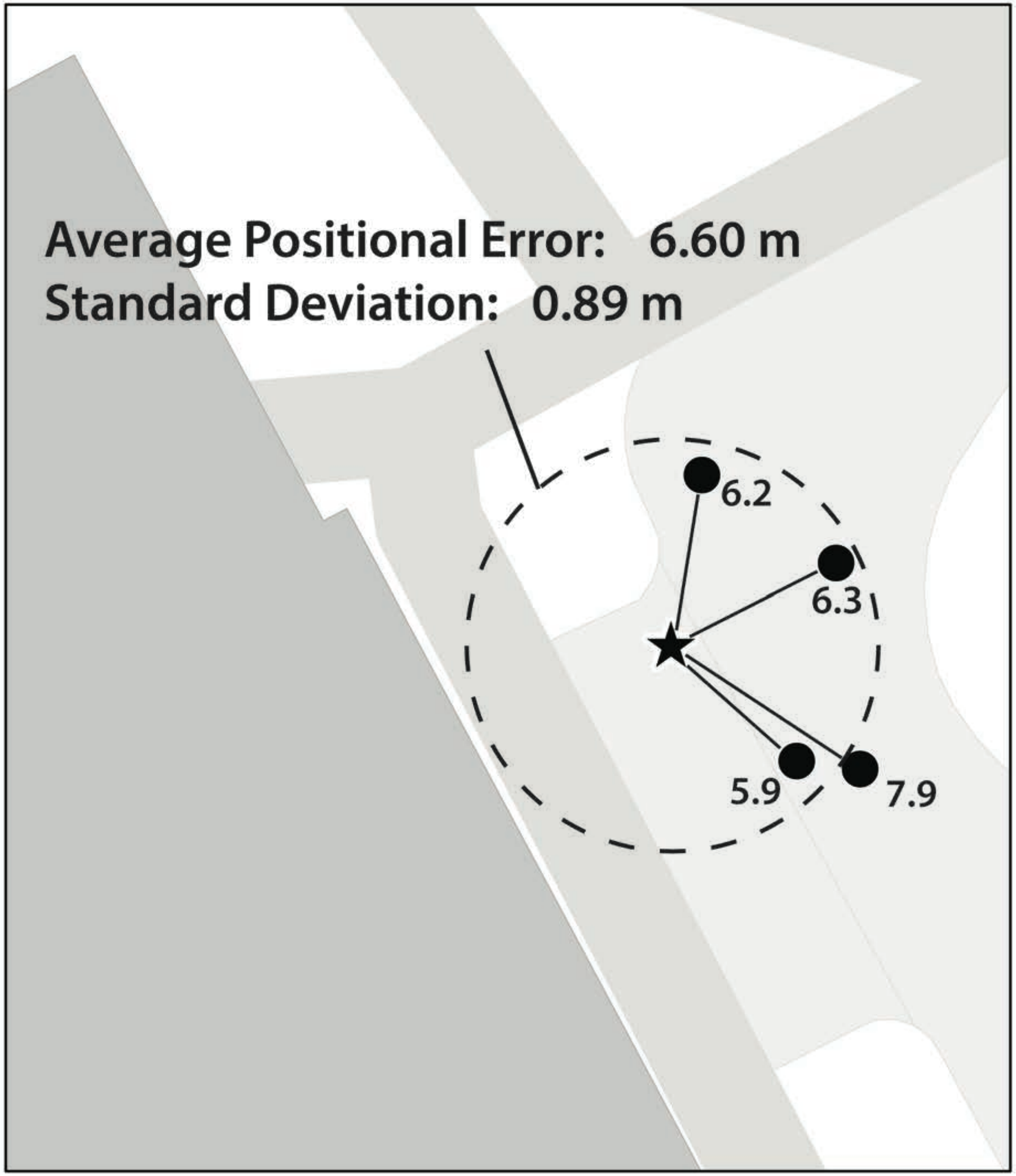
Date	October 19 2016 18:23:35
Device_Mod	iPhone 5
Lens_Model	iPhone 5 back camera 4.12mm f/2.4
latitude	38.829208
longitude	-77.305503
Image_Dire	57.574675

Date	October 19 2016 18:25:43
Device_Mod	iPhone 7
Lens_Model	iPhone 7 back camera 3.99mm f/1.8
latitude	38.829181
longitude	-77.30545
Image_Dire	86.075812

Date	October 29 2016 11:52:37
Device_Mod	iPhone 6 Plus
Lens_Model	iPhone 6 Plus back camera 4.15mm f/2.2
latitude	38.829119
longitude	-77.305467
Image_Dire	97.353086

Date	October 29 2016 11:52:56
Device_Mod	iPhone 6 Plus
Lens_Model	iPhone 6 Plus back camera 4.15mm f/2.2
latitude	38.829117
longitude	-77.305442
Image_Dire	176.126638

Positional Error Summary



Evolving quality assessment elements

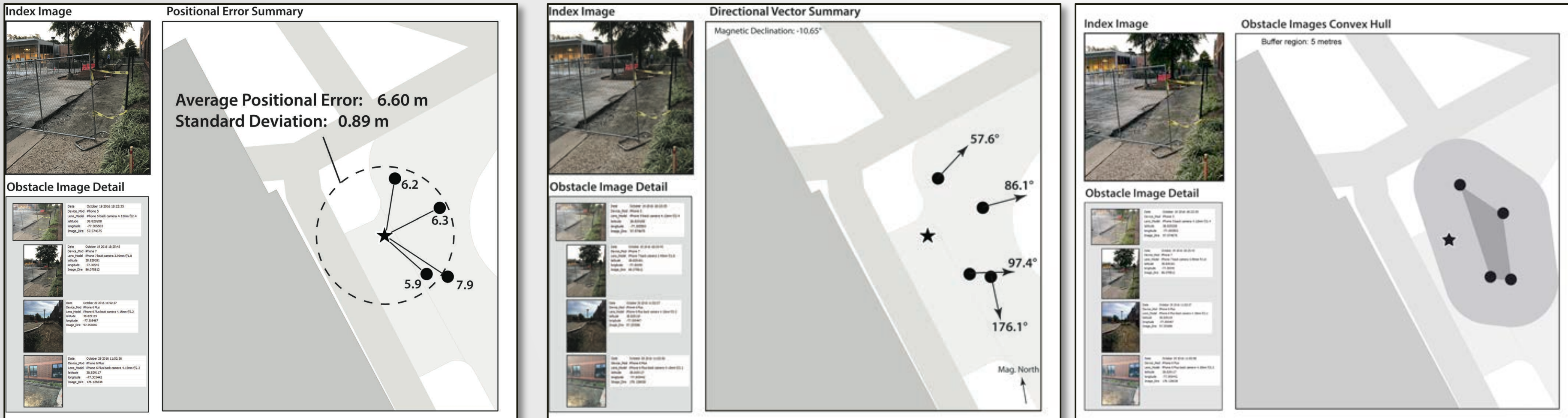


Table 2. Quality assessment elements in the evolving GMU-GcT

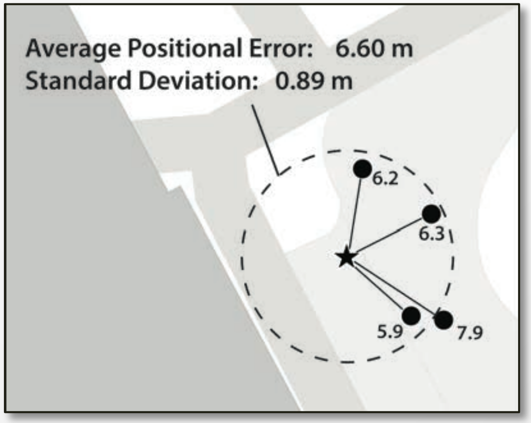
	Desktop/mobile	Image share
QA: Location (X, Y)	Metric	Derived
QA: Location text	Binary	Binary-complex
QA: Temporal consistency	Binary	Derived
QA: Obstacle type	Categorical	Not applicable
QA: Duration	Categorical	Not applicable
QA: Urgency	Categorical	Not applicable
QA: Image quality	Ordinal	Ordinal
QA: Completeness	Metric	Not applicable
QA: Moderator quality score	Ordinal	Not applicable

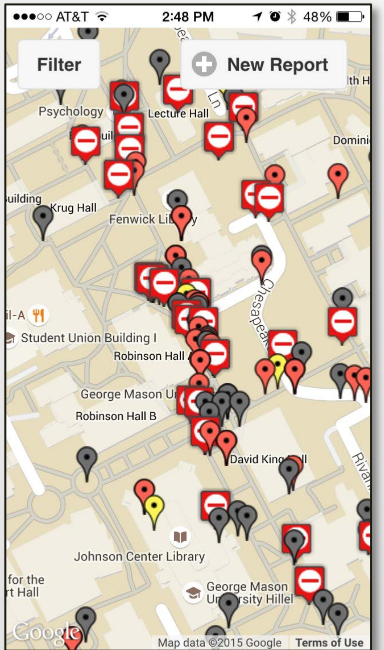
EXPERIMENTATION WITH AN IMAGE-BASED GEOCROWDSOURCING SYSTEM

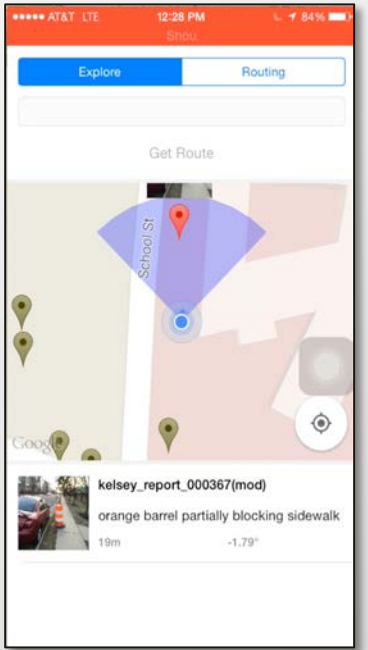
How many contributors does it take?

Haklay et al (2013) "How Many Volunteeers… "

- Experimentation (2018, with T. Williams)
- 19-21 contributors
- Mobile phone-based app
- 13 features of various sizes





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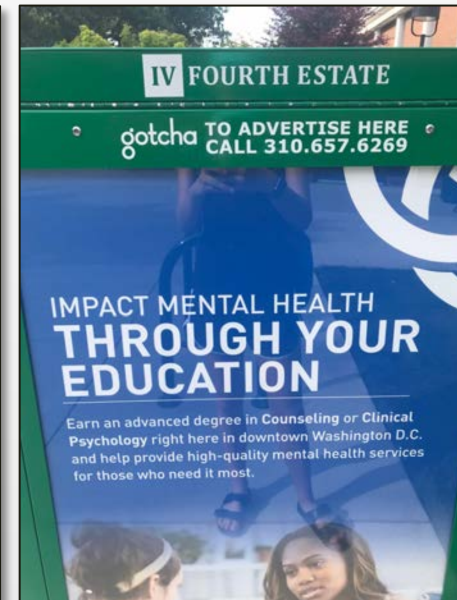
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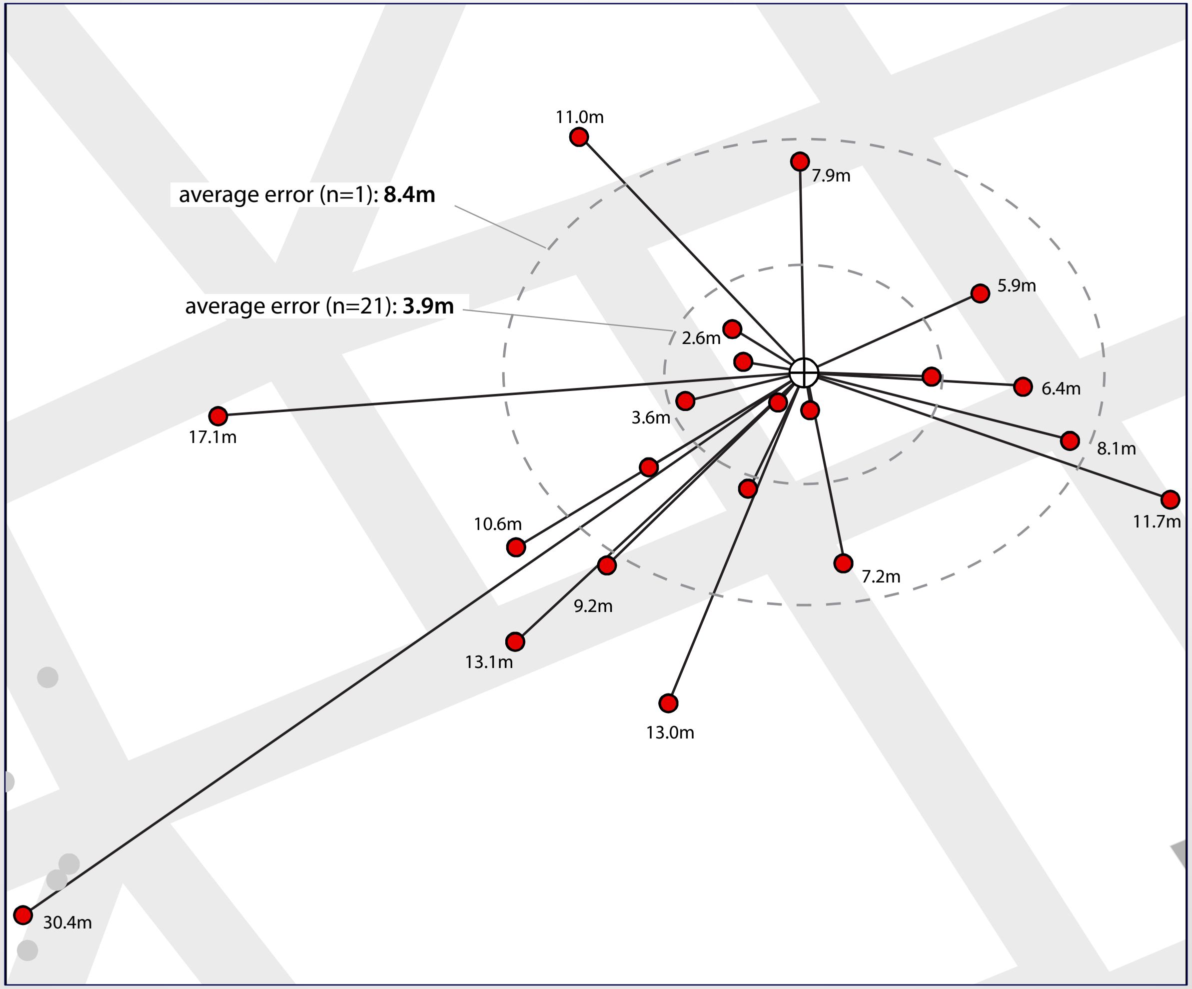
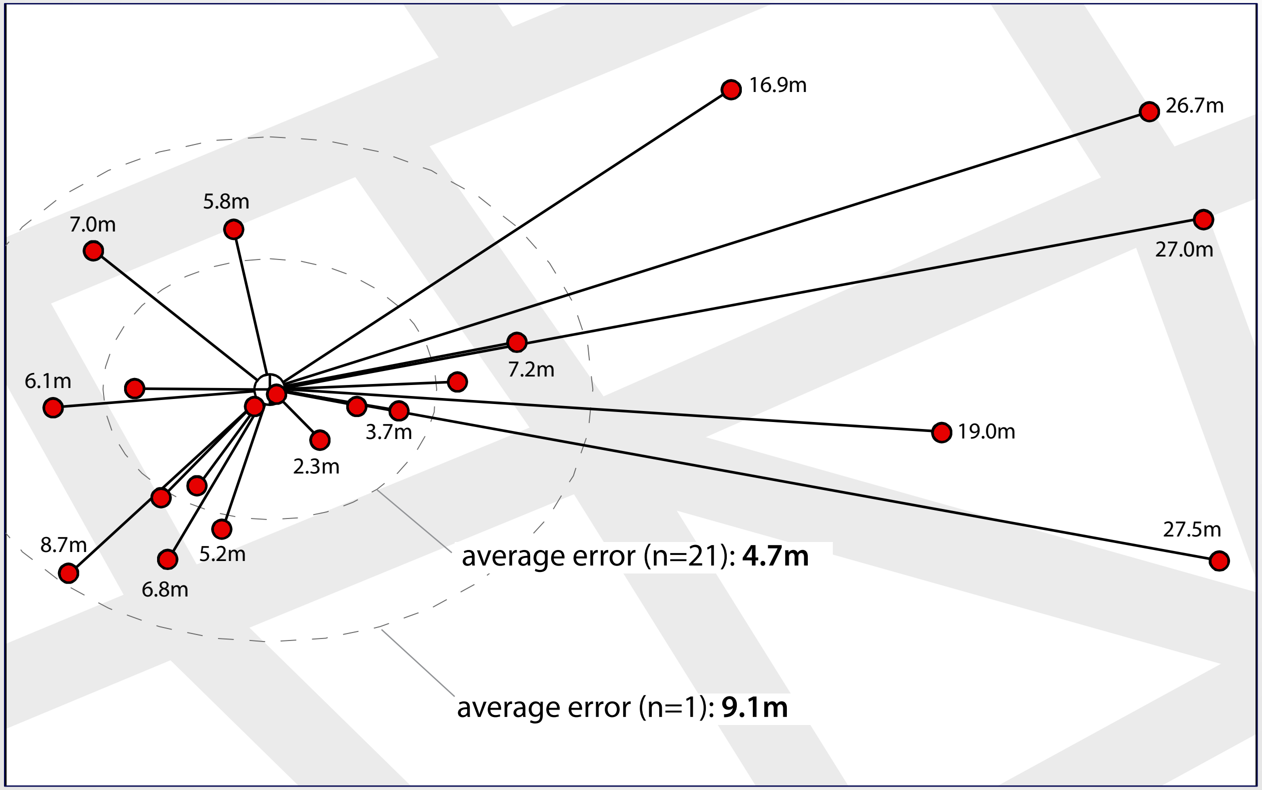
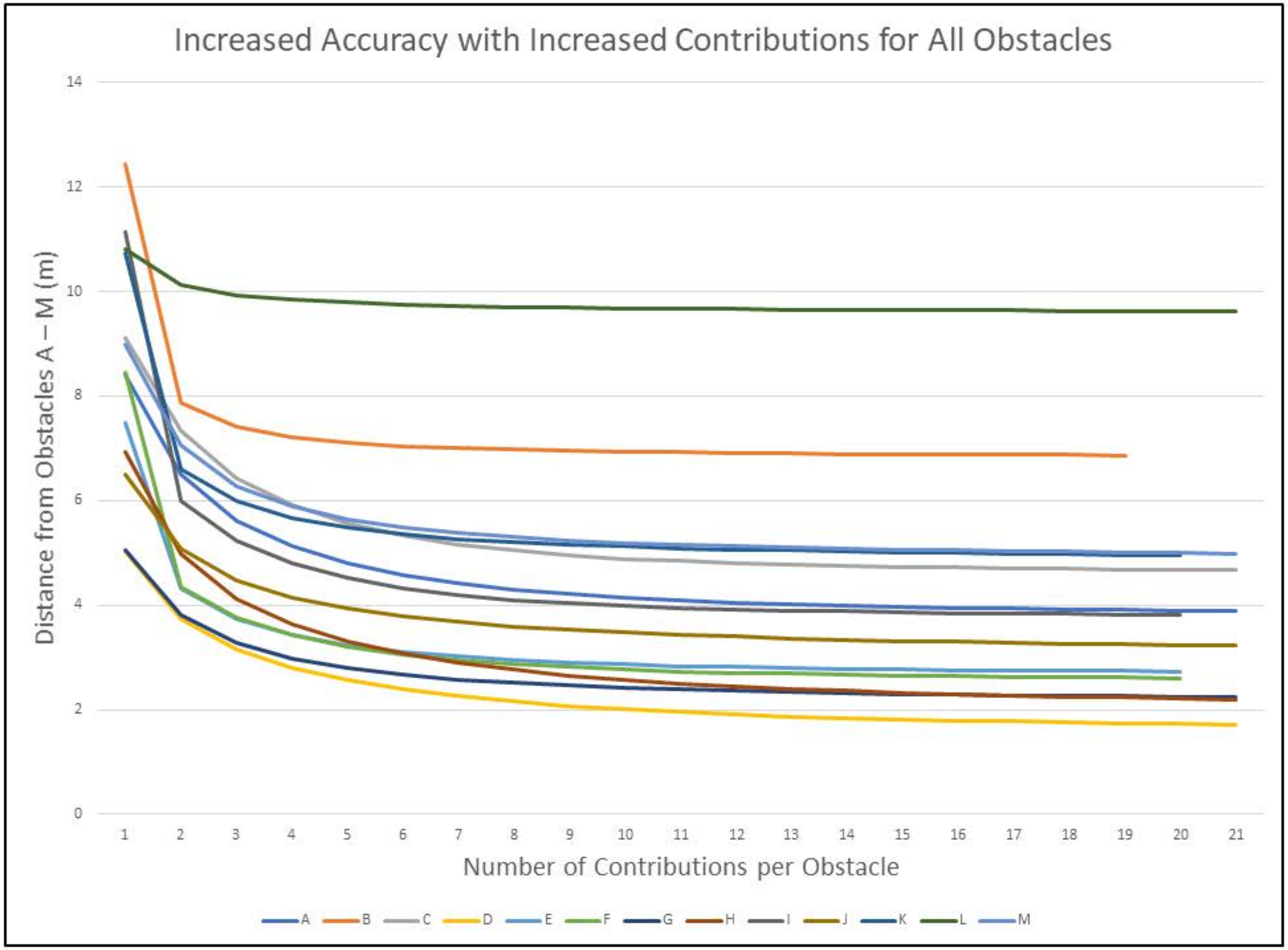
Collective Object Positioning

- 21 contributors
- Calculation of every subset
- n=1, 21!/1!*20!
- n=2, 21!/2!*19!
- . . .
- n=21,
- n=1, 8.4m
- n=21, 3.9m

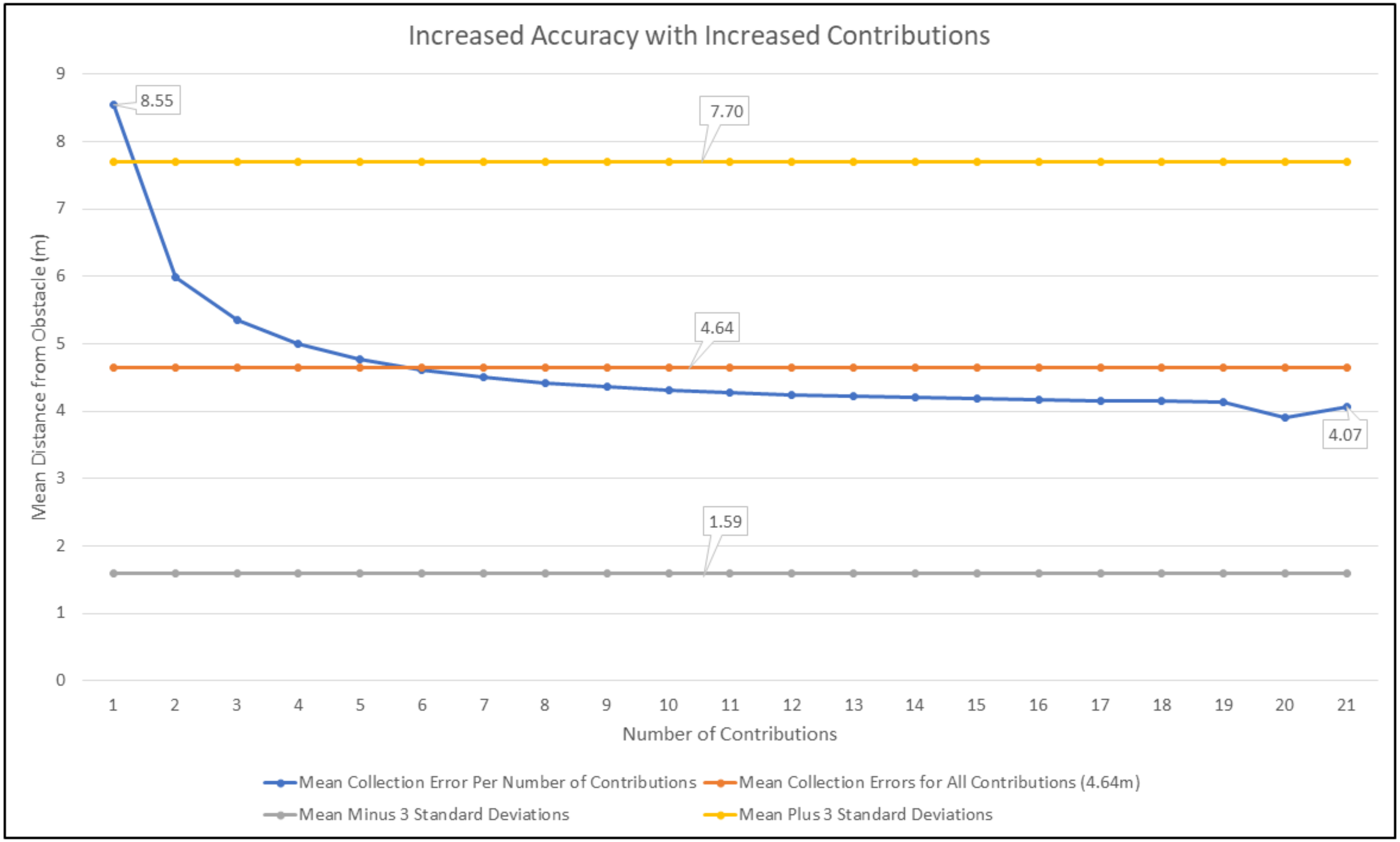


- n=1, 9.1m
- n=21, 4.7m




Increased Accuracy with Increased Contributions for All Obstacles
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Distance from Obstacles A – M (m)
Number of Contributions per Obstacle
A
B
C
D
E
F
G
H
I
J
K
L
M

Collective Positioning



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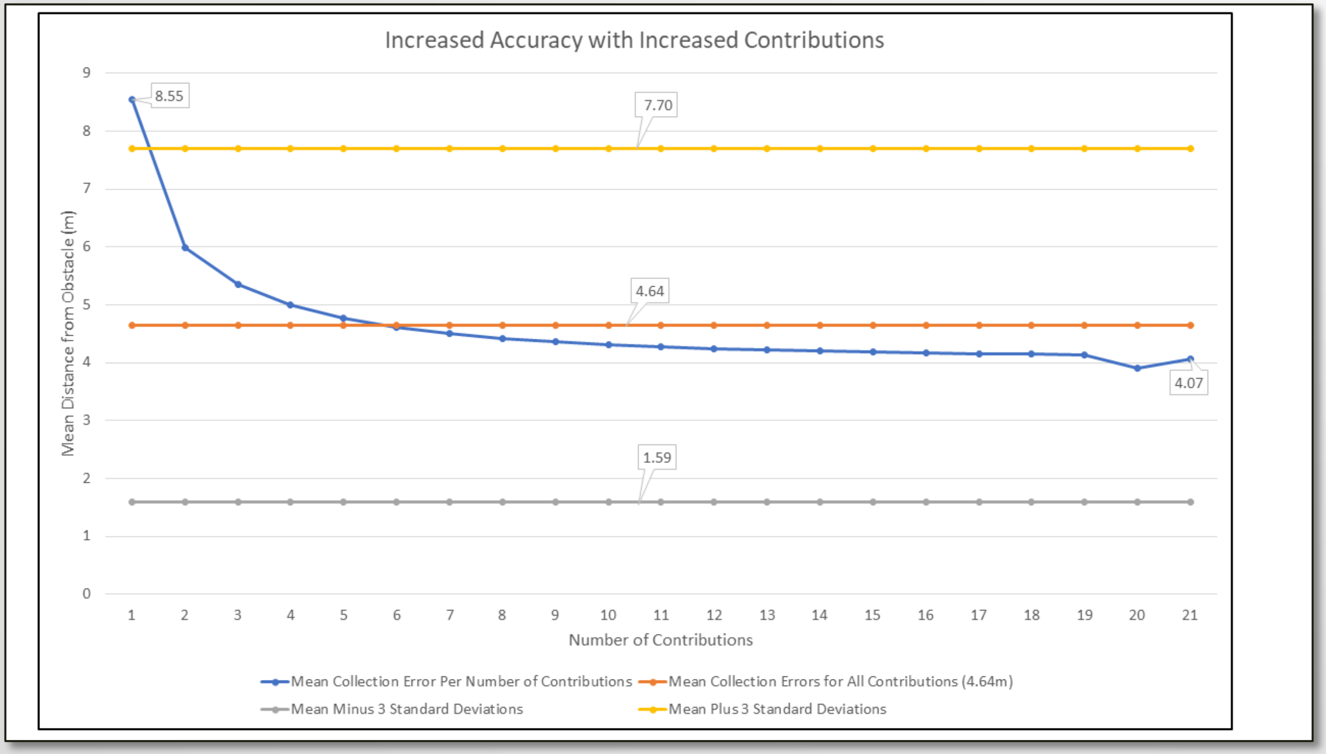
Lessons Learned

- **Quality assessment** of collective data is essential
- **3 ways to do it**: social moderation, geocrowdsourcing, rules-based approaches (Goodchild & Li 2012)
- **Social moderation** (moderator field check, fix errors) can work well for small areas, but is expensive
- **Categorization is difficult**, even for trained data contributors
  - **Problems:** semantic, ontological, perceptual
- There is a need for a simpler system with automation
- Our current approach: **image-based, collective positioning**

Lessons Learned

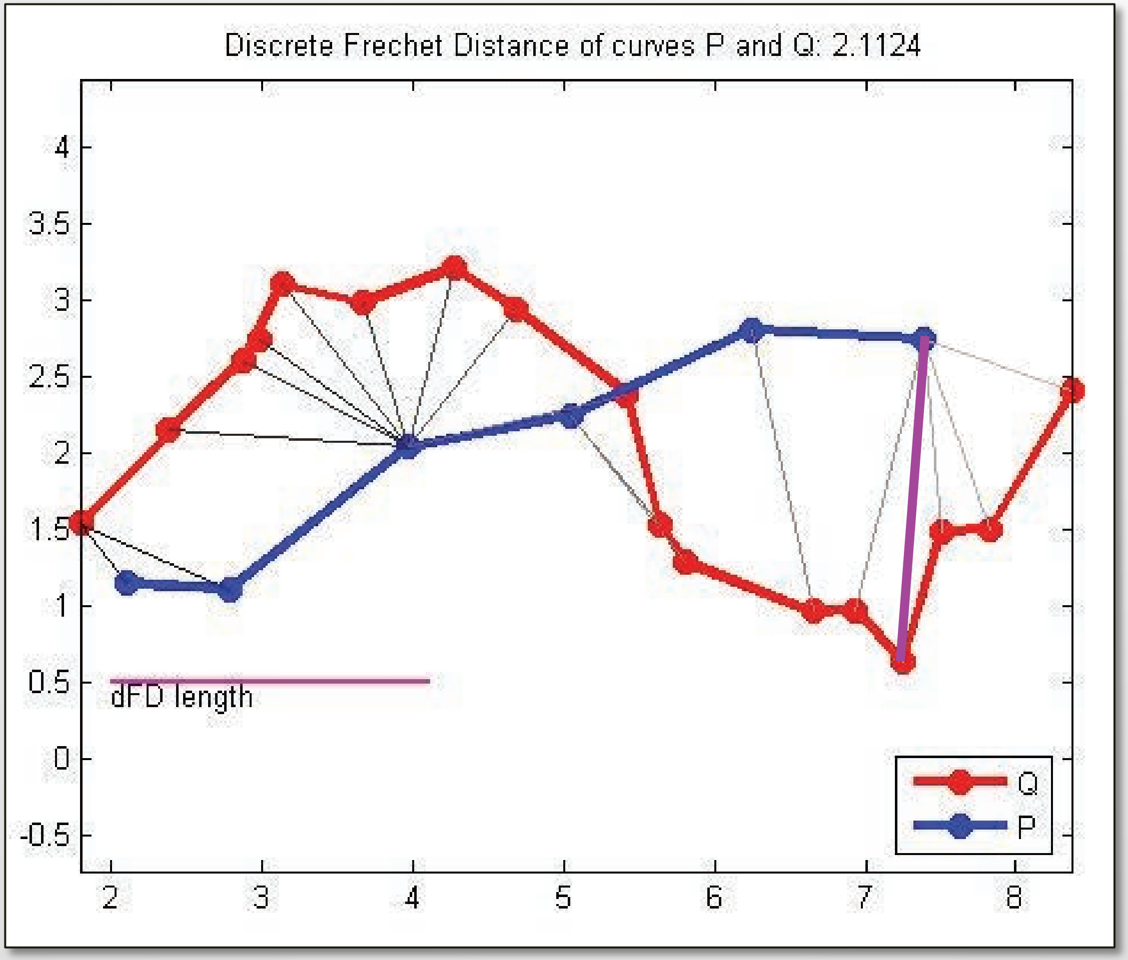
- Our current approach: image-based, collective positioning
- 4-5 independent contributors achieved < 6.0m of positional accuracy



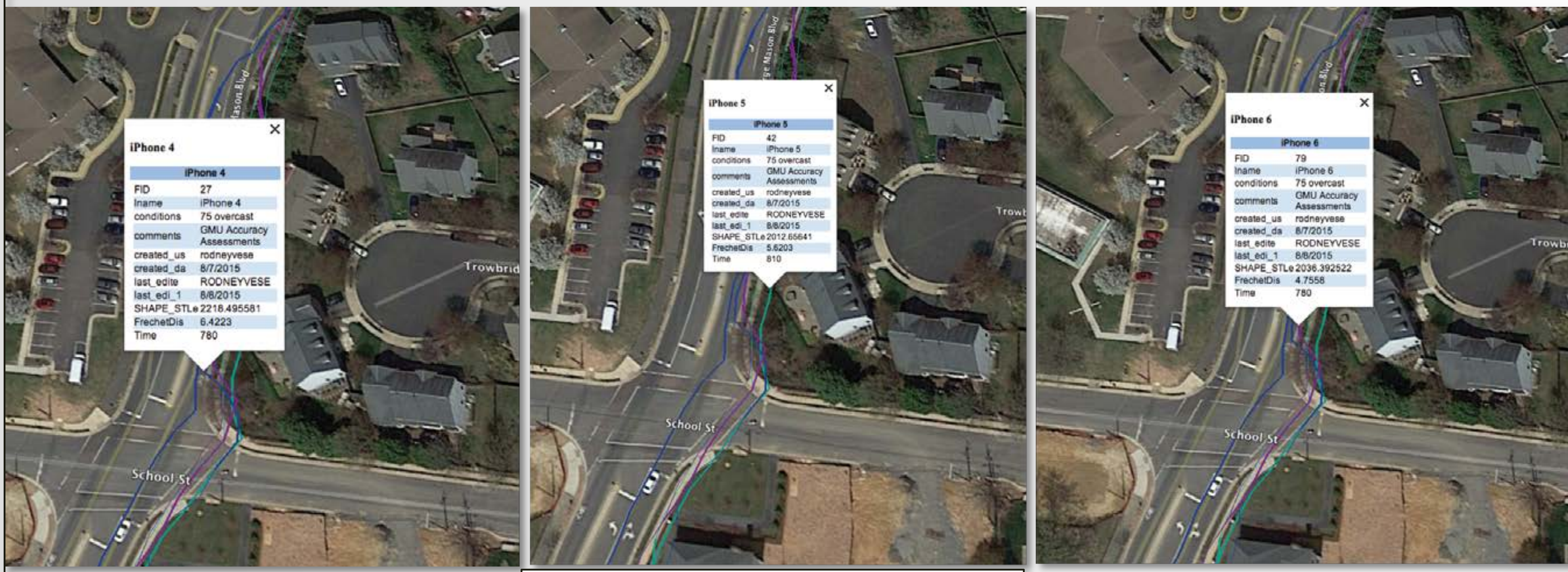
MOBILE GPS ACCURACY, AND DYNAMIC OBSTACLE ALERTS

Fréchet Distance

- Old measure (1906)
- Fréchet Distance for curves P and Q, from Brakatsoulos et al. (2005)



Mobile Device GPS Study

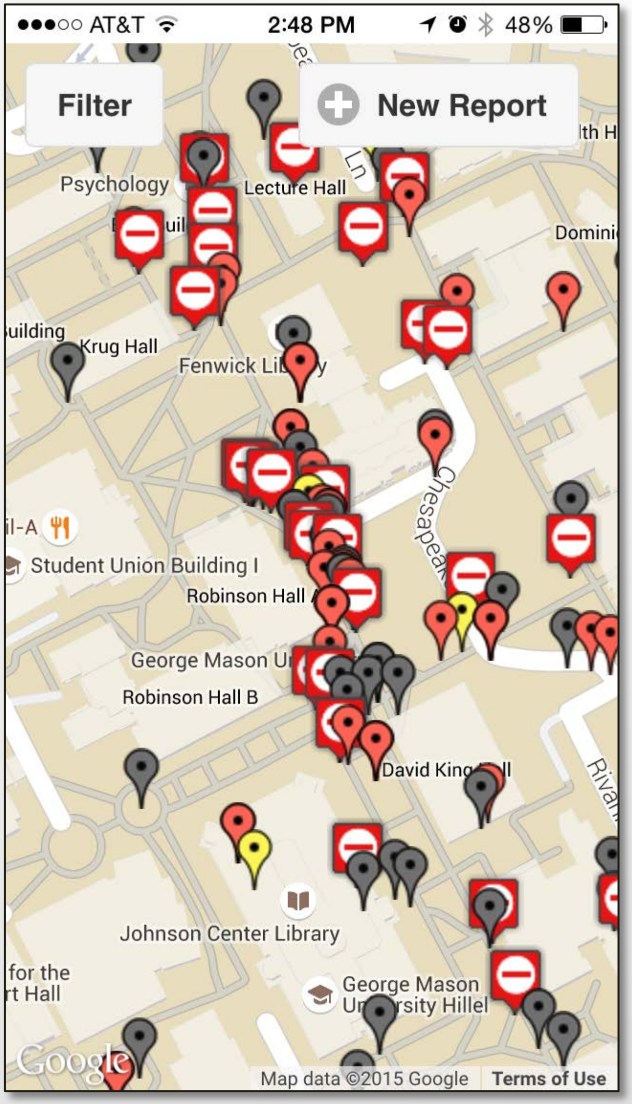


Average Frechet Distances

		Track	Total
	Track 1	5.89	
iPhone 6	Track 2	5.11	**5.92**
	Track 3	7.94	
	Track 1	5.26	
iPhone 5	Track 2	6.68	**6.72**
	Track 3	10.44	
	Track 1	8.71	
iPhone4	Track 2	11.32	**10.51**
	Track 3	13.15	

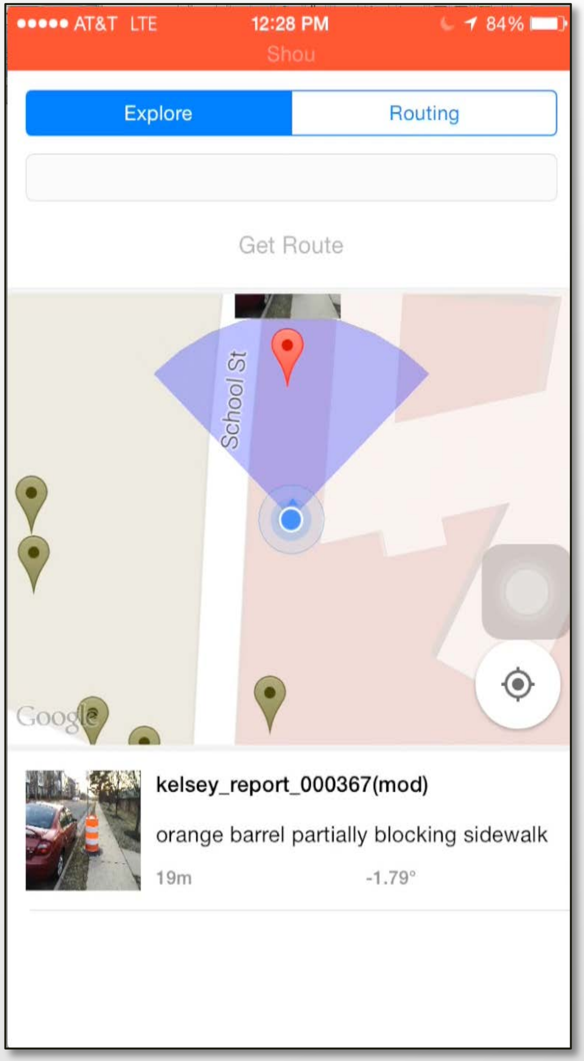
Mobile Web Application (v.1)

- Web application
- Google Maps, Sencha Touch
- Purpose: data collection



Native Mobile Application (v.2)

- Swift for iOS
- Responsive
- Modes: Explore/Routing
- Chimes/cues
- 100 ft. interaction buffer
- Stable trajectory/compass



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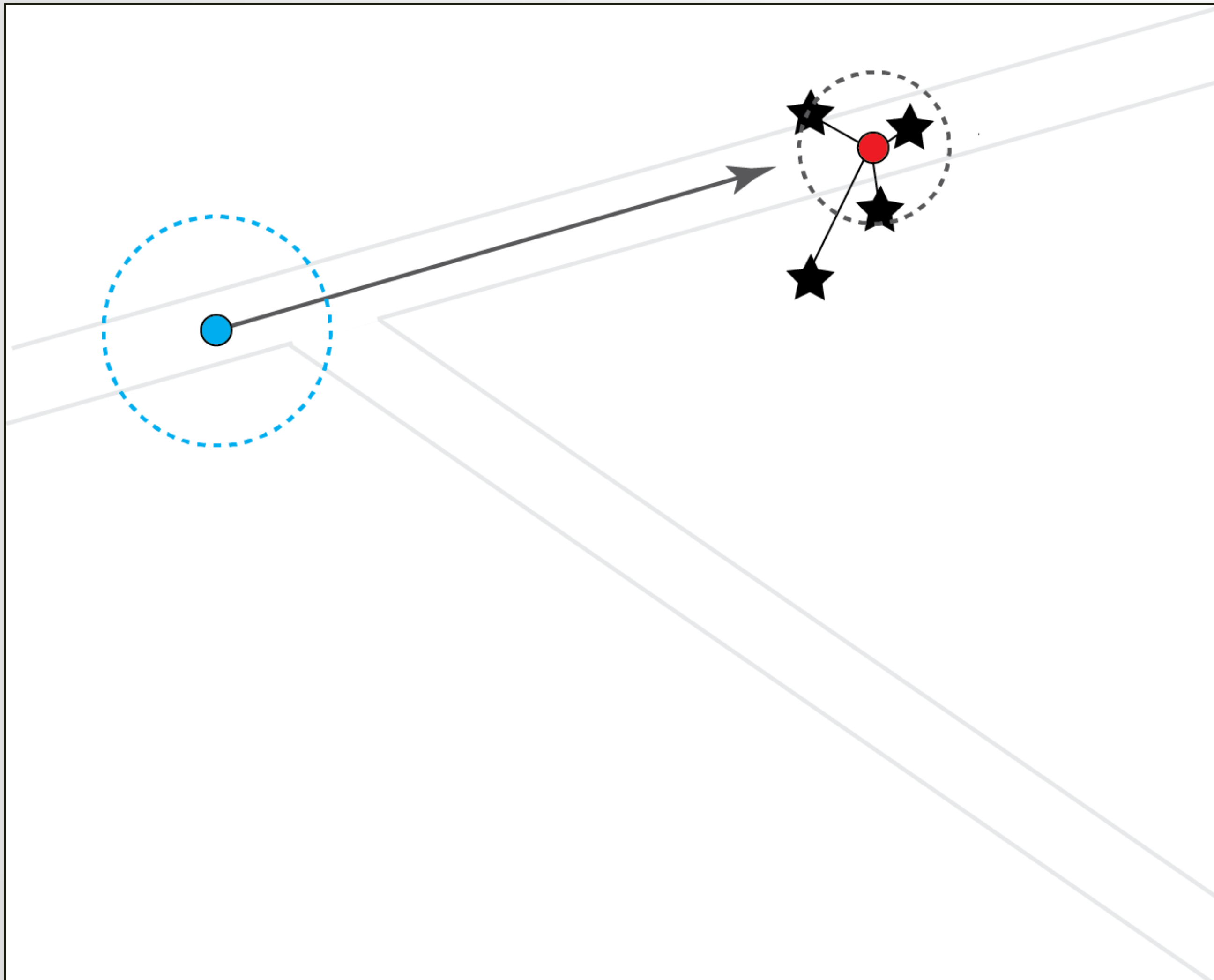
User uncertainty, obstacle uncertainty



Obstacle 11

Platform:
Web App

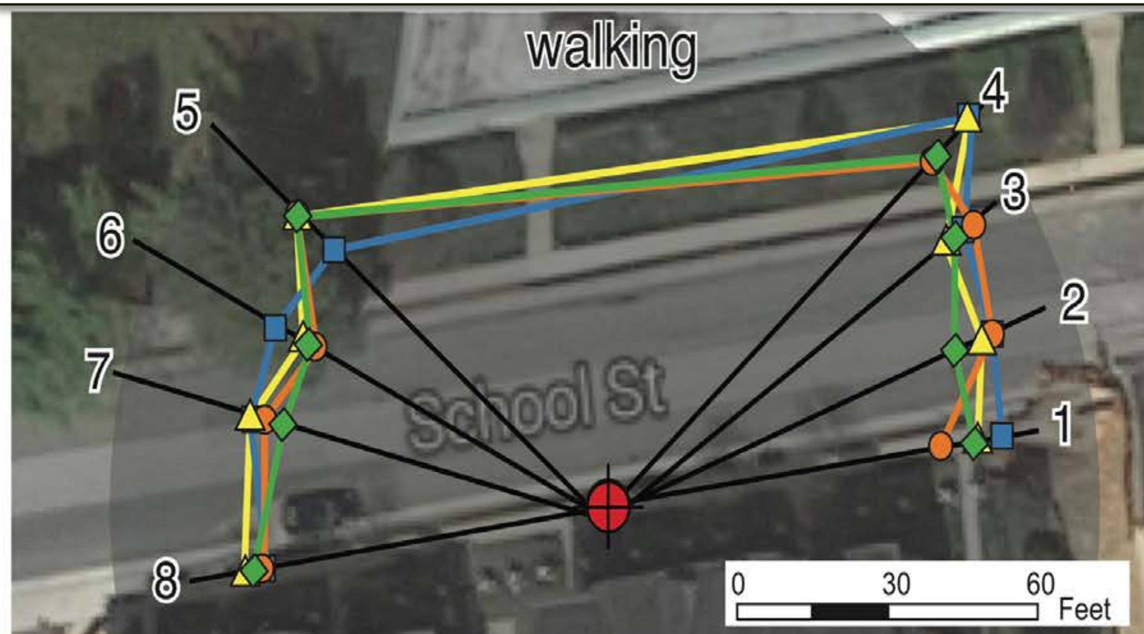
Interaction
Walking Speed

Obstacle Details

Type: Sidewalk Obstruction
Construction Detour

Location: On School St. on the sidewalk across from the Commonwealth Care Center

Description: Sidewalk excavation. Closed Sidewalk.



	△ iPhone 5	● iPhone 6	■ iPhone 6+	◆ iPad 2
Average Distance (ft):	79.1	76.4	79.3	76.6
Standard Deviation (ft):	8.4	8.4	8.9	7.7

Obstacle 11

Platform:
Web App

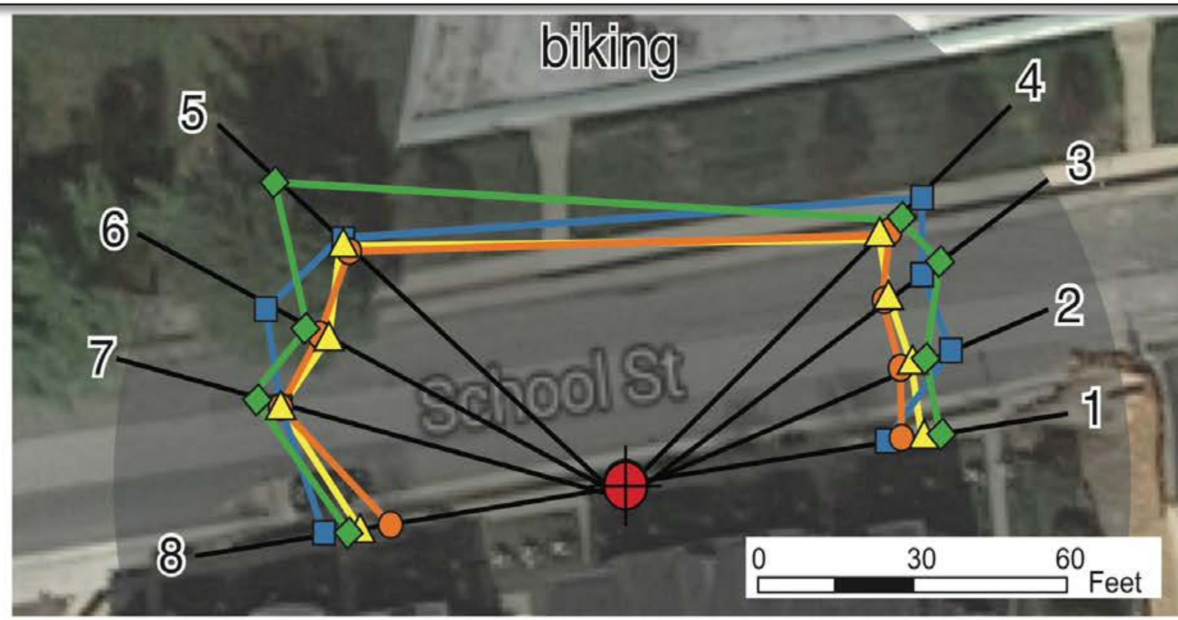
Interaction
Biking Speed

Obstacle Details

Type: Sidewalk Obstruction
Construction Detour

Location: On School St. on the sidewalk across from the Commonwealth Care Center

Description: Sidewalk excavation. Closed Sidewalk.



	△ iPhone 5	● iPhone 6	■ iPhone 6+	◆ iPad 2
Average Distance (ft):	63.1	61.8	67.8	69.4
Standard Deviation (ft):	5.5	7.5	7.7	10.2

Obstacle 11

Platform:
Mobile App

Interaction
Walking Speed

Obstacle Details

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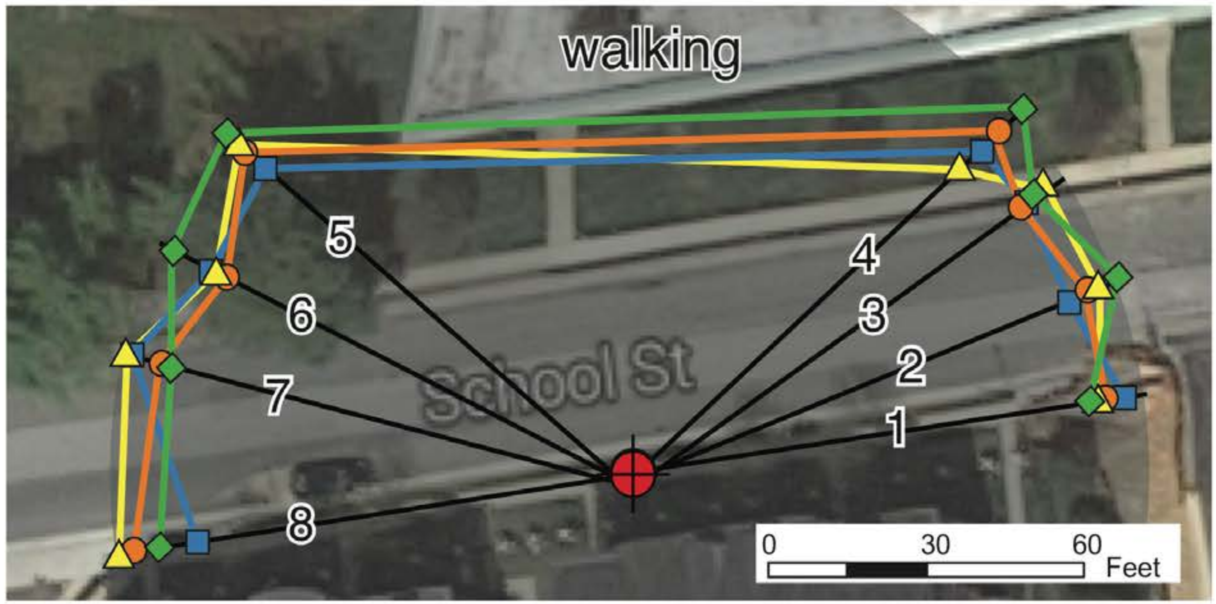

	iPhone 5	iPhone 6	iPhone 6+	iPad 2
Average Distance (ft):	93.6	92.6	91.6	95.3
Standard Deviation (ft):	7.3	7.2	7.1	7.4

Obstacle 11

Platform:
Mobile App

Interaction
Biking Speed

Obstacle Details

Type: Sidewalk Obstruction
Construction Detour

Location: On School St. on the sidewalk across from the Commonwealth Care Center

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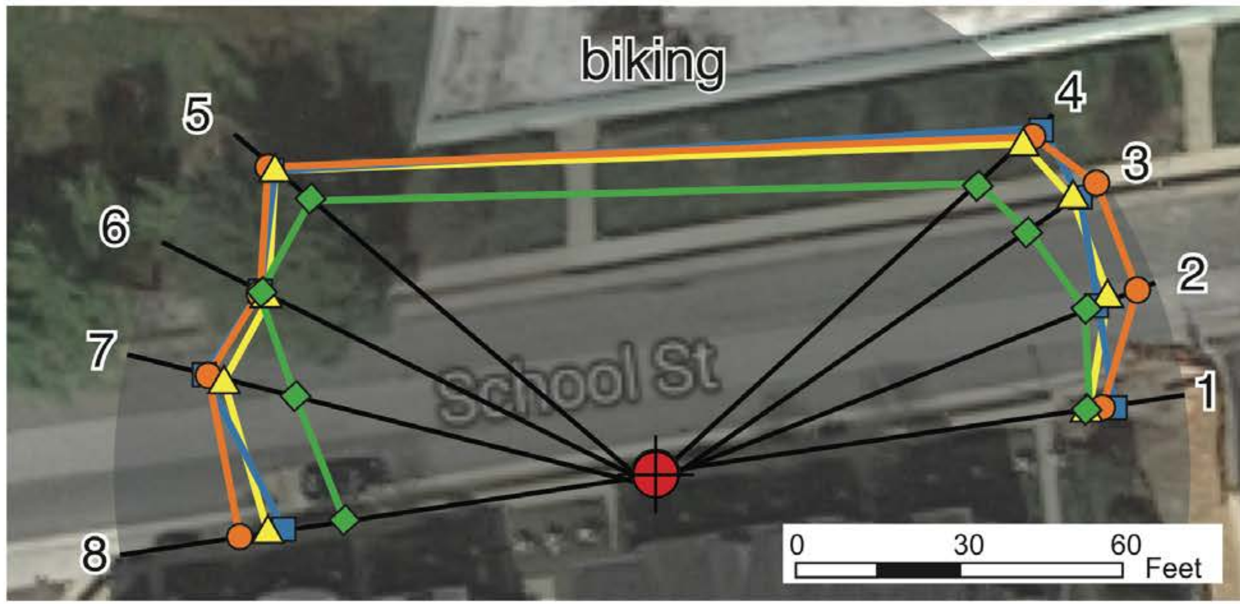
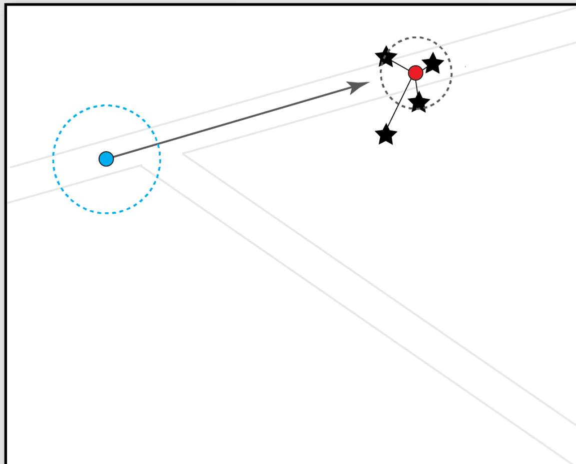


	△ iPhone 5	● iPhone 6	■ iPhone 6+	◆ iPad 2
Average Distance (ft):	85.4	88.3	86.6	78.5
Standard Deviation (ft):	7.2	7.4	5.8	6.1

Accuracy and Uncertainty, Interaction

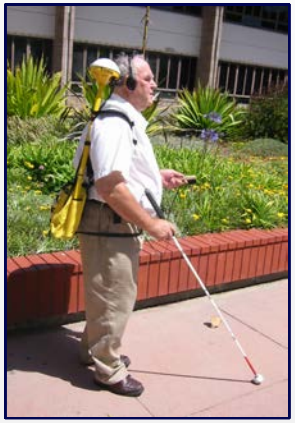


Distances in ft (meters)	Obstacle 11		Obstacle 367	
	WebApp	MobileApp	WebApp	MobileApp
Walking	77.9 (23.7)	93.3 (28.4)	69.3 (21.1)	97.9 (29.8)
Biking	65.5 (20.0)	84.7 (25.5)	52.9 (16.1)	83.9 (25.6)

Table 2. Alert distances summarized by mode of travel and by application type

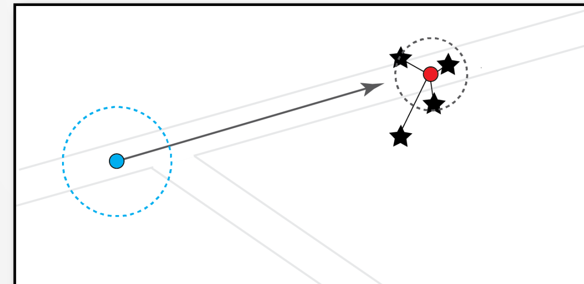
Summary

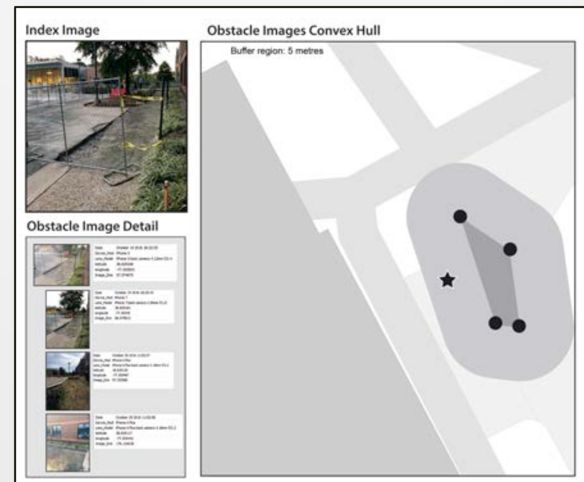
- **Two barriers** for persons with vision/mobility impairment: print and movement
- **Physical accessibility** can be facilitated with information from maps, GIS, spatial modeling, and geocrowdsourcing
- A major factor in the usefulness and quality of this information is **temporal relevancy**.
- **Geocrowdsourcing** is a key to quickly gathering relevant data.

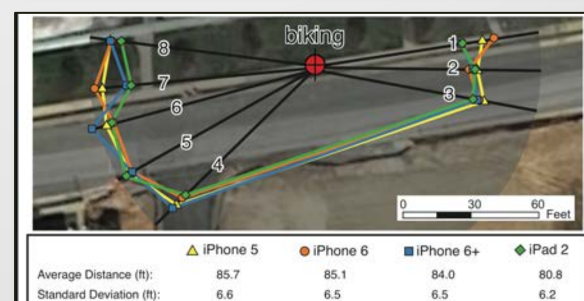


Summary

- **Quality assessment** (QA) methods, borrowed and modified from GIS, have been used successfully in many projects
- **Recent QA approaches** are based on image data and time/location elements from mobile apps
- **Interaction dynamics**, based on QA and GPS uncertainty, have been explored to better understand the use of the collected data.
- Native mobile apps can provide **proximity-sensitive warnings** for crowdsourced obstacles







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Technical Reports

2012: https://apps.dtic.mil/sti/pdfs/ADA576607.pdf
2013: https://apps.dtic.mil/sti/pdfs/ADA588474.pdf
2014: https://apps.dtic.mil/sti/pdfs/ADA615952.pdf
2015: https://apps.dtic.mil/dtic/tr/fulltext/u2/1001943.pdf

November 2012

Crowdsourced Geospatial Data

A report on the emerging phenomena of crowdsourced and user-generated geospatial data

Matthew T. Rice, Fabiana I. Paez, Aaron P. Mulhollen, Brandon M. Shore

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4400 University Drive
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Douglas R. Caldwell

Topographic Engineering Center
U.S. Army Engineer Research and Development Center
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Crowdsourcing to Support Navigation for the Disabled

A report on the motivations, design, creation, and assessment of a testbed environment for accessibility

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Quality Assessment and Accessibility Applications of Crowdsourced Geospatial Data

A report on the development and extension of the George Mason University Geocrowdsourcing Testbed

Matthew T. Rice, Fabiana I. Paez, Rebecca M. Rice, Eric W. Ong, Han Qin, Christopher R. Seitz, Jessica V. Fayne, Kevin M. Curtin, Sven Fuhrmann, Dieter Pfoser, and Richard M. Medina

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Social Moderation and Dynamic Elements in Crowdsourced Geospatial Data

A report on quality assessment, dynamic extensions, and mobile device engagement in the George Mason University Geocrowdsourcing Testbed

Matthew T. Rice, Kevin M. Curtin, Dieter Pfoser, Rebecca M. Rice, Sven Fuhrmann, Han Qin, Rodney D. Vese Jr., Eric W. Ong, Jessica V. Fayne, Fabiana I. Paez, Christopher R. Seitz

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Theses & Dissertations

1. Jeff Heuwinkel (2020) "A Geographical Analysis of Optimal Queue Locations for Autonomous Vehicles"
2. Toby Williams (2018) "Mobile Positioning Dynamics in an Image-based Hybrid Geocrowdsourcing System"
3. Han Qin (2017) "Modeling Accessibility Through Geocrowdsourcing"
4. Ahmad Aburizaiza (2017) "A Geospatial Footprint Library for Validating Volunteered Geographic Information"
5. Rebecca Rice (2015) Validating VGI Quality in Local Crowdsourved Accessibility Mapping Applications"
6. Robin Rodgers, (2015) "A Statistical Comparison of Sidewalk Slopes Deroved from Mulit-resolution Digitial Elevation Models in Support of Accessibility"
7. Patricia Pease, (2014) "The Influence of Training on Position and Attribute Accuracy in Volunteered Geographic Information"
8. Fabiana Paez, (2014) "Recruitment, Trainiung, and Social Dynamics in Geocrowdsourcing for Accessibility"

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Journal & Conference Publications

- Heuwinkel, J. R., Rice, M. T., Yu, M., Curtin, K. M., & Jacobson, R. D. (2019, January). Mobility routing optimization for physical accessibility and thermoregulation. In *Proceedings of the ICA* (Vol. 2). https://doi.org/10.5194/ica-proc-2-42-2019
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