Interaction Dynamics for Crowdsourced Obstacle Data

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- http://mason.gmu.edu/~mrice4
- http://geo.gmu.edu
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- Dr. Manzhu Yu (Penn State)

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Student assistants: Toby Williams, Rebecca Rice, Rodney Vese, Eric Ong, Kelsea Ciaroocca, Megan Rice, Chris Seitz

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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

Welcome!
We are creating a tool to report obstacles on our campus, and support the navigation for our community with disabilities... and we need your help!
For more information about the research click here.

Filter by status
- Reports
- Obstacles
- Under Review
- Confirmed
- Official Reports
- Closed

Report new obstacle
Please, complete all the information in the following tabs.
To learn how to complete the form go to "How it works" in our website.

KEY:
[This information is required]
User ID:
[More Information...]

- Time & Location
- Obstacle Details
- Upload Image

[Map of the campus with marked obstacles]
| **Report ID:** | report_000424 |
| **Report date:** | 8/14/2015 16:51 |
| **Obstacle type:** | sidewalk obstruction, construction detour |
| **Obstacle impact:** | |
| **Image:** | image(1): |
| **Duration:** | Long (> 7 days) |
| **Urgency:** | Medium |
| **Location Comment:** | Near the corner of Patriot Circle and George Mason Blvd, south of Merten Hall |
| **Obstacle Comment:** | Construction barrels & sign board for detour and road closures |
| **Status:** | submitted/in process/under review |

**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
Average Positional Error: 21.0 m
Standard Deviation: 21.9 m
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)

<table>
<thead>
<tr>
<th>Positional Accuracy</th>
<th>Attribute Accuracy</th>
<th>Completeness</th>
<th>Logical Consistency</th>
<th>Semantic Accuracy</th>
<th>Temporal Accuracy</th>
<th>Lineage</th>
<th>Usage</th>
</tr>
</thead>
</table>

**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

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

**Our approach:** Social moderation → hybrid crowdsourcing
# Obstacle Report Attributes

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

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

100
Obstacle Image Detail

<table>
<thead>
<tr>
<th>Date</th>
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<tbody>
<tr>
<td>Device_Model</td>
<td>iPhone 5</td>
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<tr>
<td>Lens_Model</td>
<td>iPhone 5 back camera 4.12mm f/2.4</td>
</tr>
<tr>
<td>Latitude</td>
<td>38.829258</td>
</tr>
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<td>Longitude</td>
<td>-117.309303</td>
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<td>iPhone 5</td>
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<tr>
<td>Lens_Model</td>
<td>iPhone 7 back camera 3.99mm f/1.8</td>
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<td>Latitude</td>
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<td>Longitude</td>
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<td>Image_Date</td>
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<tr>
<td>Device_Model</td>
<td>iPhone 8 Plus</td>
</tr>
<tr>
<td>Lens_Model</td>
<td>iPhone 8 Plus back camera 4.10mm f/2.2</td>
</tr>
<tr>
<td>Latitude</td>
<td>36.629111</td>
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<tr>
<td>Longitude</td>
<td>-117.30947</td>
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<tr>
<td>Image_Date</td>
<td>91.358586</td>
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<table>
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<tbody>
<tr>
<td>Device_Model</td>
<td>iPhone 8 Plus</td>
</tr>
<tr>
<td>Lens_Model</td>
<td>iPhone 8 Plus back camera 4.18mm f/2.2</td>
</tr>
<tr>
<td>Latitude</td>
<td>36.620117</td>
</tr>
<tr>
<td>Longitude</td>
<td>-117.30942</td>
</tr>
<tr>
<td>Image_Date</td>
<td>71.826583</td>
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</table>

Average Positional Error: 6.60 m
Standard Deviation: 0.89 m
**Evolving quality assessment elements**

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

<table>
<thead>
<tr>
<th>Element</th>
<th>Desktop/mobile</th>
<th>Image share</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA: Location (X, Y)</td>
<td>Metric</td>
<td>Derived</td>
</tr>
<tr>
<td>QA: Location text</td>
<td>Binary</td>
<td>Binary-complex</td>
</tr>
<tr>
<td>QA: Temporal consistency</td>
<td>Binary</td>
<td>Derived</td>
</tr>
<tr>
<td>QA: Obstacle type</td>
<td>Categorical</td>
<td>Not applicable</td>
</tr>
<tr>
<td>QA: Duration</td>
<td>Categorical</td>
<td>Not applicable</td>
</tr>
<tr>
<td>QA: Urgency</td>
<td>Categorical</td>
<td>Not applicable</td>
</tr>
<tr>
<td>QA: Image quality</td>
<td>Ordinal</td>
<td>Ordinal</td>
</tr>
<tr>
<td>QA: Completeness</td>
<td>Metric</td>
<td>Not applicable</td>
</tr>
<tr>
<td>QA: Moderator quality score</td>
<td>Ordinal</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
EXPERIMENTATION WITH AN IMAGE-BASED GEOCROWDSOURCING SYSTEM
How many contributors does it take?


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

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

Increased Accuracy with Increased Contributions

- Mean Collection Error Per Number of Contributions
- Mean Collection Errors for All Contributions (4.64m)
- Mean Minus 3 Standard Deviations
- Mean Plus 3 Standard Deviations

Graph showing the decrease in mean distance from obstacle as the number of contributions increases, with a notable decrease from 8.55m to 1.59m.
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 Brakatsoulas et al. (2005)
## Average Frechet Distances

<table>
<thead>
<tr>
<th>Device</th>
<th>Track</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone 6</td>
<td>Track 1</td>
<td>5.89</td>
</tr>
<tr>
<td></td>
<td>Track 2</td>
<td>5.11</td>
</tr>
<tr>
<td></td>
<td>Track 3</td>
<td>7.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>5.92</strong></td>
</tr>
<tr>
<td>iPhone 5</td>
<td>Track 1</td>
<td>5.26</td>
</tr>
<tr>
<td></td>
<td>Track 2</td>
<td>6.68</td>
</tr>
<tr>
<td></td>
<td>Track 3</td>
<td>10.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>6.72</strong></td>
</tr>
<tr>
<td>iPhone 4</td>
<td>Track 1</td>
<td>8.71</td>
</tr>
<tr>
<td></td>
<td>Track 2</td>
<td>11.32</td>
</tr>
<tr>
<td></td>
<td>Track 3</td>
<td>13.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>10.51</strong></td>
</tr>
</tbody>
</table>
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
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.
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.
Obstacle 11

Platform:
Mobile 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.

<table>
<thead>
<tr>
<th>Device</th>
<th>Average Distance (ft)</th>
<th>Standard Deviation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone 5</td>
<td>93.6</td>
<td>7.3</td>
</tr>
<tr>
<td>iPhone 6</td>
<td>92.6</td>
<td>7.2</td>
</tr>
<tr>
<td>iPhone 6+</td>
<td>91.6</td>
<td>7.1</td>
</tr>
<tr>
<td>iPad 2</td>
<td>95.3</td>
<td>7.4</td>
</tr>
</tbody>
</table>
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

Description: Sidewalk excavation. Closed Sidewalk.

![Obstacle Details Diagram](image)

<table>
<thead>
<tr>
<th>Platform</th>
<th>iPhone 5</th>
<th>iPhone 6</th>
<th>iPhone 6+</th>
<th>iPad 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Distance (ft):</td>
<td>85.4</td>
<td>88.3</td>
<td>86.6</td>
<td>78.5</td>
</tr>
<tr>
<td>Standard Deviation (ft):</td>
<td>7.2</td>
<td>7.4</td>
<td>5.8</td>
<td>6.1</td>
</tr>
</tbody>
</table>
### Accuracy and Uncertainty, Interaction

![Diagram with markers and symbols]

<table>
<thead>
<tr>
<th>Distances in ft (meters)</th>
<th>Obstacle 11</th>
<th>Obstacle 367</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WebApp</td>
<td>MobileApp</td>
</tr>
<tr>
<td>Walking</td>
<td>77.9 (23.7)</td>
<td>93.3 (28.4)</td>
</tr>
<tr>
<td>Biking</td>
<td>65.5 (20.0)</td>
<td>84.7 (25.5)</td>
</tr>
</tbody>
</table>

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.
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.
Technical Reports

3. Han Qin (2017) “Modeling Accessibility Through Geocrowdsourcing”


A few useful geocrowdsourcing references


Matt Rice - GMU
A few useful geocrowdsourcing references

A few useful geocrowdsourcing references


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