Crowdsourced Remote Assessments of Regional-Scale Post-Disaster Damage

Why do we need post-earthquake building damage information?

• The Post-Disaster Needs Assessment (PDNA) is produced in 4-6 weeks after the earthquake.

• PDNA requires spatially aggregate damage and loss estimates within an order of magnitude.

• First large-scale attempt was GEO-CAN Initiative after 2010 Haiti earthquake.

• GEO-CAN underestimated actual damage by nearly half.
Motivation for Crowdsourcing Experiments

• Address crowdsourcing by simplifying the design of the task to developing methods of analyzing the crowd’s responses

• Develop (2) area-based approaches for crowdsourcing building damage as opposed to previous in-situ building-level approaches

• Understand stakeholder needs of information: Demand Survey and collaboration
Case Study: Haiti Earthquake 2010

Study Area of Interest for (3) crowdsourcing experiments:
- Ground-validation data from field surveys of building damage (modified ATC-20)

Damage from Field Surveys
(Mean Central Damage Factor)
- 0 - 5
- 6 - 12
- 13 - 20
- 21 - 34
- 35 - 100
**Study Area of Interest for (3) crowdsourcing experiments:**

- Ground-validation data from field surveys of building damage (modified ATC-20)
- “True” damage is the average central damage factor per grid (Mean CDF)
- Area of interest exhibits distribution of building damage and density
Approach 1: Building-Level Assessment
Approach 2: Area-Based Damage Rating
Approach 3: Area-Based Damage Comparison

Click on the image that shows a higher level of damage

Images Classified: 0

Show Tutorial
Provide Feedback

Same damage in both images
Obtaining Damage Levels for Approach 3

Comparison #

1

Comparison Image

Anchor Images: Defined From Least to Greatest Damage

same

2

higher

lower

3

higher

lower

4

higher

lower

1 or 2

4 or 8

6

10
## Data Collection & Completion Rates

### Volunteer Communities

- **Humanitarian OpenStreetMap Team (HOT)**
- **Earthquake engineering community**
- **Stanford University student groups**

### Completion Rate

<table>
<thead>
<tr>
<th>Approach</th>
<th># Images Assessed / # Images Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Building-level Tagging</td>
<td>85 / 843 (incomplete)</td>
</tr>
<tr>
<td>2: Area-based Ranking</td>
<td>843 / 843</td>
</tr>
<tr>
<td>3: Area-based Comparison</td>
<td>843 / 843</td>
</tr>
</tbody>
</table>
The crowd can observe building damage in an image, but not as well as we would expect

**Approach 2: Image Ranking**

**Approach 3: Image Comparison**

Crowdsourced Trend

Volunteer Responses
The crowd’s assessment improves when weighting responses of high-performing users

Approach 2: Image Ranking Improvement by Weighting Volunteers

- Crowdsourced Trend after Weighting Volunteer Performance
- Original Crowdsourced Trend
Final Spatial Distribution of Damage

Approach 2: Image Ranking

Approach 3: Image Comparison

Crowdsourcing

Results

Error
Final Spatial Distribution of Damage

Approach 2: Image Ranking

Approach 3: Image Comparison

Crowdsourcing Results

Ground-Validation Damage

Damage Severity (Mean CDF)

- 0-15
- 15-30
- 30-45
- 45-60
- 60-78
Final Spatial Distribution of Damage

Approach 2: Image Ranking

Approach 3: Image Comparison
Conclusions

• **Area-based vs. building level assessments**: Area-assessment much quicker to reach completion and could inform aggregate loss estimates

• **Performance of the crowd**: Crowdsourcing results are noisy, but can be improved when weighting the results from high performing users

• **Potential Improvements:**
  – **Task design**: higher resolution imagery & better volunteer training
  – **Analysis**: Nonlinear modeling and systematic volunteer weighting
Acknowledgements

Research Team

- Humanitarian OpenStreetMap Team (HOT)
- University of Colorado Boulder
- GIScience Research Group, Heidelberg University
- World Bank Global Facility for Disaster Reduction and Recovery

More information:

- Blume Report No. 197:
  “The Development and Uses of Crowdsourced Building Damage Information based on Remote-Sensing”
- www.sabine-loos.com

Sponsored by: National Science Foundation under Grant No. 1645335/EAGER and the National Science Foundation Graduate Research Fellowship
Performance weights

Weight by user performance:

\[ w_{\text{performance},j} = \begin{cases} 
0, & \beta_{1,j} \leq 0 \\
\frac{\beta_{1,j}}{n_j \sum_{j=1}^{k} (\beta_j > 0)}, & \beta_{1,j} > 0 
\end{cases} \]

- \( n_j \) is the number of tasks completed by volunteer \( j \)
- \( \beta_{1,j} \) is the slope of the linear regression model for an individual user (we are assuming higher \( \beta_1 \) means better individual performance)
- \( k \) is the total number of volunteers

Weighed least squares cost:

\[ WSSE = \sum_{i=1}^{n} w_i (y_i - \hat{y}_i)^2 \]

\( \hat{y}_i = \beta_0 + \beta_1 x_i \)

\( w_i = \text{weight} \)
## ATC-20 levels

<table>
<thead>
<tr>
<th>Damage State</th>
<th>Damage Factor Range (%)</th>
<th>Central Damage Factor (%)</th>
<th>Damage Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – None</td>
<td>0</td>
<td>0.0</td>
<td>No damage</td>
</tr>
<tr>
<td>2 – Slight</td>
<td>0-1</td>
<td>0.5</td>
<td>Limited localized minor damage not requiring repair</td>
</tr>
<tr>
<td>3 – Light</td>
<td>1-10</td>
<td>5.0</td>
<td>Significant localized damage of some components, general not requiring repair</td>
</tr>
<tr>
<td>4 – Moderate</td>
<td>10-30</td>
<td>20.0</td>
<td>Significant localized damage of many components warranting repair</td>
</tr>
<tr>
<td>5 – Heavy</td>
<td>30-60</td>
<td>45.0</td>
<td>Extensive damage requiring major repairs</td>
</tr>
<tr>
<td>6 – Major</td>
<td>60-100</td>
<td>80.0</td>
<td>Major widespread damage that may result in the facility being razed</td>
</tr>
<tr>
<td>7 – Destroyed</td>
<td>100</td>
<td>100.0</td>
<td>Total destruction of the majority of the facility</td>
</tr>
</tbody>
</table>
Examples of pre-experiments

Quantify the level of damage visible in the image

Damage Scale:
- 0-20
- 20-40
- 40-60
- 60-80
- 80-100

Images Classified: 13

Link to PDF tutorial with instructions

Finish

Save
Examples of pre-experiments

Click on the image that shows a higher level of damage

Images Classified: 0

Link to PDF tutorial with instructions

Finish

Same damage in both images
Not sure
Area of Interest Damage Distribution
Bar charts of responses for each approach

[Bar chart for Experiment 2 showing response distribution across different damage indicator values for different datasets: All Data, Excessive Response Users Removed, Only One and Same Response Users Removed.]

[Bar chart for Experiment 3 showing response distribution across different damage indicator values for different datasets: All Data, Excessive Response Users Removed, Only One and Same Response Users Removed.]
Building damage and building density correlation
Error Metric

\[ \text{Error Metric} = \frac{\beta_{1\text{expected}} - \beta_{1\text{regression}}}{\beta_{1\text{expected}}} \]

\( \beta_{1\text{expected}} = \beta_1 \) for the probable linear relationship

\( \beta_{1\text{regression}} = \beta_1 \) for the regression model
Examples of tutorials