Proximate Sensing Using Georeferenced Community Contributed Photo Collections

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Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- Volunteered Geographic Information
- Georeferenced Flickr images
- Using Flickr images for land-cover classification
Volunteered Geographic Information

- Wikipedia:
  - Volunteered Geographic Information (VGI) is the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild, 2007). Some examples of this phenomenon are Wikimapia, OpenStreetMap, and Google MyMaps. These sites provide general base map information and allow users to create their own content by marking locations where various events occurred or certain features exist, but aren’t already shown on the base map.
Traditional Geographic Information

- Created by authorities and their experts
  - USGS
  - NGA
  - Ordnance Survey
  - Military in many countries
  - State and local governments

- Disseminated to non-expert users
  - With restrictions
  - At cost of production or reproduction?
  - Restrictions since 9/11

From Michael Goodchild
Volunteered Geographic Information

- A phenomenon of the 21st Century
  - Recent months
- User-generated content
- Collective intelligence
- Crowdsourcing
- Asserted information
- The empowerment of millions of private citizens
  - Largely untrained
  - No obvious reward
  - No guarantee of truth
  - No authority

From Michael Goodchild
Volunteered Geographic Information

Advantages
- Temporal coverage in terms of frequency and latency
- Size
- Represents the “people’s perspective”

Disadvantages
- Quality?
- Provenance?
VGI: Wikimapia – “Let’s describe the whole world”
VGI: Pop vs. Soda

Generic names for soft drinks by county

Most popular term used:
- Pop: 30% - 50%
- Coke: 50% - 80%
- Soda: 80% - 100%
- Other: 30% - 50%
- 50% - 80%
- 80% - 100%
- No data

Map by Matthew T. Campbell
Spatial Graphics and Analysis Lab
Department of Cartography and Geography
East Central University (Oklahoma)

Respondents through:
March 1, 2003

Survey data courtesy of Alan McConchie
Visit www.popvssoda.com to participate.

Map template courtesy of www.mymaps.com
VGI: Spheres of influence

The CommonCensus Map Project (48 States)
Shows spheres of influence of major US cities; based on 45380 votes from www.commoncensus.org
Spheres of influence labeled and colored with states faintly overlaid; numbers in parentheses indicate number of votes
Note: this map is still highly inaccurate and expected to change significantly with more votes
VGI: Flickr

- 89,298,540 geotagged items
- 2.8 million things geotagged this month
How to geotag images?

- Place on a map.
- Correlate photo time stamps with GPS trace.
- Bluetooth connection between camera and GPS.

GPS enabled camera:
- Ricoh 500SE via attachment
- Nikon P6000 has built-in GPS (~$500)
- GPS enabled camera phone
VGI: Flickr

- **Location information**
  - **lat (Required):** The latitude whose valid range is -90 to 90. Anything more than 4 decimal places will be truncated.
  - **lon (Required):** The longitude whose valid range is -180 to 180. Anything more than 4 decimal places will be truncated.
  - **accuracy (Optional):** Recorded accuracy level of the location information. World level is 1, Country is ~3, Region ~6, City ~11, Street ~16. Current range is 1-16. The default is 16.
Georeferenced Flickr Images: Previous Work

- Previous (image analysis) research incorporating georeferenced Flickr images focuses on using the location information to *infer something about the images*.

- Our work is novel in that it *uses the images to infer something about locations*. 

- **Goal:** Annotate photos whose location is only approximately known.

*Figure 9: Auto-annotation of novel images using the mined clusters.*

- **Goal**: estimate the geographic location of an image using only visual features.

**Figure 1.** What can you say about where these photos were taken?

**Figure 2.** The distribution of photos in our database. Photo locations are cyan. Density is overlaid with the jet colormap (log scale).

- **Goal:** provide textual annotation for images whose geolocation is known.

- **Goal:** provide textual annotation for images whose geolocation is known.

<table>
<thead>
<tr>
<th>Image</th>
<th>Owner tags (after upload)</th>
<th>SpiritTagger suggestions (before owner annotation), in order of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td>trevor gordon, shortboarding sandspit</td>
<td>Barbara, Santa, santa barbara, surf, Pier, surfboard, Lemon, surfing, harbor, Surfer, Wednesday, channel islands, al merrick, boarding, maasen, bogus, kneesdboard, offshore, white, cocktail, longboarding sandspit, hama, tyler anderson, damncool, oysters, person, Media, Hurricane, picture, dean, wave, fun...</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image 2" /></td>
<td>USA, Vacation, travel, California</td>
<td>California, USA, Beverly Hills, Stores, Archipel, 90210, flagship stores, N. Rodeo Drive, boutiques, designer boutique, high end retail stores, 433 N Rodeo Drive, La Perla, La Perla boutique, <a href="http://www.laperla.it">www.laperla.it</a>, Rodeo Collection, Hermes of Paris, 2007, Vacation, Shopping, architecture, travel</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image 3" /></td>
<td>Anaheim, Angels, minnesota, Twins, MLB, majorleaguebaseball, major, league, baseball, ballpark, Edison, field, California, geotagged</td>
<td>Anaheim, California, Angels, baseball, Twins, AngelStadium, MLB, major, Motorcycle, jones, Edison, majorleaguebaseball, kennedy, figgins, supercross, pierzynski, ana, league, davanon, ballpark, Racing, geotagged, minnesota, field</td>
</tr>
</tbody>
</table>

Figure 7: Example Flickr uploads, the tags the owner ultimately applied for the image, and the tags that could have been suggested by SpiritTagger (bold for correct, plaintext for irrelevant, italics for incorrect.) Note that SpiritTagger has no knowledge of the owner’s tags but suggests many of the annotations the owner eventually gives. The left example shows the power of SpiritTagger to properly weight terms particularly applicable to southern California, such as “surf” and “surfboard.” Middle example shows SpiritTagger’s learning of upscale shopping in Los Angeles. Surfing and shopping are two associations that go beyond place or neighborhood labeling.
Can georeferenced community contributed photo collections be used to infer something about a location which is not available from other data sources?

This paper: can georeferenced community contributed photo collections be used to estimate land cover?

Method:

- Label georeferenced Flickr images as developed or undeveloped.
- Use labels to classify locations as being developed or undeveloped.
- Labelling:
  - Manual
  - Automated
Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- **Proximate Sensing:**
  
  “If remote sensing is considered as using (primarily) images of distant scenes to derive geographic information then proximate sensing is using images of close-by objects and scenes.”
Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- **Study area:** 33x42km section of CA between and partly encompassing San Jose and Santa Cruz.
- **Ground truth ~ NLCD (National Land Cover Database)**
Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- Defined two superclasses:
  - Developed:
    - NLCD Class 21, Developed, Open Space
    - NLCD Class 22, Developed, Low Intensity
    - NLCD Class 23, Developed, Medium Intensity
    - NLCD Class 24, Developed, High Intensity
  - Undeveloped:
    - Everything else
Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- NLCD binary map
Partitioned study area into ~3x3km tiles:
- 14 x 11 = 154 tiles total.

Downloaded Flickr images:
- Maximum of 50 images per tile.
- ~10 tiles have no images.
- Total of 5,509 images.
- Average = 35.8 images/tile.
- “Medium” sized Flickr images – largest dimension is 500 pixels (or smaller)
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Distribution of Flickr images for study area. Machine generated boundaries of NLCD developed areas are displayed as landmarks for comparison.
Generated 2 ground truth evaluation datasets from the NLCD binary map.

- **NLCD ratio map:**
  - For each tile, indicates ratio of developed to total area.

- **NLCD binary classification map:**
  - Labels each tile as developed if above ratio > 0.5 and undeveloped otherwise.
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Ground truth: NLCD ratio map
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Ground truth: NLCD binary classification map
Results: manual labelling

Two users labelled each of the 5,509 Flickr images as developed or undeveloped.

Developed ~ depicts scenes containing constructed materials such as used in houses, buildings, etc.

Undeveloped ~ of open areas and/or contained mostly trees and vegetation.

Limited accuracy!

E.g. indoor scenes always classified as being “developed” even though photos might have been taken inside isolated homes in rural regions.
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Figure 4: Examples of Flickr images manually labelled as developed or undeveloped.
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Ground truth ratio map.

Ratio map from manual labelling.
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Ground truth binary classification map.  
Binary classification map from manual labelling.
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- **Results:** manual labelling
- **Quantitative analysis:**
  - Compute correlation coefficient for ratio maps:
    \[
    \rho_{XY} = \frac{\text{cov}(X,Y)}{\sigma_X \sigma_Y}
    \]
  - Compute % tiles with same label for binary classification maps.

<table>
<thead>
<tr>
<th></th>
<th>User 1</th>
<th>User 2</th>
<th>Random</th>
<th>All labelled dev.</th>
<th>All labelled undev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient ((\rho))</td>
<td>0.651</td>
<td>0.604</td>
<td>0.186</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>% with same label</td>
<td>73.4%</td>
<td>69.5%</td>
<td>55.6%</td>
<td>37.0%</td>
<td>63.0%</td>
</tr>
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</table>
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- Results: automated labelling
- Extract edge histogram features for each Flickr image.
- Split Flickr dataset into training and test sets.
- Train SVM using labelled training set.
- Classify test set.
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Figure 4: Examples of Flickr images manually labelled as developed or undeveloped.

Figure 7: Edge images corresponding to example Flickr images in figure 4. The captions under each subfigure contain the five dimensional edge histogram feature vectors. The components of these vectors indicate the relative strength of edges in the horizontal, vertical, 45° diagonal, 135° diagonal, and isotropic (non-orientation specific) directions.
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- **SVM classifier with RBF kernel:**
  - Trained with 2,740 images:
    - ~30% labelled as developed.
  - Parameter selection:
    - Five fold cross validation.
    - Grid search.
  - Classification rates:

<table>
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<tr>
<th>Training set</th>
<th>Validation rate</th>
<th>Test rate</th>
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<tr>
<td>User 1 labels</td>
<td>72.2%</td>
<td>70.2%</td>
</tr>
<tr>
<td>User 2 labels</td>
<td>68.9%</td>
<td>69.0%</td>
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</table>
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Ground truth ratio map.  

Ratio map from SVM 1 labelling.
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Ground truth ratio map.

Ratio map from SVM 2 labelling.
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Ground truth binary classification map.

Binary classification map from SVM 1 labelling.
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Ground truth binary classification map.

Binary classification map from SVM 2 labelling.
Proximate Sensing Using Georeferenced Community Contributed Photo Collections

- **Results:** automated labelling
- **Quantitative analysis:**

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<tr>
<th>Correlation coefficient ($\rho$)</th>
<th>SVM 1</th>
<th>SVM 2</th>
<th>Random</th>
</tr>
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<tbody>
<tr>
<td>% with same label</td>
<td>77.3%</td>
<td>71.4%</td>
<td>35.7%</td>
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Discussion:

- Even though initial, straightforward approach, results are significant.
- User and SVM generated maps are similar to NLCD ground truth maps.
- Maps derived from Flickr images tend to overestimate how developed a region is.
Discussion:

- User generated ratio maps are more similar to ground truth than the SVM ratio maps while the opposite is true for the binary classification maps.
  - Humans can manually classify individual Flickr images more accurately than SVM classifiers since they incorporate higher-level understanding of the images.
  - However, SVM classifiers are better able to learn overall distribution of the two classes.
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- **Extensions:**
  - More image features: texture, quantized SIFT.
  - Textual tags.
  - Filter out ambiguous or non-informative images:
    - Indoor vs. outdoor classification.
    - Face detection.
- **Semi-supervised learning.**
- **Prior information:**
  - Prior class probabilities.
  - Spatial distribution of classes: Tobler’s first law of geography and Markov random fields.
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- **Extensions:**
  - Interpolate where there are no Flickr images:
    - Kriging/linear least-squares estimation/Gaussian processes.
    - How to combine with MRFs?
  - Generalization:
    - Train with one region, classify another.
  - Expand the number of land cover superclasses.
VGI: GeographUK

- Collect geographically representative photographs and information for every square kilometre of Great Britain and Ireland.

"Drainage Ditch, Seal Sands Road
View east along a drainage ditch alongside the road to the Seal Sands petrochemical works."
Thank you!

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  - DOE Early Career Scientist and Engineer Award/PECASE
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