Large-scale Social Sensing
(with Humans as Sensors)

Tarek Abdelzaher
Dept. of Computer Science
University of Illinois at Urbana Champaign

Poll Results

Poll Results

- “RunBuddy: A Smartphone System for Running Rhythm Monitoring” (Prepared by: Ashutosh Dhekne) 3.97

Poll Results

- “Evaluating Tooth Brushing Performance with Smartphone Data”
  (Prepared by: Syeda Persia Aziz and Shegufta Bakht Ahsan)

- “When Attention is not Scarce; Detecting Boredom from Mobile Phone Usage”
  (Prepared by: Bilge Acun, Zhangxiaowen Gong, and Mengjia Yan)
Poll Results

- “Tracking Motion Context of Railway Passengers by Fusion of Low-Power Sensors in Mobile Devices” (Prepared by: Xiaoming Chen, Hathfi B. Hakim, and Piyush Shrivastava)

Poll Results

- “ZapDroid: Managing Infrequently Used Applications on Smartphones” (Prepared by: Tejala Thippeswamy and Madhushree Sreenivasa)
Earthquake Shakes Twitter Users

Using Humans as Sensors:

- Assumption: Each Twitter user is regarded as a sensor. A sensor detects a target event and makes a report probabilistically.
- Assumption: Each tweet is associated with a time and location, which is a set of latitude and longitude.
Event Detection: The Classifier

- Not all occurrences of a keyword (e.g., “earthquake” or “shaking” is about an ongoing event:
  - I am afraid of earthquakes
  - Shaking hands with boss
- How to solve this? (How to classify occurrences that constitute “sensing” of an ongoing event from others?)

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Event Detection: A Probabilistic Model

- Spikes in occurrence of related keywords help detect corresponding events:

![Graphs of Earthquake-related and Typhoon-related keywords]

When a user detects an event at time 0, the time to make a tweet follows an exponential distribution.
Event Tracking

- Given (i) detected noisy location of the event at each point in time and a (ii) mobility model for the event, compute the most likely trajectory.
- Multiple tracking techniques available in literature:
  - Kalman filter
  - Particle filter

Information Diffusion

- Assuming little/no diffusion (no retweets)

Diffusion of Earthquake tweets  Diffusion of Typhoon tweets
Evaluation

- Detection of an Earthquake

![Image of earthquake detection diagram]

<table>
<thead>
<tr>
<th>Date</th>
<th>Actual center lat.</th>
<th>Actual center long.</th>
<th>Median (baseline) lat.</th>
<th>Median (baseline) long.</th>
<th>Weighted ave. (baseline) lat.</th>
<th>Weighted ave. (baseline) long.</th>
<th>Particle filters lat.</th>
<th>Particle filters long.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 10 01:00</td>
<td>33.10</td>
<td>138.50</td>
<td>3.40</td>
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<td>-4.63</td>
<td>-1.00</td>
<td>-1.00</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Average distance: 3.47

8
Evaluation

- Detection and tracking of a Typhoon
The Human Sensor Model

- Humans are better at binary observations. For measurements on a scale, use sensors.
- Examples of actual Twitter feeds that can be thought of as “binary observations”:
  - “Crash blocking lanes on I-5S @ McBean Pkwy in Santa Clarita”
  - “105E past LakewoodB: traffic stopped to clear tire debris out of lanes”
  - “@BostonGlobe: BREAKING NEWS: Shots fired in Watertown; source says Boston Marathon terror bomb suspect has been pinned down.”
  - “The police chief of Afghanistan’s southern Kandahar province has died in a suicide attack on his headquarters.”
  - “Yonkers mayor has lifted his gas rationing order. Fill it up! #SandyABC7”

Dow Jones Hickup

- Dow Jones lost 150 points on a rumor of two explosions in the White House on April 23rd, 2013.
Reconstructing Event Timelines
The Apollo Fact-finder

People

Clean Event Summary?

Sources

Claims

Sources

Claim Clusters

Network of Claims and Sources

Claim Credibility Assessment

Sources Credibility Assessment

Define \( a_i \) as:
- \( P \) (source, makes an original observation | it is true)

Define \( b_i \) as:
- \( P \) (source, makes an original observation | it is false)

What are the source reliability parameters that maximize the probability of received observations?

\[
P(SC|\theta) = \sum_z P(SC, z|\theta)
\]
Humans as Sensors

True Assertion
False Assertion

Reliability of Participant $i$

Participant Reliability

$t_i = P(C'_j | S_i C_j)$

$S_i C_j$: participant $i$ claims assertion $j$

Speak Rate of Participant $i$

Participant $i$ speak with rate $s_i$

$s_i = P(S_i C_j)$

Expectation Maximization

True Assertion
False Assertion

$a_i = P(S_i C_j | C'_j)$

Using Bayesian Theorem:

$a_i = \frac{t_i \times s_i}{d}$

where $d$ is the overall prior that a randomly chosen assertion is true

$b_i = P(S_i C_j | C'_j)$

Using Bayesian Theorem:

$b_i = \frac{(1-t_i) \times s_i}{1-d}$

where $d$ is the overall prior that a randomly chosen assertion is true
Expectation Maximization

**Likelihood function of EM**

$$L(\theta; X, Z) = p(X, Z|\theta)$$

$$= - \sum_{i=1}^{N} \left\{ \prod_{j=1}^{M} \left\{ \frac{\alpha_i^{Z_{ij}}(1 - \alpha_i)}{\beta_i^{Z_{ij}}} \right. \right.$$  

$$\times \frac{1}{1 - \alpha_i} \times (1 - \beta_i)^{(1 - Z_{ij})} \times \left. \frac{1}{1 - \beta_i} \times (1 - \alpha_i) + \log(1 - \beta_i) \right\}$$

**Expectation Step (E-Step)**

$$Q(\theta|\theta^{(t)}) = E_{Z|X,\theta^{(t)}} \log L(\theta; X, Z)$$

$$= \sum_{i=1}^{N} \left( \prod_{j=1}^{M} \left[ \frac{\alpha_i^{Z_{ij}}}{\beta_i^{Z_{ij}}} \right] \sum_{j=1}^{M} \left[ S_{ij} \log(1 - \alpha_i) + (1 - S_{ij}) \log(1 - \beta_i) \right] \right)$$

**Maximization Step (M-Step)**

$$\theta^{(t+1)} = \arg\max \theta Q(\theta|\theta^{(t)})$$

Iterate
Simulation

Parameters:
Number of Participants: 20–110, Number of True Assertions: 1000,
Number of False Assertions: 1000, Average Number of Claims per
Participant: 100

EM outperforms state-of-art heuristics
Simulated Geotagging

False Negatives:
Missed Litter Locations/Total Litter

False Positives:
Incorrectly labeled Locations/Total Locations

$P_c$: probability to continue

Reported Litter
Litter
Trail

Litter Geotagging Accuracy versus Number of People

(a) False Negatives (missed/total litter)
(b) False Positives (false/total locations)
Twitter-based Evaluation (Hurricane Irene)

<table>
<thead>
<tr>
<th>Step</th>
<th>Claim</th>
<th>Source</th>
<th>EM Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A quick move for hurricane in the area</td>
<td>Twitter</td>
<td>Media Report</td>
</tr>
<tr>
<td>2</td>
<td>Hurricane Sandy begins moving fast in NC</td>
<td>Twitter</td>
<td>Media Report</td>
</tr>
<tr>
<td>3</td>
<td>Hurricane Irene changes path up the U.S. East Coast on Saturday toward New York, dumping down the city and millions of Americans were left from the huge storm</td>
<td>Twitter</td>
<td>Media Report</td>
</tr>
<tr>
<td>4</td>
<td>Social Media: Hurricane Irene: Flooded NYC Dominates Twitter</td>
<td>Twitter</td>
<td>Media Report</td>
</tr>
<tr>
<td>5</td>
<td>Boston Bombing: J suoi has created a way for New Yorkers to interact with location-based social media apps</td>
<td>Twitter</td>
<td>Media Report</td>
</tr>
</tbody>
</table>

A Maximum Likelihood Estimation Problem

- Joint estimation of:
  - Source reliability
  - True/false value of each observation

- Given:
  - Who said what
Source Dependencies

- Joint estimation of
  - Source reliability
  - True/false value of each observation
- Given
  - Who said what, and
  - Correlations between sources

Reconstructing Event Timelines

A Twitter Example
Expectation Maximization

Likelihood Function Incorporating Source Dependency

\[ P(S_C, z | S_D, \theta) = \prod_{j=1}^{N} P(z_j) \times \left\{ \prod_{g \in M_i} P(S_g | C_j \theta, z_j) \prod_{i \in C_g} P(S_i | C_j) \right\} \]

\[
P(S_C | C_j) = \begin{cases} 
\rho_{i-g} & S_g C_i = 1, S_Ci = 1 \\
\rho_{i-g} & S_g C_i = 1, S_Ci = 0 
\end{cases}
\]

Claim

Dependent Sources

---

Expectation Maximization

**E-Step**

\[
Q(\theta | \theta^{(n)}) = -\sum_{j=1}^{N} \left\{ \log P(S_C | \theta, z_j) \times \left[ \sum_{g \in M_j} \left( \log P(S_g | C_j \theta, z_j) \right) \right] + \log \bar{a} \right\} \\
+ (1 - Z(n,j)) \times \left[ \sum_{g \in M_j} \left( \log P(S_g | C_j \theta, z_j) \right) \right] + \log(1 - \bar{a}) \right\}
\]

**M-Step**

\[
a_{i-g}^{(n+1)} = \frac{\sum_{j \in \mathbb{S}_g} Z(n,j)}{\sum_{j=1}^{N} Z(n,j)} \\
b_{i-g}^{(n+1)} = \frac{\sum_{j \in \mathbb{S}_g \setminus N_{i-g}} Z(n,j)}{\sum_{j=1}^{N} Z(n,j)} \\
\bar{a}^{(n+1)} = \frac{\sum_{j=1}^{N} Z(n,j)}{N} \\
\bar{a}^{(n+1)} - \bar{a} = \frac{\sum_{j=1}^{N} (1 - Z(n,j))}{N} \\
\bar{a}^{(n+1)} - \bar{a}^{(n)}
\]

for \( i \in \mathbb{S}_g \)
Collected Data Traces

<table>
<thead>
<tr>
<th>Trace</th>
<th>Hurricane Sandy</th>
<th>Hurricane Irene</th>
<th>Egypt Unrest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locations</td>
<td>16 cities in East Coasts</td>
<td>New York</td>
<td>Cairo, Egypt</td>
</tr>
<tr>
<td># of users tweeted</td>
<td>7,583</td>
<td>207,562</td>
<td>13,836</td>
</tr>
<tr>
<td># of tweets</td>
<td>12,931</td>
<td>387,827</td>
<td>93,208</td>
</tr>
<tr>
<td># of users crawled in social network</td>
<td>704,941</td>
<td>2,510,316</td>
<td>5,285,160</td>
</tr>
<tr>
<td># of follower-followee links</td>
<td>37,597</td>
<td>3,902,713</td>
<td>10,490,098</td>
</tr>
</tbody>
</table>

The Experiments

- Run the maximum likelihood estimator on Twitter data to determine the probability of correctness of different tweets
- Sort tweets by probability of correctness.
- Give the top N tweets to a human for “grading”
- Human must investigate each tweet to determine if it is true.
- Any tweet that cannot be shown to be true is considered “unconfirmed”
- Compare the percentages of unconfirmed tweets across different credibility estimation algorithms
The Experiments

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Note: To remove bias, the grader was not told which algorithm "believed" which tweet.

Evaluation: Sandy Trace
A Comparison of Confirmed True Tweets
Evaluation: Irene Trace
A Comparison of Confirmed True Tweets

Evaluation: Egypt Trace
A Comparison of Confirmed True Tweets
Example

<table>
<thead>
<tr>
<th>Media</th>
<th>Tweet found by Apollo-social</th>
<th>Tweet found by Regular IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rockland County Executive G. Scott Vanderhoef is announcing an Local Emergency Order restricting the amount of fuel that an individual can purchase at a gas station.</td>
<td>Rockland County Orders Restrictions on Gas Sales Nyack, Frambourg, NY [Tweet: <a href="https://twitter.com/VanD/Sngm7">https://twitter.com/VanD/Sngm7</a>]</td>
</tr>
<tr>
<td>2</td>
<td>New York City Mayor Michael Bloomberg has announced that the city will impose an indefinite program of gas rationing after fuel shortages led to long lines and frustration at the pump in the wake of superstorm Sandy.</td>
<td>gas rationing plan set for New York City. The move follows a similar announcement last week in New Jersey to ease... [Tweet: <a href="https://twitter.com/mork7USI">https://twitter.com/mork7USI</a>]</td>
</tr>
<tr>
<td>3</td>
<td>New Jersey authorities filed civil suits Friday accusing seven gas stations and one hotel of price gouging in the wake of Hurricane Sandy.</td>
<td>RT [RT] @Marketline: NJ plans price gouging suits against 8 businesses. They include gas stations and a lodging provider. A madrid City Room Gas Rationing in New Jersey to End Tuesday at news... [Tweet: <a href="https://twitter.com/Y1o5umPo">https://twitter.com/Y1o5umPo</a>]</td>
</tr>
<tr>
<td>4</td>
<td>The rationing systems are designed to evenly distribute fuel, with even-numbered license plates on even days, and odd-numbered or odd days will be discontinued at 5 a.m. Tuesday. Gov. Chris Christie announced on Monday.</td>
<td>Mayor Bloomberg: Gas rationing in NYC will continue for at least 3 more days. [Tweet: <a href="https://twitter.com/SandyA3C3">https://twitter.com/SandyA3C3</a>] Bloomberg: Gas Rationing To Stay In Place At Least Through The Weekend [Tweet: <a href="https://twitter.com/Natio7YR">https://twitter.com/Natio7YR</a>]</td>
</tr>
<tr>
<td>5</td>
<td>New Yorkers can expect gas rationing for at least five more days. Bloomberg.</td>
<td></td>
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</tbody>
</table>
Another Example

The Washington Post

Shark in the street!

FAKE!