Context Aware Weather Warning Systems

Brenda J. Philips
CASA Co-Director
Univ. of Massachusetts, Amherst

VLAB Forum
May 30, 2018
Collaborators & Funding Sources

ACADEMIC
- V. Chandrasekar, CSU, Radar Engineering
- J. Trainor, UDEL, Sociology
- Q. Yu, UMass, Geosciences
- D. Westbrook, UMass, CS
- A. Bajaj, UMass, ECE
- C. League, W & S Consulting, sociology, geography
- E. Lyons, UMass, Systems Engineering
- M. Zink, UMass, Computer Networking

PRACTITIONERS
- Molly Thoerner (North Central Texas Council of Governments)
- Amanda Everly (City of Fort Worth Emergency Management)
- Joe Frizzell (Mayor Pro Tem, City of Midlothian)
- Ranjan Mutttiah, Ft. Worth Storm Water
- National Weather Service Weather Forecast Office (KFWD)
  - T. Bradshaw
  - T. Ryan
  - M. Fox

FUNDING
- NSF: “Hazards SEES Type 2: Next Generation, Resilient Warning Systems for Tornados and Flash Floods” NSF-AGS
- North Central Texas Council of Governments
- National Weather Service
Severe Weather Warning Systems Are Complex

Technology Trends & Severe Weather Warning

- Mobile phone penetration & usage
- Attitudes towards privacy & sharing
- Social media
- Internet of Things (IoT)/Cloud Computing
- Mobility-optimized Information & Communications Technology (ICT)
What are the opportunities for Severe Weather Warning Systems?

- How should we integrate the current broadcast paradigm and the potential for dynamic, personalized warnings?
- Can IoT help us better understand the linkages among warning system components?
  - Human interpretation, perception and response
  - New types of weather information: high resolution radar data, ensemble forecasts, etc.
  - New warning policies
- What are innovative ways to research these types of questions given the complexity of warning systems?
Today’s Talk

1. Background: CASA and the CASA DFW Living Lab
2. Context-aware warning systems
3. Current Research Projects (Three of many!)
   - Publics’ perception of rain intensity & radar data
   - Mobility patterns & warning
   - Flash flood case study
4. Broader implications and next steps
Background
My Background

- Co-director, CASA: severe weather warning system innovations
- Sociotechnical systems research: integrating natural/technical/behavioral parts of warning systems
- Research in real-world contexts: living labs, test beds
- Multidisciplinary research, "spanner"
CASA DFW Living Lab: Technology, People, Real-world, Real-time Contexts & Urban Scales (since 2011)

- Sensors & Software
- WX Info
- CASA Alerts App
- Stakeholders
- Publics

- Sensors-to-People Severe Weather Warning System centered around X-band CASA radars & other sensors
- Demonstrates benefits of high resolution, lower atmosphere sensing: Urban, gaps, users
- Multidisciplinary research in live environment (physical, technical, social sciences)
- Flexible infrastructure for technology development & R2O
- Co-Creation with users through a public private partnership
CASA DFW Living Lab: Concept of Operations

- 7 node network, doppler, dual polarization radar + other sensors
- Operates year round when there is precipitation
- Real-time single & merged radar data, + derived products (QPE, hail, winds, nowcasts, forecasts)
- CASA radar data available on AWIPS2 to NWS-FWD, SRH
- CASA products available on CASA WX website for real-time operational use with low latency
- 1500+ users: ~750 local public safety users from 50 NTX cities and counties, ~600 App holders

CASA network covers approximately 32,000 sq. km. Radar range is 40 – 60km. Overlapping coverage helps to address X-band attenuation
North Central Texas community contributes resources for installation and operation of radar network

- North Central Texas Council of Governments coordinates local efforts through 5-year agreement with CASA. In second renewal period.
- Local Exec Committee of EMs, media, NWS sets local policy
- A membership fee to local towns and cities supports radar operations. ~$1 million in fees to date.
KFWD issues tornado warning based on CASA data on 01/15/17

165
WFUSS4 KFWD 160204
TORFWD
TXC251-160230-
/O.NEW.KFWD.TO.W.0007.170116T0204Z-170116T0230Z/

BULLETIN - EAS ACTIVATION REQUESTED
Tornado Warning
National Weather Service Fort Worth TX
804 PM CST SUN JAN 15 2017

The National Weather Service in Fort Worth has issued a

* Tornado Warning for...
Northeastern Johnson County in north central Texas...

* Until 830 PM CST

* At 802 PM CST, a severe thunderstorm capable of producing a tornado was located just north of highway 67 between Avarado and Venus. CASA radar indicates that this circulation will approach Pleasant Point and Lillian over the next few minutes.

HAZARD...Tornado.

SOURCE...Radar indicated rotation.

EF0 tornado near Mansfield, TX captured by CASA radar
Media Pilot: NBCDFW Using CASA Radar Data 5/3/18
Context Aware Warning Systems
CASA Alerts App Enables Research on User Perception & Response to Weather Information

- 600+ app users
- Random sample
- Convenience sample
- Location tracking

- Pre-experiment surveys
- Event-based mobile phone surveys
- Link location, surveys responses, weather, environment via archive data base
Context-Aware Warning System: Links Hazards Infrastructure, Policy, People Contexts Dynamically in Time & Space

Environmental Risk
- Rainfall rate

Infrastructure Risk
- Thresholds for flood risk

Mobile App
- Alerts (Automated, Manual)
- Surveys

Management Policy
- Alert when 15 min. Rain Accumulation exceeds .5” within 5 miles radius

People
- Preferences, Surveys, Location, Demographics

Data Archive
- Spatio-Temporal Data Survey Results
Research Projects
Linking the publics’ perception of rain intensity & radar data pilot study

- Pilot study
- Survey automatically sent to all app users when more than 8 people are in heavy rain (.75” rain in 15 mins)
- Convenience sample
- 437 responses
Human Mobility Research: Individual Foot Prints

- Individual mobility patterns are largely predictable in time and in space
- 240 app holders’ location sampled every 5 mins for 6 months
- Convenience Sample
- Kernal Density Function used to determine time-weighted location density & activity weighted locations
- “Hot Spots” represent home, work, places of daily activity
Individual Footprint: Time-Weighted Density

Footprint at all times

Footprint During Commute Time

Value
high density

Low density
People spent 80% of their time in 23% of their footprint

<table>
<thead>
<tr>
<th>% Density</th>
<th>Median % of Area</th>
<th>Median # of Nodes</th>
<th>Median Sq. Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>100</td>
<td>3</td>
<td>221</td>
</tr>
<tr>
<td>90</td>
<td>36</td>
<td>3</td>
<td>71</td>
</tr>
<tr>
<td><strong>80</strong></td>
<td><strong>23</strong></td>
<td><strong>2</strong></td>
<td><strong>45</strong></td>
</tr>
<tr>
<td>70</td>
<td>16</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>60</td>
<td>11</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>50</td>
<td>8</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
Why are individual footprints important?

- Personalization is crucial in the warning perception and response process
- Footprints contain the important locations that help with personalization: home, work, school, commuting
- Footprints are spatio-temporal artifacts that can represent people in warning system technology.

Personalization: “People’s expectations of the personal impacts from an extreme environmental event” including “death, injury, property damage, and disruption to daily activities such as work.” (Lindell and Perry 2012)
7/9/17 Flash Flood Case Study

Environment and Infrastructure Risk

Policy and Rules: NWS Flash Flood Advisory & CASA Targeted Alerts
Individual footprints can represent people’s spatial, temporal and perceptual contexts.

Person #1: Potential Risk dependent on time of day
Person #2: High potential risk of floods
Person #3: Low potential risk of floods
Broader Implications and Next Steps
Footprints Can Be a Spatial/Temporal Representation of People in Time and in Space in Operational Warning Systems

Environmental Risk

Infrastructure Risk

Warnings Policy

People

Alerts (Automated, Manual)

Surveys

Data Archive

Spatio-Temporal Data Survey Results

Mobile App

Context-Aware Systems can incorporate and operationalize individual perception and preferences
Next Steps

- If we can link user perception (about rain) and radar data, can we create better warning communications?
- Do footprints make a difference? Communicate hazards and warnings to people based on their footprints, anticipated locations, preferences
- Use data analytics (survey responses, app preferences, location data) to refine personalized alerting approaches
- Evaluate how current warning policy and individualized warnings can complement one another
- Address issues of convenience sampling, generalizeability, confounding variables in field experimentation
Thank you

Questions and comments:

Brenda Philips: bphilips@ecs.umass.edu

Look for upcoming papers on this topic