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Computing for Disasters*

*or everything I wished someone had told me 20 years ago

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About Me

- since 1995, field 1999
- 27 disasters
- Technical search specialist 200-2008
- 35+ exercises
- Yearly "all stakeholders" exercises called Summer Institutes
- Texas A&M is largest trainer of emergency responders in world and most comprehensive facilities



DISASTER ROBOTICS





Hurricane Harvey

сып 35

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60

The average number of major federal disasters each year

Annual direct costs just from FEMA Disaster Relief Fund (before Harvey)





Main Points

- Types and phases of a disaster
- Emergency management is like academia
- Informatics
- Networks
- Social media
- Data and Visualization
- Research needs



For Fort Bend County... -Record 111 UAV flights -Started 2 days before hit Houston -Fulfilled every legitimate request



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For Fort Bend County... -Record 111 UAV flights -Started 2 days before hit Houston -Fulfilled every legitimate request

HOW MANY PEOPLE ON ROOFS DID THE UAVS RESCUE?

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NONE!

- Route finding
- Flood inundation tracking
- Damage assessment
- Rumor control
- Bridge and levee inspection

No Two Disasters Are Alike

Harvey (111 flights)

- Missions: Damage assessment, Flood inundation, Route, Public information- rumor control, Mapping levees, Bridge inspection
- Data products: Video as the primary data product in initial 5 days, then mapping as focus on monitoring river levee

Irma (247 flights)

 Missions: FEMA Property Damage Assessment, USAR overwatch

 Data products: "5 picture" stills (elevation views of all sides plus nadir) and overview video as primary data product, some mapping for larger targets to produce orthomosiac



TYPES OF DISASTERS AND RESPONSES

Disasters versus Incidents



"Routine" emergencies in law enforcement, fire rescue, emergency medicine Multiple agencies, exceeds local resources



All Hazards: Functional Decomposition

Urban	Wide Area	Medical
Localized to a small area, buildings, or built structures	Diverse and distributed geographically	Infectious diseases versus casualties

deal with point of injury casualties

By "look and feel"



Example Medical isn't Just Medical: Ebola Outbreak in Dallas

• Allowed to enter USA

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- Misdiagnosed on the first visit
- Hospital personnel overreacted
- Fire Department Hazmat Team took over for everything outside hospital
 - 2 ambulances contaminated









PHASES OF DISASTERS AND ACTIVITIES

Phases of a Disaster





Humanitarian Relief is Different



greater good versus reducing individual suffering



Phases Post-Disaster

INITIAL RESPONSE

- Life saving activities
- Incident command has authority, right of entry (but public accountability)
- >52 hours low probability of long term survivors
- FEMA: 10 day deployments

"Response" = Initial + Restoration



- Mitigation and restoration of basic services needed for Citizen re-entry
- Reverts to local agencies

time

No Emergency Powers or Funds



- Sustainable mitigation and restoration of basic services needed for Citizen re-entry
- Shift from Engineering and Infrastructure to Health and Human services

24

time



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Affordances for End of Phase



STAKEHOLDERS



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Stakeholders for Initial Response and Restoration

- Formal
 - in NRF with a specific role, authority or accountability
- Informal
 - non-disaster related businesses
 - Citizens
 - NGOs (not Red Cross)



National Response Framework

Second Editor May 2011



fema.gov



15 Federal Emergency Support Functions (ESF)



- L. Transportation Department of Transportation
- 2. Communications National Communications System



4. Firefighting Department of Agriculture/Forest Service



5. Emergency Management Federal Emergency Management Agency



- 6. Mass Care, Housing, Human Services Department of Homeland Security American Red Cross
- 7. Resource Support General Services Administration





9. Urban Search and Rescue Federal Emergency Management Agency



- 10. Oil and Hazardous Materials Response Environmental Protection Agency
- 11. Agriculture and Natural Resource US Department of Agriculture/Department of the Interior
- 12. Energy Department of Energy
- 13. Public Safety and Security Department of Homeland Security/Justice



- 14. Community Recovery, Mitigation, and Economic Stabilization U.S. Small Business Administration
- **15. External Communications** Federal Emergency Management Agency





But UIC is only part of it, Formal Stakeholders May Not Be Educated

- Andrew: Governor's office forgot to officially request National Guard
- Katrina: Governor's office forgot to officially request FEMA
- Local authority: Texas- county judges declare the emergency and evacuation, Florida- sheriffs
- Oso: County overrode Incident Command



Stakeholders, Types of Decisions





Think of Emergency Management as Academia

- There's not an enforceable top-down hierarchy
- There are lots of ESF (departments) with different needs so "one size fits all" doesn't work
- The culture and organization varies from state to state (university)
- Outsiders think they can come in and run it like a business
- Outsiders think that local community college instructor is as knowledgeable as Turing Award winner

INFORMATICS

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Focus on Most Critical SubPhases







15 Federal Emergency Support Functions (ESF)



A M





Mismatch of Impact of Information Versus Information Availability





Informatics => Networks

- Who would they talk to?
- What Information do they need?



Spatial Distribution





Where Is Everyone?



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Warm Zone

Cold Zone
State of the Disaster Response Practice in 2015

~25 agencies/organizations involved in every disaster; often multiple, independent incident commands

Responders in Hot Zone routinely use mobile devices and small

Responders in Cold Zone routinely monitor newsfeeds and social media, have laptops, full network connections and access

What the Strategic Planners Want



copyright Older Zone

Warm Zone

Essential Elements of Information ROBOTICISTS WITHOUT **On A Map BORDERS**

Disaster Area

Boundaries of the Disaster Area

Access Points to the Disaster Area

Jurisdictional Boundaries

Social, Economic and Political Impacts

Hazard-Specific Information

Seismic and/or Other Geophysical Information

Weather Conditions/Forecasts

Historical and Demographic Information

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Assessment Predictive Modeling Impact Projections Initial Needs and Damage Assessments Status of Communications Systems Status of Transportation Systems and Critical **Transportation Facilities** Status of Operating Facilities Status of Critical Facilities and Distribution Systems Status of Energy Systems

Status of Critical Resources and Resource Shortfalls

Response & Recovery EEI

ESF Activations Major Issues/Activities of ESFs and Other **Functional Areas** Key Federal and State Personnel and Organizations **Remote Sensing Activities**

FCO/SCO Priorities

http://www.disasters.org/emgold/ES





What Everyone Else Wants...



Video, Images, Photogrammetrics





ESF 3 wanted reconstructions in less than 2 days

ESF 9 wanted real-time situation awareness

Oso Mudslides

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UAV: ~40 Acres, 4cm resolution in 3 Hours but 0.5-1 GB files, no comms



UAV fun facts...

- Carry 4K cameras, can't real-time stream under normal conditions
- a single 20-minute UAV flight produces roughly over 800 images totaling 1.7GB

SO WHERE'S THE NETWORK?





Actually, There is Usually One Within 6 Hours

- COWS
- Repeaters on Civil Air Patrol
- But even in Hot Zones, BANDWIDTH EXCEEDS capacity



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People Have to Solve Bandwidth, Distribution Issues



How Did He Know It Would Get There? How Did They Know It Was Real?

- Ability to handle the demand cycle
- Visibility of what is the state of the network
- Autonomous selection of alternatives
- Context-sensitive **prioritization** and routing
- **Cybersecurity** that allows rapid addition of new individuals within known organizations AND previously unknown organizations
- Provenance of data





Visualization of what was collected where when

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Photo courtesy of Rick Smith

Need HPC in a TravelPro

Processing the data (Edge Exa Computing) Pho



Example: Photogrammetrics

- ~800 images
- One ortho is ~150MB
- 8-24 hours of upload, cloud processing, download

SOCIAL MEDIA: BUT MAYBE WE DON'T WANT THE INTERNET



Fort Bend: Chasing Rumors

- County Judge and OEM had to monitor social media to see about rumors, concerns
- Tasked UAV to get photographic evidence to confirm or deny
- Had seen a similar problem in 2015
 - But couldn't get access to the group to take it down



Spatial Scanning of Social Media



NewsStand and TwitterStand

 find emerging concepts before there is even a #hashtag



Credentialing

- Are they who/what they say they are?
- Whose up to date on certifications?
- How can I add them to the database to give them permissions without taking a person all day?

Volunteerism/Disaster Tourism

- Harvey saw untrained out of state teams called in (but not under a MOA or contract) by the American Red Cross and local and out of state self-deployed teams seeking missions (and funding) from agencies
 - New apps and a business spontaneously created to encourage self-deployment
 - Courses being offered on flying for disasters- may lead to situations such as untrained canine search teams
- Flights for ARC were in violation of Texas Privacy Statute 436
- Self-deployed teams
 - often relied on "friend of a friend" relationship (e.g., a sheriff, county assessor) to get a mission or a E-COA, which violated county or state processes for assets and Air Operations
 - posted data to social media, violating Texas Privacy Act
 - duplicated effort for existing damage inspection and debris removal contracts
 - appeared to be unprepared for austere conditions, being self-sufficient, and unaware of challenges of flying in disasters

Can't Crowd Source if There's No Crowd

 2015 Houston floods, ambulances couldn't find routes to hospitals

 They depended on Waze but no one was out driving around...





LET'S TALK DATA



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Example : Need to Find Human-Sized Debris

 High likelihood that 21 missing persons were wrapped in debris, washed over a 5 mile area in hard to reach areas on private land







Volunteer NGOs for canines:

- Uncertified dogs gave false positives
- (credentialing)





"Bring your own device" 4 counties, 6 jurisdictions

- untagged imagery
- no centralized data repository
- posted imagery to public sites
- no consistent image collection and analysis method
- Even if given flight path, don't have coverage







- There were over a dozen platforms flying daily for two weeks as well as Civil Air Patrol and satellite imagery
- 8,000 images at 1 image/10 sec = 22 hours
 probably 3 or more independent coders

-But some groups posted to the web, crowd sourcing



Anomaly Detection (Julia Proft)



AAAS 2016 Topical Lecture



Urban Debris (Matt Hegarty)



AAAS 2016 Topical Lecture



Computer Vision

22 hours manually or...

In ~90 minutes on a laptop, classifies 83%-92% of the images and highlights where to look



Need to Learn Responder-Defined Visual Concepts...



Texas Floods

Web search



But can't rely on web for useful source of examples "overhead imagery floods debris"



Visual common ground for coordination, trust

Ideal: spatial data symbolization, spatial/temporal queries to opportunistically determine available data resources

Existing systems:



Hard problems:

- Ontology for accessing and manipulating data and represented by the "pins"
- What is the requisite meta-data and how to reason over it?
- Cartographic symbology for representing temporal (and other) relationships between "layers" of data
- How to manage the volume and heterogeneity of the data sources





Reasoning and Tools



UNIVERSITY

WHAT IT MEANS TO ACM COMMUNITY



Disasters Pose Computing Challenges

- Computer systems organization
- Networks
- Information systems
- Security and privacy
- Human-centered computing (HCI, Social media)
- Computing methodologies (AI and machine learning)

Specific Fundamental Research



- Correlating asynchronous linguistic, imagery, and geospatial data
- Handling uncertainty such as new concepts, image properties, linguistic ambiguity, geospatial resolution
- Spatial and temporal visualization of heterogeneous data at multiple scales and how to manipulate it
- Trust in data, provenance, staleness
- Working individually on underspecified tasks or with others with loosely shared goals



But Disasters Are Hard



"CRICIS requires fundamental new research in socio-technical systems that enable decision-making for extreme scales under extreme conditions. This research cuts across physical and engineered artifacts, information technology, and

human-computer collaboration."

2012 NSF/CCC National Workshop
Each year: 1 Million people killed 2.5 Million displaced or disabled \$Billions in economic loss

2010 World Disaster Report



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