The Role of Mobile and Ubiquitous Computing in Emergency Response

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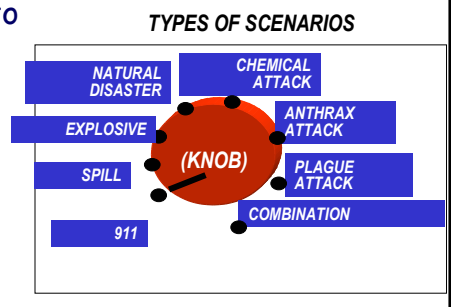
Mobiquitous 2005

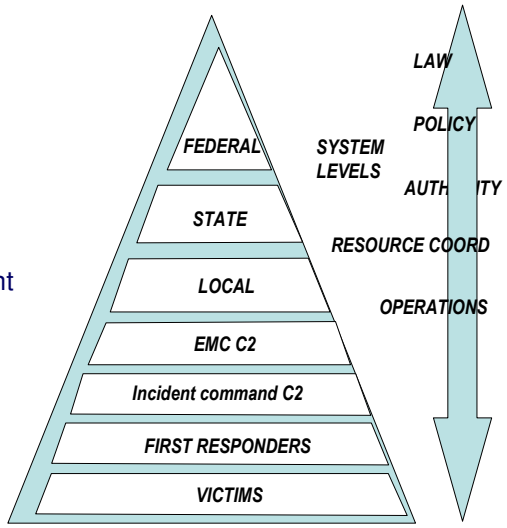
Crisis Landscape

- Man made (usually localized to a single region)
  - Terrorism
  - Accidents
- Natural causes (region wide disasters)
  - Earthquake, hurricanes, floods
- Unexpected
  - The first is the unknown itself
  - The second is the fear of the unknown

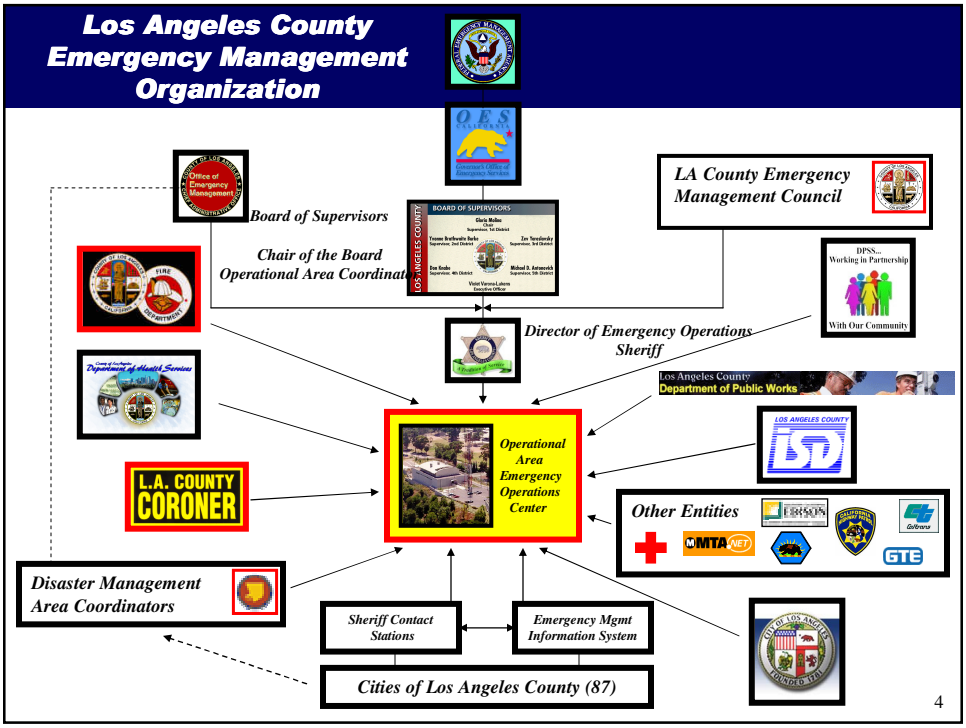


Emergency Management

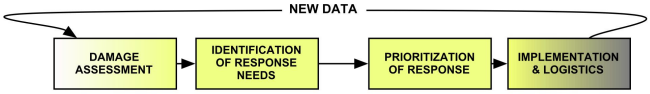
- Preparedness
  - Early detection, prevention
  - Predict terrorist attacks, surveillance, epidemic outbreak
- Response
  - save lives & property, limit/contain impact, prevent cascades
- Recovery
  - Bring society & infrastructure back to normalcy



Los Angeles County Emergency Management Organization



Abstraction of an Iterative Crisis Response Process



- Phases of Response
  - Damage Assessment
    - Quantify damage at site/regional scale
    - Identify severely impacted regions, disrupted lifelines, etc.
  - Response Need Identification
    - Who needs what resources.
  - Response Prioritization
    - Hard choices given limited resources
  - Implementation and logistics
    - Plan optimization, plan monitoring,

Operational View of Response

- **Crisis Management**
  - **Field level operation**
  - **Command and control**
  - **Usually local government incharge**
- **Consequence Management**
  - **Analyze consequences with focus on the future**
  - **Develop plan of action**
    - **Life safety**
    - **Property loss**
    - **Environment**
    - **Reconstruction**
  - **Establish who is responsible**

Operations- Consequence Analysis

Potential need for:

- Security for damaged/evacuated structures
- Route management
- Civil disturbance control
- Casualty/Fatality collection points
- Fire fighting/HAZMAT support

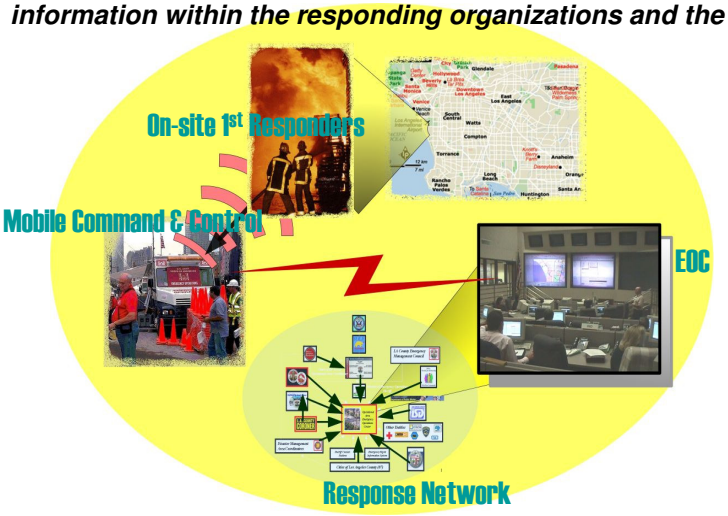
- Shelter requirements
- Impact on poor
- Language, other cultural needs
- Food/water distribution
- Impact on schools
- Impact on non-profit agencies

Operations – Consequence Analysis

- Need for building inspections
- Removal of hazardous materials
- Demolition/debris removal
- Transportation network – impact and restoration
- Water/sewage/flood control system impacts

Goals of the RESCUE Project

Transforming the ability to collect, analyze, share and disseminate information within the responding organizations and the public



The RESCUE Project (http://www.itr-rescue.org)

RESCUE Research Team

BYU Brigham Young University · Colorado University of Colorado at Boulder · Natural Hazards Center · Illinois University of Illinois at Urbana-Champaign · ImageCat, Inc. · University of Maryland · UCSD · UCIrvine University of California, Irvine

NSF funded multidisciplinary research effort on responding to crisis and unexpected events

- *Information Technology*
- *Social and Disaster Science*
- *Engineering*

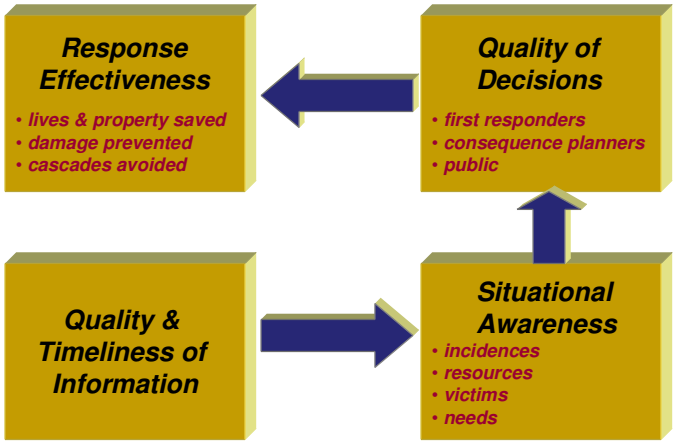
Collaborating With

Emergency Management Organizations In

- California Governer's Office
- County of Los Angeles
- City of Irvine, Los Angeles, & San Diego
- Space and Naval Warfare
- San Diego Police Department
- UC Irvine Environment Health and Safety

Key Observation

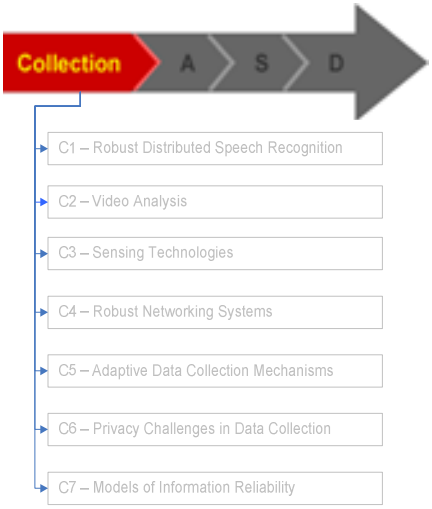
Right Information to the *Right Person* at the *Right Time*
can result in dramatically better response



Information Flow

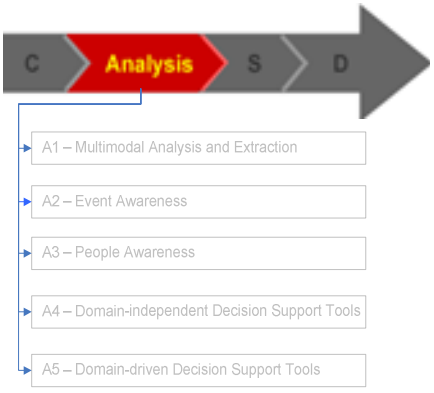
Information Collection

- Objective:
  - Capturing & bringing relevant situational information from information sources to decision makers in a timely and efficient manner
- Challenges:
  - Diversity of data sources
  - Diversity of Data
  - Concerns of privacy
- Focus
  - Robust and adaptive infrastructure to meet surge capacity needs

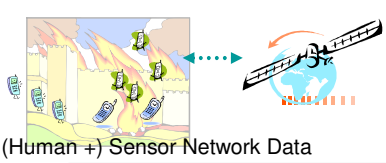


Information Analysis

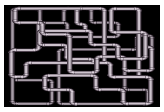
- Objective:
  - Bridging the gap between raw data and semantically richer representations useful to decision-makers in the content of their tasks
- Challenges:
  - Diversity of Data
  - Incompleteness of Data
  - Urgency
- Focus:
  - Human-as-sensor
  - People Awareness



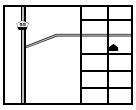
Access to integrated real-time information



(Human +) Sensor Network Data

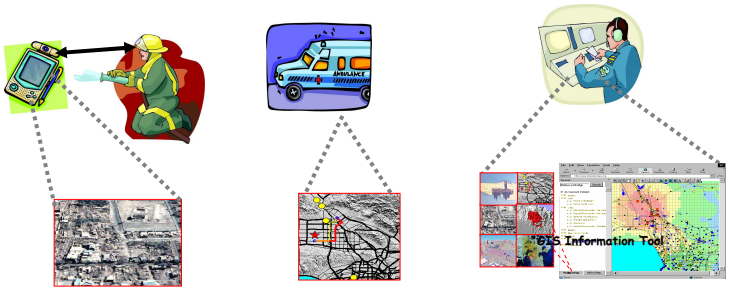


CAD Database



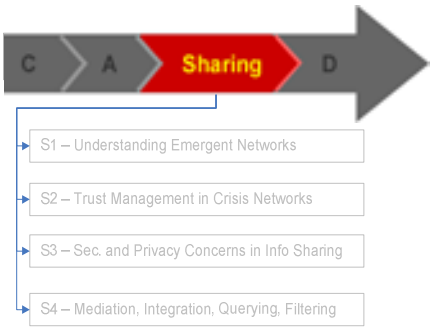
GIS Database

Global Situation Awareness Database



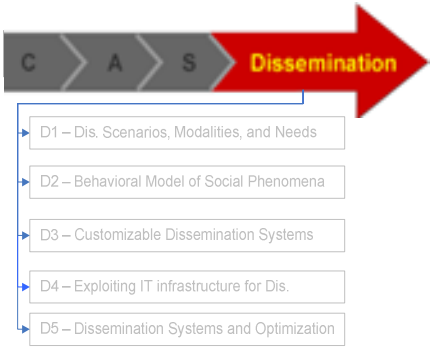
Information Sharing

- Objective:
  - Facilitating seamless information flow across dynamically evolving virtual organizations
- Challenges:
  - Frequent structural and functional changes within organizations
  - Lack of centralized control
  - Element of surprise
  - Lack of trust, fear of misuse
- Focus:
  - Scalable data sharing architecture for *heterogeneous* & *autonomous* environments



Information Dissemination

- Objective:
  - Timely delivery of hazard advisories, instructions, and other information to entities, organizations, and to the general public
- Challenges:
  - Confusion
  - Heterogeneity
  - Urgency
  - Scale
- Focus:
  - Customizable dissemination of crisis information & its impact



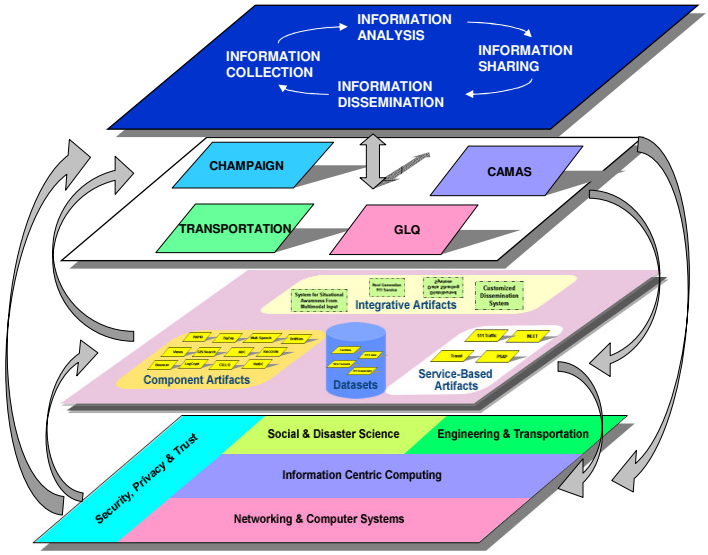
RESCUE Research Components

Societal Impact - Crisis Response

Testbeds
Simulations/Drills that mimic crisis response activities

System Artifacts
IT systems & tools of direct relevance to crisis response

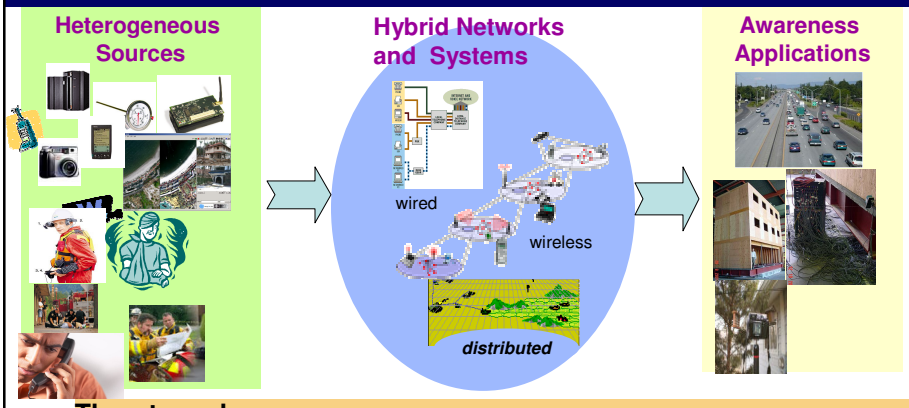
Fundamental Research
Core research driving new technologies



Where does Mobile & Ubiquitous Computing Fit In?

- **Collection**
  - Sensing technologies
  - Information from humans and about humans
- **Analysis**
  - People forecasting
    - Where are people now?
    - Where are people headed? As individuals? As groups?
  - Situational awareness from mobile and dynamic data
    - Damage assessment tools and techniques
- **Sharing**
  - Adaptive Secure Group Communication in Mobile Environments
    - Security with Relaxed Synchrony
  - Secure, trusted data sharing through service providers
    - Preventing theft at service provider's site
    - Preventing service provider from tampering with data
- **Dissemination**
  - Contextualized, personalized rapid dissemination of emergency information

Goal of Information Collection



Thrust emphases

- ***Sensing Technologies*** **for capturing situational information in crises**
- ***Robust, adaptive IT infrastructure for capture and delivery*** **to enable seamless flow of information from sources to collection points**

EVENTUAL GOAL: Robust, adaptive multimodal data collection systems

Information Collection Challenges

- Challenges
  - Diversity
    - Of data sources, data, data transport infrastructures, data needs
  - Dynamically changing conditions
    - Inaccuracies of capture
  - Failure-prone, Insecure Environments
  - Sensing Humans
    - Privacy Concerns
  - Human-as-a-sensor
    - Reliability of human reports
  - To be addressed at several levels
    - Devices/Sensing infrastructures
    - Networking
    - Distributed Systems
    - Data Management
    - Social Science

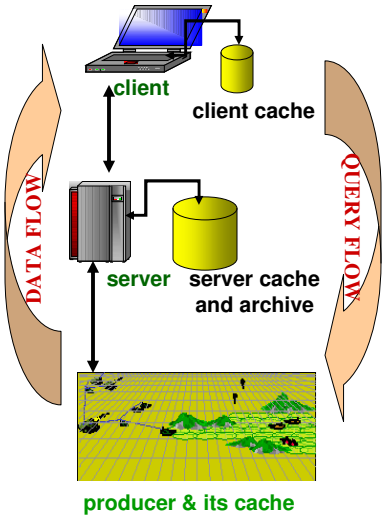
Multimodal Data Collection in Pervasive Spaces

Networking in the Extreme

Sensing for Monitoring and Damage Detection

Principles of Dynamic Data Collection

Principles of Dynamic Data Collection



- Challenges
  - Competing goals of QoS, QoD, cost
  - Composing non-functional concerns of timeliness, security, reliability
- Elements of a Solution
  - Architectures
    - Server, in-network, mobile agents
  - Data
    - Representations, Archival, Storage
    - Quality Aware Query Processing
  - Cross Layer Techniques to support diverse application requirements
- Mobility and sensing
  - Energy-awareness, fault tolerance
  - Mobile Sensors tracking localized phenomena
  - Static sensors tracking moving objects

Mobile Computing and Communications

Current View

- Focuses on person-to-person communication, personalized end-user services.
- Designed and deployed based on expected usage scenarios.
- Unpredictable in extreme situations.

London Explosions Lead To Jammed Mobile Phone Networks

Mike Slocombe

07 July 05

Mobile phone networks in London were overwhelmed for several hours following a series of terrorist blasts across central London.

As news of the attack spread, networks were running at near capacity as concerned Londoners reached for their phones to check up on friends and family.

Broader View

Large pervasive network of devices that forms a sensing and communication infrastructure

Collected Information

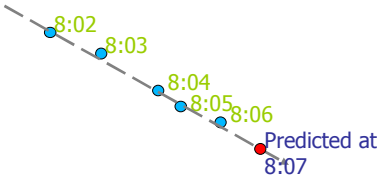
- •User location and device information
- •Radio network state
- •Traffic characteristics, usage patterns

Extended Possibilities

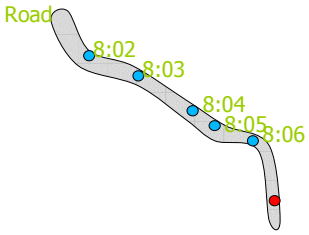
- •Crisis Related Services
  - •Occupancy Modeling for Network Planning
  - •Surge capacity handling
  - •Customized Information Dissemination
  - •Crisis-aware, location-aware navigation support
- •Traditional radio resource mgmt.

Quality Aware Localization

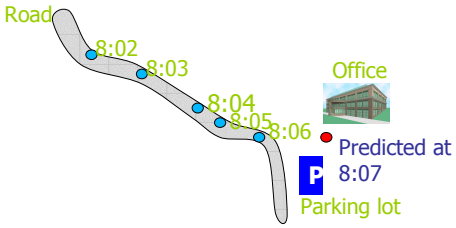
Location information collection involves converting "application quality" into "data collection quality" which is constrained by "localization service quality". Prediction can be exploited to reduce communication cost.



Constant Velocity Model Fit



Incorporating GIS knowledge (e.g., road network constraints)



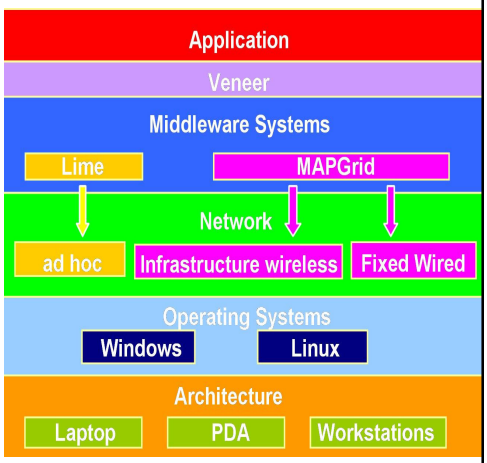
Incorporating profile information to infer motion model transition points

Robust Infrastructure: Networking under Extreme Conditions

- Problem
  - How to establish robust communications at a crisis site?
- Challenges
  - Unavailable or Unreliable on-site infrastructure
  - Partially functioning fragments of pre-deployed systems
  - Lack of interoperability
- Approach
  - Bring in infrastructure and integrate into available services at site
    - Be technology agnostic
      - Mix competing licensed and unlicensed band wireless
      - Exploit wired links as they become available
  - Adapt to demand and supply
    - Converge when possible on IP based transport
    - Allow room for rapid changes and reconfiguration
  - Keep it simple

Multidimensional Interoperability Ad-hoc ⟺ Grid

- Mobile hosts (in ad hoc groups)
  - need computational or data intensive services
- Objective: Seamlessly bridge the connection between mobile hosts and resources so that:
  - high quality data when connected to access point
  - Lower quality information from neighbors o/w
- MAPGrid: Using grid resources for mobile applications
  - Discovering localized grid resources
  - Service and data placement



Bring the power of distributed idle resources to a constrained mobile device

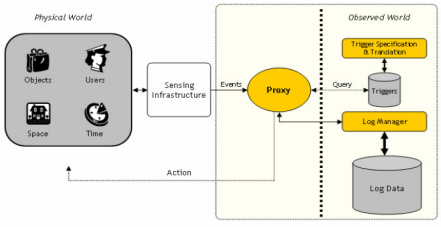
Other Challenges

- Privacy vs. Utility (in pervasive instrumented spaces)
- Reaching People – Customized dissemination
- Information Reliability
  - Human informant reports

The Privacy/Utility Balance in Data Collection

- Challenge: Privacy Preservation and Security
  - Can we design systems that collect 'enough' information to serve their purpose while preserving the privacy of users in these spaces?
  - What is privacy in pervasive spaces?
- Privacy Preserving Surveillance
  - Multisensor fusion
    - Media Processing challenges
  - Trigger based architectures
    - How to map privacy policies to triggers
  - Privacy Implications of triggers
    - Triggers over encrypted data
  - Secure Logging of Pervasive Information
    - Tamper-proof logs

A Trigger Based Infrastructure for Privacy Preservation



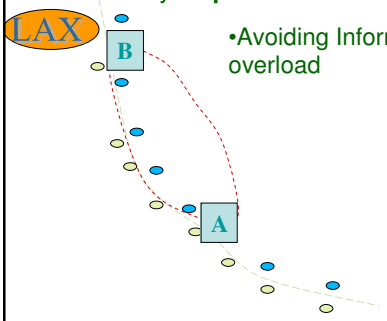
Reaching People: Customized Dissemination

Customized Dissemination

- "Warn all **drivers** heading **North** who are **between exit A and B on 405**"

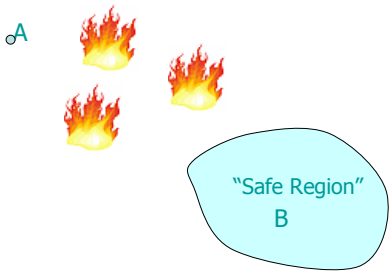
Why customize?

• Limited resources: sending messages indiscriminately wastes bandwidth and costs money => **prioritize**



•Avoiding Information overload

Crisis-Aware Navigation:



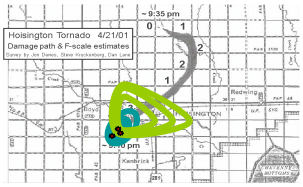
• Often *B* stands for "any place of safety" Road

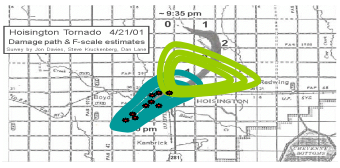
• Network's condition changes rapidly (e.g., tornadoes, falling branches, landslides)

• Safety *not* speed is the primary concern

Information Reliability: Utilizing Informant Reports

- Goal
  - Using Spontaneous Human Reports to gain awareness in evolving crisis
- The Difficulty
  - Inferring properties (e.g. timing) of unknown events from reports of unknown accuracy
- Basic ideas
  - Informants report at a higher rate when they *have* happened than when they *haven't*
    - False positives scatter, true positives cluster
  - Prior knowledge of probable event patterns
  - Prior knowledge of reporting process
    - Can infer unknown parameters via joint probability model
- Solution
  - Stochastic model for event/reporting processes and conduct Bayesian inference





Questions?