First Year RESCUE Progress Report

ITR: Collaborative Research: Responding to the Unexpected

National Science Foundation award numbers:

IIS-0331707, University of California, Irvine

IIS-0331690, University of California, San Diego

June 30, 2004

Table of Contents

1. Participants

1.1 People who have worked on RESCUE project

Below is a listing of all RESCUE project personnel at UCI and UCSD. We have the tables separate primary personnel from senior personnel and others who have worked on the project. In addition to listing affiliations, the role of each investigator or participant is given. All participants have generally worked at least 160 hours on this project.

1.1.A. UCI Primary Personnel

Name	*Role(s) on Project*	*>160 hours*	*Work on project*
Sharad Mehrotra	Principal Investigator	Yes	Data Management
Carter Butts	Co-Principal Investigator	Yes	Social Phenomena
Ronald T. Eguchi	Co-Principal Investigator	Yes	Loss Estimation
Nalini Venkatasubramanian	Co-Principal Investigator	Yes	Middleware
Marianne Winslett	Co-Principal Investigator	Yes	Trust Negotiation

1. 1. B. Other UCI Senior Personnel

Additional people who contributed to project, and received a salary, wage, stipend or other support from this grant.

Brigham Young University

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Tim van der Horst	Graduate Student	Yes	Trust Negotiation
Robert Bradshaw	Undergraduate Student	Yes	Trust Negotiation
Kent Seamons	Senior Personnel	Yes	Trust Negotiation

ImageCat, Inc.

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Beverly Adams	Senior Personnel	Yes	Remote Sensing
Sungbin Cho	Senior Personnel	Yes	Transportation Analysis
Howard Chung	Senior Personnel	Yes	Image Processing
Charles Huyck	Senior Personnel	Yes	GIS Applications
Michael Mio	Senior Personnel	Yes	Software Development

University of Colorado, Boulder

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Kathleen Tierney	Senior Personnel	Yes	Organizational Networks
Jeannette Sutton	Graduate Student	Yes	Organizational Networks

University of Illinois-Urbana-Champaign (UIUC)

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Mike Rosulek	Graduate Student	Yes	Trust Management
Lars Olson	Graduate Student	Yes	Trust Management

University of Maryland, College Park (UMD)

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Peter Chang	Senior Personnel	Yes	Bridge Sensor Development
Ms. Sujata	Graduate Student	Yes	Bridge Sensor Development

University of California, Irvine (UCI)

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Mohanned Alhazzazi	Undergraduate Student	Yes	Video Applications
Kemal Altıntaş	Graduate Student	Yes	Spoken Language Understanding
Swagata Banergee	Graduate Student	Yes	Post-disaster Routing
Ravi Chandra Jammalamadaka	Graduate Student	Yes	Privacy and Data Collection
Stella Zhaoqi Chen	Graduate Student	Yes	Event Extraction
Mahesh Datt	Graduate Student	Yes	Privacy and Data Collection
Mayur Deshpande	Graduate Student	Yes	Peer-to-Peer Dissemination
Maria Feng	Senior Personnel	No	Sensor Development
Qi Han	Graduate Student	Yes	Data Collection
Ramaswamy Hariharan	Graduate Student	Yes	GIS Modeling
Lynn Harris	Administrative Support	Yes	Project Administration
Bijit Hore	Graduate Student	Yes	Privacy and Data Collection
R. Jayakrishnan	Senior Personnel	No	Transportation Modeling
Dmitri Kalashnikov	PostDoc	Yes	Data Cleaning, Event Extraction
Gabriel Lawson	Graduate Student	Yes	Dissemination Modeling
Iosif Lazaridis	Graduate Student	Yes	Quality Aware Querying
Fabio Leite	Graduate Student	Yes	Reliability Modeling
Chen Li	Senior Personnel	Yes	Data Integration
Yiming Ma	Graduate Student	Yes	Data Filtering
Gloria Mark	Senior Personnel	No	Technology Assessment
Amnon Meyers	Programmer/Analyst	Yes	Event Extraction
Sridevi Parise	Graduate Student	Yes	Video Trajectory Modeling
Miruna Petrescu-Prahova	Graduate Student	Yes	Data Analysis
Will Recker	Senior Personnel	Yes	Transportation Analysis
Nitesh Saxena	Graduate Student	Yes	Group Admission Control
Hope Seligson	Graduate Student	Yes	Post-disaster Routing
Masanobu Shinozuka	Senior Personnel	Yes	Post-disaster Routing
Michal Shmueli-Scheuer	Graduate Student	Yes	Data Dissemination Architecture
Padhraic Smyth	Senior Personnel	Yes	Data Mining Techniques
Gene Tsudik	Senior Personnel	Yes	Security
Jehan Wickramasuriya	Graduate Student	Yes	Access Control and Privacy
Xingbo Yu	Graduate Student	Yes	Distributed Data Collection
Qi Zhong	Graduate Student	Yes	Data Sharing Querying

1.1. C. UCSD Primary Personnel

Name	*Role(s) on Project*	*>160 hours*	*Work on Project*
Ramesh Rao	Principal Investigator	Yes	Wireless Applications
Bhaskar Rao	Co-Principal Investigator	Yes	Voice Recognition
Mohan Trivedi	Co-Principal Investigator	Yes	Image Processing

1. 1. D. Other UCSD Senior Personnel

Additional people who contributed to project, and received a salary, wage, stipend or other support from this grant.

University of California San Diego (UCSD)

Name	***Role(s) on Project***	***>160 hours***	***Work on Project***
John Miller	Post doc	Yes	GIS Applications
Ganapathy Chockalingam	Principal Development Engineer	Yes	GIS Applications, Software Development
Babak Jafarian	Senior Development Engineer	Yes	Wireless Applications
Helena Bristow	Project Support	Yes	Administrative Support
Jean-Baptiste Haue	Post doc	Yes	Organizational Behavior
Nicole Peterson	Graduate student	Yes	Organizational Behavior
Wenyi Zhang	Graduate student	Yes	Voice Recognition
Diep Ngoc Nguyen	Undergraduate Student	No	Software Development

San Diego State University (SDSU)

Name	***Role(s) on Project***	***>160 hours***	***Work on Project***
Robert Welty	Consultant	Yes	Community Outreach

1.2 Organizations that have been involved as partners

Jim Watkins, California Governor's Office of Emergency Services (OES)

Member, RESCUE Community Advisory Board. OES is partnering with RESCUE to beta test and review the products of RESCUE research. These products include the integration of GIS and other spatial data in an online environment for emergency response. OES is especially interested in processed data and its integration into maps in real-time during disasters, and getting it to incident commanders and decision makers.

Dawna Finley, Tom Hume, Eileen Salmon; City of Irvine, Emergency Management

Members, RESCUE Community Advisory Board. Local city agency providing access to local information and facilities.

Bob Garrott, Los Angeles County

Member, RESCUE Community Advisory Board. Provides access to Los Angeles County facilities, data, and emergency operations management strategies.

Karen Butler, Communications Division, San Diego Police Department

Member, RESCUE Community Advisory Board. Participant in GLQ testbed.

William (Bill) Maheu, Asst. Chief of Police, City of San Diego

Member, RESCUE Community Advisory Board. Participant in GLQ testbed.

Paulette Murphy, Space and Naval Warfare Systems Command

Member, RESCUE Community Advisory Board. Provide additional testbeds for examining 'human as sensor' as a information technology solution.

Ellis Stanley, City of Los Angeles, General Manager Emergency Preparedness Department.

Ellis Stanley serves as Chair of the RESCUE Community Advisory Board (CAB) whose primary goal is to advise and help guide RESCUE researchers with specific applications of information technology within the first responder and emergency management community. Mr. Stanley acts as liaison between RESCUE, CAB members, and the first responder community bringing issues of importance to the emergency management community and the IT community. Mr. Stanley will be hosting two RESCUE interns during summer, 2004, to work on IT solutions for emergency management.

Dr. Gokhan Tur and Dr. Dilek Hakkani Tur, AT&T Research

Member of Industry Affiliates Group. Provide materials, resources and information for 'human as sensor' research.

1.3 Other collaborators and contacts

Charles Jennings and Grant Roholt, Regional Alliances for Infrastructure and Network Security (RAINS-Net)

RESCUE has opened up discussions with RAINS-Net and are engaged in developing a partnership with this non-profit private/public organization working on the development of information sharing tools for the first responder community.

Samuel Kang, IT specialist and former firefighter

Meets with RESCUE research team to advise on issues of interoperability, field response, and IT solutions for first responders.

Professor Rina Dechter, University of California, Irvine

Transportation testbed team member. Dechter's student will intern at RESCUE, summer 2004, to work on closing the gap between theory and practice in constraint processing. To that end, using the transportation testbed as a model, they will perform a large-scale experimentation on both real-life and simulated systems

Professor Nikil Dutt, University of California, Irvine

CAMAS testbed team member.

Professor R. Jayakrishnan, University of California, Irvine, Institute for Transportation Safety (ITS)

Transportation testbed team member.

Linda Bogue, University of California, Irvine, Emergency Management Coordinator

Partnering with RESCUE to develop university-wide emergency drill under which RESCUE researchers can employ IT solutions to observe behaviors and to get a better understanding of how IT can assist in emergency situations.

Partha Mitra, Lucent Technologies

Member of Industry Affiliates Group

Jim Basney and Von Welch, National Center for Supercomputing Applications

Invited member of Industry Affiliates Group.

Clifford Neuman and Tatyana Ryutov, USC/ISI

Invited member of Industry Affiliates Group.

MLB

A UAV company. Invited member of Industry Affiliates Group.

DigitalGlobe

Satellite data provider. Invited member of Industry Affiliates Group.

Lucent Technology

Invited member of Industry Affiliates Group.

QualComm

Invited member of Industry Affiliates Group

2. Activities and Findings

The mission of this multidisciplinary project is to enhance the ability of emergency response organizations to mitigate crisis, save lives, and prevent secondary and indirect human and economic loss by radically transforming the way in which these organizations gather, process, manage, use and disseminate information during manmade and natural catastrophes. The project is predicated on the assumption that information quality, accuracy, and timeliness at all levels of emergency management profoundly affects the quality of decisions and that better information leads to improved decision making and more effective performance of crisis-related tasks. As a result, significant improvements in crisis response capabilities can result from research on how to apply advanced information technology solutions to the crisis management field. Our goal is to show that such a fundamental transformation can be achieved by a coordinated interdisciplinary research program that synthesizes:

(a) scalable and robust IT solutions to facilitate access to the right information, by the right individuals and organizations, at the right time, and

(b) social science research to understand the distinctive nature of dynamic virtual organizations and their information needs in the crisis and disaster context

The project has been officially organized under the title of RESCUE (RESponding to Crises and Unexpected Events), www.itr-rescue.org, and a project center has been established on the UCI campus. Research in RESCUE encompasses numerous sub-areas within both IT and social science. In particular, our IT research covers topics within the areas of networks, mobility and location management, middleware, distributed systems, security, data management, data analysis & mining, decision support tools, image analysis, automated speech recognition, spoken language understanding, computer vision and image interpretation. Our social science research focuses on the analysis of inter-organizational networks, emergent responses to rapidly-occurring events, organizational behavior in the crisis environment, information sharing needs, reliability modeling, and information dissemination to organizations and to the broader public.

While our research touches many different topics, our project is a tightly integrated multidisciplinary effort focused on crisis response. The fundamental basis for integration is the process of information flow through disaster networks: information collection, analysis, sharing, and dissemination. Our project seeks breakthrough innovations in computer systems, information management, and social science to revolutionize the mechanisms for collecting, analyzing, sharing, and disseminating information in disaster response networks. Below, we first discuss our Year 1 milestones, and then discuss our research progress within each of these thrust areas.

Year 1 Milestones: Our proposed Year 1 Milestones, as described in our *Responding to the Unexpected* Cooperative Agreement, have been met:

In Year 1, we have developed a prototype voice-based event processing network consisting of distributed audio sensors, a backend server infrastructure for extraction of events from voice signals, and for the event-triggered notification of crisis response echelons. This has involved determining the quality of off-the-shelf speech recognizers, and identifying areas of improvement for deployment in the crisis response framework.

We have also investigated different solutions for a reliable high-speed data network (combination of unlicensed band or experimental high data rate cellular system) to create a testbed. The prototype system will be used to test the 'human as sensor' concept at the campus level.

We have finalized the scope of the *Transportation Demonstration* study. Specific details that have been worked out include: a) which sub-area of the *California Advanced Transportation Management System or ATMS* that will be used in the demonstration study; b) the selected scenario/hazard to be used to test damage assessment methodologies and tools; and c) the roles and involvement of other government partners, e.g., the City of Santa Ana, the City and County of Los Angeles, the California Department of Transportation (Caltrans), and the Governor's Office of Emergency Services (OES) with the research program.. In addition, a prototype software program to characterize the effects of large earthquakes on transportation systems has been developed. The purpose of this testbed is to explore the efficacy of information technology solutions in mitigating the effects of large, regional disasters.

An initial CAMAS (Citizen Awareness System for Crisis Management - see discussion below) framework has been developed for campus level trouble reporting. It is enabling users to provide input via a web interface thus allowing the research team to monitor a few key university facilities. Event classification and categorization techniques are being used to organize collected data. Collected data are currently being used to evaluate the event extraction and assimilation techniques developed.

Additional steps to carry out tasks specified in the cooperative agreement include the following:

Hardware Infrastructure: A network of voice sensors (e.g.. PDAs, laptops, and bare microphones in on-campus settings) will be established and connected to speech recognition "backends", residing on powerful servers suitable for load balancing. A control room will be developed at UCSD and outfitted with projection equipment to visualize the data and monitor the various testbeds. At both the UCI and the UCSD campuses, computers will be brought on line to support voice recognition, data storage and management, information collection and data analysis.

Software Architecture and Components: Initial software prototypes for event-extraction from text and event assimilation will be developed. Software components will be developed and deployed for the audio sensors, voice processing, and notification; these components will be connected via prototypical software architecture for testing purposes and for demonstrating feasibility. Prototype software will be developed that will allow real-time assessment of damage to transportation systems (mainly bridges). This software will address a) damage to critical bridges, b) impact on traffic levels or congestion, and c) ability of emergency vehicles to respond to key incidents, e.g., search and rescue.

Education and Outreach Activities: A RESCUE community advisory board (CAB) has been established that consists of representatives from local, regional, and national government agencies as well as from industry. On February 23, 2004, key researchers from RESCUE met with the CAB group to discuss research priorities and educational opportunities and ways in which that group can interface with researchers within the context of the three demonstration studies or testbeds. A website for RESCUE has also

been launched (see www.itr-rescue.org). The website, besides providing information about RESCUE, is serving as an important focal point for information on homeland security issues, as well as a resource to researchers (both RESCUE members and others). The RESCUE education and outreach team (working with government partners and other faculty) is developing laboratory exercises that will help test and validate research ideas generated by the project, In addition, this same team is defining a suite of projects for undergraduate courses that deal with various aspects of disaster mitigation. CAL-IT2 seminars (open to a wide audience) are also being organized on topics related to RESCUE research this first year. In addition, the first annual RESCUE Principal Investigators meeting/workshop was held at the RESCUE project center on November 24, 2003.

Major Research Thrust Areas: Four specific research thrust areas have been defined for this project: information collection, information analysis, information sharing, and information dissemination (see Figure 2-1). In addition to these major thrust areas, three key testbeds have been initiated: a) Transportation Testbed; b) CAMAS – A Citizen Awareness System for Crisis Management; and c) GLQ – Gas Lamp Quarter. Research progress in each of these seven areas is discussed below:

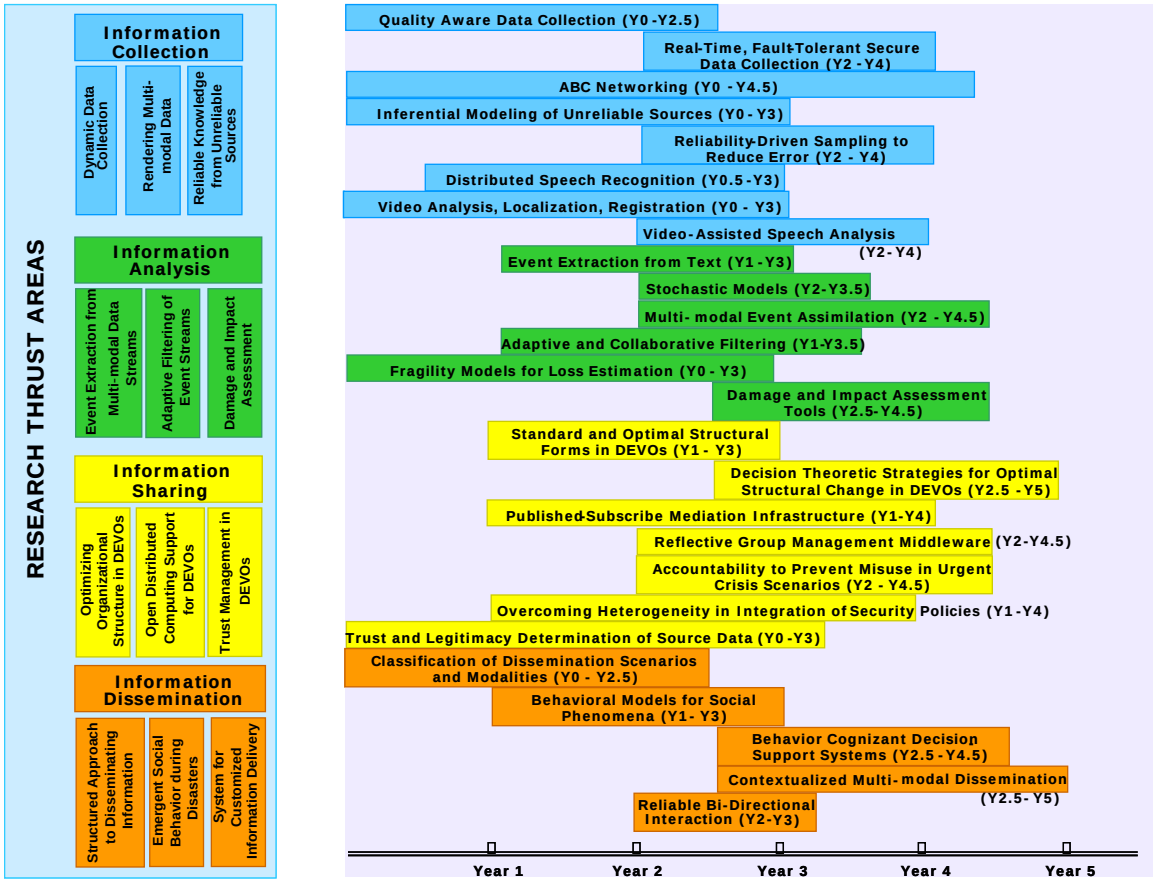

Figure 2-1. Major Thrust Areas and Timeline for RESCUE Project

2.1 Major Research and Education Activities, Including Major Findings

The following sections provide a summary of major research and education activities for the RESCUE project. In addition, within these discussions, we provide our assessment of major findings, as they relate to the four main thrust areas: Information collection; information analysis, information sharing and information dissemination. A discussion of outreach activities (first responder community, industry, community in general, and education) is also provided at the end of this section.

Information Collection

This thrust area involves research activities for gathering and managing very large and diverse types of highly-dynamic information over networks that might be unreliable and possibly insecure. Emphasis has been on enabling humans to act as vital information sources in a crisis (human as sensor). Specific research foci include:

- Dynamic Data Collection – to design a robust data management architecture that provides access to highly-dynamic multimodal information from heterogeneous unreliable sources connected via unreliable networks.
- Rendering Multimodal Data - to seamlessly capture and analyze voice and video input from in-field rescue workers.
- Reliable Knowledge from Unreliable Informants – to develop an inferential modeling framework for analyzing personal accounts in order to simultaneously infer the true state of an event or incident; the social network of information flow among informants; and determinants of informant accuracy.

Research Priorities: Quality-aware data collection mechanisms that exploit predictability of sensor and compute/storage capabilities at the sensor or nearby sources; Quality-aware query-processing mechanisms for ad-hoc and continuous queries that arise in monitoring based applications; ABC Networking – explore the feasibility of available physical alternatives for best-connected networking; Design link-tracing interviewer protocols for inferential modeling of unreliable sources; Evaluation of existing Speech Recognition software for human-sensor realization.

Major Activities and Findings:

- *UCI (Mehrotra and Venkatasubramanian)* is exploring quality/energy tradeoff in data collection with a target tracking application. In such an application, a quality requirement is defined by end users. UCI has developed a middleware structure to map application quality to individual data quality, which is further used to reduce communication overhead in data collection. These researchers have shown that the mapping is application-specific and an optimal solution is not easy to achieve. However, even approximate mapping can yield significant savings on communication overhead and thus, energy consumption in sensor networks. UCI presented their results at CNDS 2004 in San Diego.
- *UCI (Mehrotra and Venkatasubramanian)* is investigating the problem of approximate processing of important types of queries and aggregations in sensor networks. Clustering is the most commonly adopted technique for sensor networks topology management. Based on this observation, UCI has enforced group-quality

constraints, in addition to constraints on single sensor node, to achieve approximate data collection/aggregation. The group-quality constraints are further adjusted (dynamically) to balance workloads in networks. UCI's experiments show that this technique can reduce overall communication overhead and achieve uniform energy consumption across the network.

- Since many real-world applications can tolerate data imprecision at varying levels, the error tolerance of applications can be exploited to reduce energy consumption during sensor data collection. Blindly transmitting sensor updates at a fixed periodicity to the server results in a suboptimal solution due to the differences in stability of sensor values and due to the varying application needs that impose different quality requirements across sensors. *UCI (Mehrotra)* is exploring data collection protocols for sensor environments that exploit the natural tradeoff between application quality and energy consumption at the sensors. UCI has considered a series of sensor models that progressively expose increasing number of power saving states. For each of the sensor models considered, UCI has developed quality-aware data collection protocols that enable quality requirements of the queries to be satisfied while minimizing the resource (energy) consumption. Both theoretical analysis and experimental results have validated the effectiveness of these approaches.
- *UCI (Mehrotra and Venkatasubramanian)* is considering the problem of evaluating continuous selection queries over sensor networks when faults are likely to occur. The presence of faults degrades the quality of the answer given to the user, but more importantly, presents a semantic challenge, making it difficult to interpret this answer unless its potential discrepancy from the exact answer is quantified (the one that would have been acquired if faults did not occur). UCI has developed a taxonomy of faults that are likely to occur, proposed a metric for quantifying the quality of an answer set, and developed a protocol FATE-CSQ for trying to achieve this quality efficiently. FATE-CSQ applies in-network processing to localize and quickly fix the effects of faults. Researchers have conducted a thorough empirical evaluation of the FATE-CSQ protocol demonstrating its good performance in a number of different settings.
- *UCI (Mehrotra)* has developed a framework for evaluating Quality-Aware Queries (QaQs) over imprecise data. Replicas of dynamic data items are stored in the query processing site in imprecise forms in order to limit bandwidth- and energy-expensive communication. Queries applied to such data will produce approximate results, however, researchers want to quantify their level of approximation and give supporting quality guarantees in addition to the approximate answer. In this framework, QaQs specify their quality requirements, and the query optimizer devises a plan to do minimal combined local data access/probing of remote data sources to achieve these requirements. Even though answers may now deviate from the exact answer, their deviation is deterministically bounded, while the resulting economy of resources is critical to system performance, especially in a crisis situation when multiple agents may be trying to query remote assets simultaneously, thus taxing available resources.
- Significant progress has been made in identifying sensors to assess the performance of highway bridges (a major element in the Transportation Testbed). It is noted that piezoresistive strain gauges are susceptible to signal drift. As part of this project, the *University of Maryland (Chang)* is designing a gauge that will compensate for many of the factors that can cause drift in strain gauges (such as temperature, pressure,

and humidity). This sensor will result in deflections accurate to within 1 inch. Since large deflections correspond to significant damage states, the proposed technique will be able to determine the level of damage on a bridge.

- *UCSD (Trivedi)* has been working on the design and implementation of wearable sensory devices. They are currently focusing on a GPS+camera based device using tablet PCs and iPAQ PDAs. The tablet PC is being used for applications that require more local processing ability (for example, landmark detection, speech processing) in the event that remote access to computational resources are unavailable. The larger display size and graphical rendering power makes Tablet PC's amenable to tasks that are more visualization dependent such as on-site real-time task planning. PDA-sized devices sacrifice computational and display resources for high portability, while still retaining the ability for intuitive pen-based interaction and network connectivity with RESCUE support infrastructure. Data collected from these wearable devices will be processed and analyzed to both filter irrelevant information, as well as synthesize the meaning from incoming data sources. This data analysis will be local, distributed across multiple devices, or centrally processed. Researchers are focusing on "self-data" analysis and event detection including landmark detection, person image capture, and self-tracking.
- *UCI (Mehrotra and Venkatasubramanian)* is working on the development of a testbed for studying techniques for privacy preservation in media spaces (specifically video surveillance). Utilization of RFID technology and its' fusion with video streams to achieve 'on demand', privacy-preserving video monitoring in user space is an important focus of research for the RESCUE project. Successful integration of group-signature schemes for anonymous authentication with the testbed is being examined. In addition, UCI is focusing on privacy specification and access control. This aspect of research has required the development of a spatio-temporal specification language for access control in media spaces. Specification and formalism of the language as well as integration with a XML-based rule-base in developing triggers for sensor data (e.g. video) has been a major focus in this first year. Finally, development of a multilevel access control framework for mobile environments has been accomplished. As part of this research, data hiding techniques based on mobility patterns of objects and hosts have been developed. Current work is examining evaluation of spatio-temporal predicates in a privacy-preserving manner, as well as enhancing the robustness functionality of the PP-Video processing algorithms (improved UI multiple cameras, etc.)
- *UCSD (Rao) i*s working on the development of ABS (Always Best Connected) networking solutions with regard to information collection. In an ABC environment, users are able to connect over the best available access network, e.g. wireless LAN, GPRS, UMTS, CDMA2000 and DSL. The definition of "best" depends on a number of parameters, such as personal preferences, network characteristics, device capabilities, application requirements and network operator preferences. In the ABC solution developed by UCSD, the ABC service is offered to one client device, which hosts the ABC client functionality. The decision of which network to use will affect which external interface to use for the device. ABC provides seamless interoperability among various network infrastructures to maintain constant - and the most powerful - connection to the Internet for mobile users using both licensed (e.g., cellular networks) and unlicensed (e.g., IEEE 802.11b) spectrum. This work is making it possible for user devices to seamlessly roam among varying network access technologies, including IEEE 802.11b, CDMA2000, GPRS, and Ethernet,

with controlled adaptation of applications' performance to the network capabilities at hand. Current efforts involve creating a case where the ABC service is offered across an ad-hoc network of wireless ad-hoc router devices, each of which may have a combination of wireless and wired interfaces. The devices are interconnected in an 802.11b/g based ad-hoc network that will form an extended infrastructure for ABC clients to connect to (via their 802.11b/g interfaces). The choice of which external access network to use may be made in an ABC client site several radio hops away from the device offering the external access (the ad-hoc ABC router gateway).

- *UCSD (Zhu, R. Rao)* has developed a Location Based Service (LBS) framework which has applications for first responder mobile force management. This secure framework manages the map rendering for both the mobile (cellular) interface and web browser, the logging of position and position management of the mobile device, and group messaging. One application developed from our LBS framework, which is called “Buddy Finder,” allows users to determine their current location, the current location of another member of their group, the location trace of a member over time, all via cellular-assisted GPS, enabling accurate location to be determined anywhere cellular signal is available, even indoors. It also supports the group messaging and location-based POI (point of interest). These features are available both on a mobile (cellular) interface utilizing the BREW platform, as well as on a command-center style web form. Buddy Finder is further enhanced to send a location-based alert to server, so that a first responder with a mobile device could define an alert in an area, and inform all those in the group located in that area of the alert. This application has been tested with several first responders, and was determined that it provided sufficiently accurate tracking information for providers at a San Diego county-wide drill. Use of a cellular device for this platform ensures not only a bright and highly visible screen (even outdoors), it also allows maximum battery life, and the application can run for over eight hours before the battery is run down.
- An important component of the situation assessment process is the rapid accumulation of information from eyewitnesses and other on-site informants by response personnel. Tasks of this nature may include attempts at determining the evacuation status of an endangered structure, the presence of hazardous materials within a facility, or the extent of losses within a given community. In the past year, *UCI (Butts)* has made progress in identifying techniques for surveying hidden or otherwise difficult to reach populations with promising applications in the context of crisis response. These include link-tracing designs, adaptive cluster sampling, capture-recapture methods, and so-called "scale-up" methods (based on the composition of informants' personal networks). Work is currently underway to translate these techniques into automated procedures which can be followed by responders, using handheld devices to coordinate data collection and integration activities.

Information Analysis

This thrust area involves related research activities that focus on extracting useful information (from the perspective of crisis workers) from raw data (sensor data, text, voice, and video streams) and assimilating/fusing data across multiple modalities to make higher-level observations. Specific research areas include:

- Event Extraction from Multimodal Data Streams – to develop analysis techniques that extract events useful for damage assessment and decision support from

multimodal data streams (speech, video, sensor) collected as part of a human-as-sensors paradigm.

- Adaptive Filtering of Event Streams - to develop an adaptive filtering strategy for monitoring crisis-related event streams.
- Damage and Impact Assessment - to develop novel damage assessment strategies that exploit the aforementioned post-event information analysis and event extraction techniques for accurate loss estimation.

Research Priorities: Techniques for classification and categorization of online text-based "event reports"; Techniques for integration of multiple reports over time into coherent events, using ideas from hidden Markov models, stochastic grammars, and dynamic Bayesian networks; Develop both real and simulated testbed datasets, such as freeform text from Web-based trouble-reporting systems, to support the empirical evaluation; Fragility models for loss estimation; Traffic simulation analysis tools; Simulation of natural and manmade threats; and Loss estimation models for large, transportation networks.

Major Activities and Findings:

- Robust feature extraction methods are an important mechanism for developing robust speech recognition systems. Work at *UCSD (B. Rao)* is expanding on the MVDR framework of feature extraction. The MVDR method is a frequency and data dependent filter bank approach that provides a powerful mechanism for dealing with the dynamics associated with speech signals. This is in contrast to FFT-based methods that are frequency and data independent. The computational complexity of the MVDR method is also quite reasonable making them attractive. UCSD's initial experimentation with this method has been quite promising. However, much remains to be done in terms of analytically quantifying the improvements. In addition, there are many other avenues for harnessing the MVDR framework for developing robust speech recognition systems and these will be explored in future work.
- *UCSD (B. Rao)* is also working on the development of multi-microphone based speech recognition systems. Spatial processing using multiple microphones provides an unique mechanism for dealing with environmental noise. UCSD work is beginning with a framework of joint spatial and temporal processing methods for robust recognition. This is in contrast to optimizing the spatial and temporal processing in a decoupled and independent manner. In addition to the signal processing, the experimental framework has to be developed as most databases available are single microphone based. UCSD has completed the background work necessary for transitioning into the development of robust multi-microphone based speech recognition systems.
- Significant progress has been made by *ImageCat* in transitioning loss estimation models from a desktop to online environment through the development of an open, non-proprietary online mapping system. Remote sensing technology is being integrated into this system as a new element, with the ultimate vision of using images from satellites or UAVs (unmanned aerial vehicles) to validate loss model estimates. In addition, there is a strong visualization element that will help portray results to end-user communities in more effective ways. Current efforts are beginning to address the next-generation of building damage functions, hazardous materials

release and impact models, and transportation models that will support the implementation of emergency rerouting algorithms for large-scale disasters.

- Developing suitable filtering techniques is critical to the RESCUE project, especially in information sharing and dissemination. *UCI (Mehrotra)* is conducting research to adapt existing filtering algorithms in text information retrieval to apply in crisis settings. UCI has developed a set of new techniques that are specially designed for structured and semi-structured data. A demo system has been built to illustrate the basic ideas of adaptive filtering. The demo system has been connected to the CAMAS testbed, which uses UCI facility report data as initial events. A location map with geo-referenced information has been mapped to mobile devices (HP iPAQ) that are being used by field agents. The event server is able to receive new events and disseminate information on the events to individual mobile devices based on individual profiles stored on the server. Field agents are using the mobile devices to provide important feedback on the event back to server, and server updates the profile accordingly.

- Spoken language understanding and event extraction from speech has been a major focus of research being conducted at *UCI (Mehrotra).* A survey conducted by RESCUE researchers shows that representing events as text is not sufficient to achieve accurate results. More accurate representations that allow comparison of locations, times, involved parties and objects of the events must be developed. It is also necessary to develop similarity measures between the features of the event. The similarity may be domain dependent as well as context dependent within a domain. UCI is investigating the possibility of representing events in terms of their features rather than only the text features given in the report. Although the event features are based on text features, as the events evolve and new features about the event start to appear in reports, these features can be extracted and added to existing event features. Reports coming later may be compared against the features of the event rather than previous reports and similarity may be acquired more accurately.

  The proposed method may be useful especially with unstructured speech data such as phone calls to a 911 dispatch center. In contrast to speech transcripts from broadcast news, phone conversations do not originate from previously edited text and may contain a lot of incomplete sentences with grammatical, even logical errors. A full syntactic and semantic parsing may not be necessary and may not yield successful output due to the nature of the data. However, an event-based method such as the one presented above may capture considerable information from the reports.

- *UCI (Mehrotra and Kalashnikov*) is also working on data cleaning approaches. Current data cleaning methods concentrate on identifying the same records in two flat tables (or eliminating duplicates from a single table). To achieve this, these approaches rely on comparing values in the attributes of those records. However, many datasets can be viewed as a collection of entities linked via *relationships*. So far, these relationships are largely ignored by traditional data cleaning approaches. UCI views this research as a first step towards shifting from the paradigm of merging two flat tables to the paradigm of merging two databases in the context of data cleaning. They show how to combine the traditional data cleaning approaches with graph-based relationship analysis techniques to achieve higher disambiguation accuracy. UCI also views the underlying database as a graph of entities connected via relationships.

At the core of this approach lie algorithms for computing the degree of connectivity between two nodes in the graph. UCI has studied such algorithms: one is defined by the *weight-based model (WM)* and the other is defined by *the probabilistic model (PM)*. They have developed several optimization schemes that are crucial for scaling the approach to large datasets. UCI has shown that in this approach (for both WM and PM), a given data cleaning problem is reduced to a corresponding non-linear programming (NLP) problem.

- *UCI (Mehrotra and Seid)* is addressing complex analytical querying and mining of large attributed graph data, e.g., data in a wide variety of applications that are characterized by heterogeneous entities/events with heterogeneous relationships among them. Such data are best modeled as attributed graphs that can explicitly represent both attribute and structural (relationship) aspects. Examples of such data are found in intelligence link analysis, geographic information systems (e.g. spatially embedded graphs like transportation networks and various utility networks), social network analysis, web data mining, and bio-informatics. Although database systems can easily store such data, they do not yet provide a mechanism (language) to easily query such data. The first aim of this research is to design and implement a minimal, yet powerful query language for attributed graphs that can be incorporated in database systems. The research also aims to go beyond supporting ad hoc querying to develop novel data analysis operations that facilitate exploratory analysis as well as discovery (mining) of interesting patterns over attributed graphs.
- For video and pedestrian traffic data analysis, statistical learning and data mining techniques are being used by researchers at *UCI (Smyth)*. Probabilistic generative models have been constructed for observed data using dynamic Bayesian networks whose structure captures both spatial and temporal constraints that are natural to both pedestrian and traffic movement. Statistical learning techniques have been used to fit the parameters of these models to observed time-series and video data. Since the models will typically be intractable from a computational viewpoint, Monte Carlo sampling techniques have been employed for model learning. Special-purpose inference and prediction algorithms are now being used to allow for real-time applications that combine the models of historical behavior with current data, enabling anomaly detection, situation assessment, and forecasting. Some key findings include: a) trajectories of individual pedestrian movement can be automatically and reliably extracted from outdoor video images; b) these trajectories can be used to construct stochastic models for pedestrian movement by decomposing each trajectory into local linear movements between landmarks in the scene – these models can simulate pedestrian motion in a manner that is virtually indistinguishable from real pedestrian motion; c) automatically learning the structure and parameters of these models from sets of trajectories is a challenging statistical learning problem; and d) researchers in this study have developed specialized algorithms that can detect anomalous and unusual trajectories by scoring trajectories according to their likelihood under the model, and make online predictions based on partial trajectories of what location an individual is likely to be moving towards.

  Possible applications of this research include simulation of motion in computer graphics, video surveillance, and architectural design and analysis. The models are based on a combination of Kalman filters and stochastic path-planning via landmarks, where the landmarks are learned from the data. A dynamic Bayesian network (DBN) framework is used to represent the model as a position-dependent switching state space model. UCI illustrates how such models can be learned and

used for prediction using the block Gibbs sampler with forward-backward recursions. The ideas are illustrated using a real world data set collected in an unconstrained outdoor scene.

- *UCSD (Jafarian, R. Rao)* has developed an Enhanced Multimedia Messaging Service by adding capabilities to classify the incoming images sent to the server by users. Researchers would ideally like to know whether each image has good quality and correct orientation, whether it is a duplicate or not, what event it depicts, etc. This would enable the cell phone operators to remove all the spurious data that is clogging their servers. The service could essentially make each mobile user into a photographer whose reports would be available to the whole world. However, the received data would undoubtedly be unstructured and of widely varying quality. The server-side processing applied by the cell phone operators would simply dump all the incoming data into a single directory. Images of many different events and all of the events would be grouped together in a single depository and the bad quality images would be classified into another category or eliminated.
- *UCI (Butts)* has made significant progress in formalizing analysis procedures relating to informant reports. Effective decision making for crisis response depends upon the rapid integration of limited information from possibly unreliable human sources. In this project, a hierarchical Bayesian modeling framework has been developed for the analysis of informant reports which allows simultaneous inference for informant accuracy and for an underlying event history. This model permits use of information regarding classes of informants, as well as individuating information where available; thus, it can be deployed in environments wherein privacy or data collection constraints do not permit identification of informants at the individual level. Contextual information on events (including known dependencies in event timing, e.g., the geometry of storm tracks or fire spreading) is also included, as is covariate information linking informants to the events on which they report (e.g., distance from reported event, where informant localization is possible). Algorithms have been developed for obtaining both point estimates and posterior draws for the model, the latter via a random walk Metropolis algorithm (a Markov Chain Monte Carlo technique).

  This model has primary applications in situation assessment for complex crisis situations, reconstructive analysis of disasters, and prediction of ongoing hazards such as tornadoes and wildfires. Secondary applications include the analysis of data from unstructured interview or survey data, ethnographic observation, and studies with endogenous selection mechanisms. A preliminary evaluation of model behaviors has been carried out using Monte Carlo simulations with known event structures. Current efforts involve the collection of empirical data to validate the model, and refinement of the MCMC algorithm to reduce computational cost.

Information Sharing

This thrust area addresses related research activities that facilitate seamless sharing of information amongst decision-makers across organizational boundaries. Specific emphasis will be on seamless information sharing and collective decision-making across highly-dynamic emergent virtual organizations. Research areas include:

- Optimizing Organizational Structure in Dynamic and Evolving Virtual Organizations (DEVO) – to derive optimal change strategies for individual organizations and inter-

organizational structures during crisis conditions that will address the problem of secure continued operation during periods of disruption.

- Open Distributed Computing Support for DEVOs - to design adaptive protocols and services that independently specify interaction parameters and service/protocol functionality; this will allow independent dynamic adaptation of middleware services and protocols to ensure timeliness, accuracy and safety.
- Trust Management in DEVOs – to explore challenges in using Automated Trust Negotiation (ATN) techniques for access control and authentication in crisis response scenarios.

Research Priorities: Investigate information sharing practices and policies in the information systems associated with testbeds (e.g., types of information shared, placement, means of access, access control and auditing policies); Model the organizational structures in the context of crisis response; Explore issues of trust and legitimacy determination for source data; Design link-tracing interviewer protocol for inferential modeling of unreliable sources; Study group formation scenarios and solicit/collect DEVO admission control policies; and New certification infrastructure for crisis management.

Major Activities and Findings:

- A major component of the RESCUE project focuses on the organizational infrastructure and context in which IT solutions are employed in the management of crisis events. The assumption underlying this work is that contextual factors play a key role in the adoption and use of technologies, both during routine organizational operations and during disasters. Thus, while a wide range of technological solutions may be theoretically available to manage crisis events, factors such as funding levels, organizational culture, workforce characteristics, prior experience with technologies, routine patterns of information sharing, and interorganizational relationships (including trust-related factors) affect which solutions will actually be chosen. While other components of the RESCUE project focus on the *technical* feasibility of various approaches to information gathering and information sharing, this aspect of RESCUE focuses on the *organizational* feasibility of implementing these approaches in real-world settings. Thus, while the emphasis within RESCUE is on crisis response systems as *virtual* organizations, this work focuses on the activities, priorities, and practices of the entities that comprise those organizational networks. Investigators from the *University of Colorado (Tierney)* are engaging in a variety of activities, including collaboration with end-users and key actors in the RESCUE testbeds on organization-technology interface issues; collaboration on outreach and educational activities; collection and analysis of data on organizational issues related to crisis coordination and information sharing; assistance with model development related to emergent behavior in crises; and production of white papers, research reports, peer-reviewed articles, and student research projects.
- Crisis management contexts often generate extensive demands for information, including video surveillance of both public and private spaces. While various privacy preservation mechanisms exist for video data, less is known about how subjects perceive (and are willing to trust) these mechanisms in practice. In this project, *UCI (Butts)* has undertaken a survey of subjects to evaluate the effect of various privacy preservation techniques on perceived privacy, and examine the determinants of

acceptability of such mechanisms to subjects. The initial instrument design has been completed and the present focus in on initial data collection.

- At *UCI (Li),* researchers are studying data integration and sharing issues within the context of Peer-Based Systems. There is a great need to allow diverse organizations to integrate and share their heterogeneous information in crisis situations. UCI has built a system prototype called "RACCOON" to study research issues on supporting distributed data integration and sharing in a peer-based environment. The main research thrust focuses on how to connect the semantics of different databases using different schema mappings, how to search for relevant data sources, how to visualize the system for users to pose queries, and how to answer user queries by accessing necessary sources. In addition, UCI is also studying security and privacy issues that arise in such environments, e.g., how to publish a peer's XML data without leaking sensitive information, even if public users can do data inference using common knowledge. Currently, UCI is studying the semantics of schema mappings between peers, keyword-based searches in the peers, and information security and privacy with different requirements.
- The crisis response scenario is a highly dynamic, open distributed system (ODS) consisting of a heterogeneous infrastructure with mobile and fixed components. Middleware services and protocols that support end-user requirements in ODSs (e.g. reliability, resource availability, security and timeliness) may interact and interfere with each other. Dynamic reconfiguration of middleware services and protocols to deal with changing conditions adds further complexity (especially in mobile environments). Designing middleware frameworks for emergency response that are capable of dynamically adapting themselves to the environment while ensuring the correctness of the underlying services and protocols is an important challenge.

  At UCI (Venkatasubramanian), research in distributed computing has used the concept of reflection to provide modular and adaptive solutions to deal with the problems posed by composition of distributed services. We build upon a customizable and composable middleware framework called CompOSE|Q that simplifies reasoning about the composability of multiple resource management services and protocols in ODSs.

  Our work has addressed the development of an adaptive, composable framework to support dynamic protocol composition through separate specification of interaction parameters and protocol functionality. Specifically, issues pertaining to inter-protocol interactions, protocol-service interactions have been analyzed. The composition order of these protocols and services are very important, and the framework examines situations in which inconsistent configuration states may violate the semantics of the basic operations. We are currently extending these solutions in order to provide secure reliable group communication among mobile users for onsite crisis response. Situations involving crisis or emergency related activities involve many types of information (possibility in a ubiquitous fashion). This information may be accessed by different users under varying conditions and context (e.g. location). The ability for users to access this information in a secure, transparent and non-intrusive manner while adapting to changing conditions of the spaces they operate in is highly desirable. We combine access control and multilevel security to support a domain-based access for mobile entities that maintains concurrency while providing secure access to resources. To facilitate this, we have developed view maintenance mechanisms for hiding sensitive information from mobile users as they navigate in

insecure environments. We have also developed support for efficient dynamic delegation and revocation of access rights in the presence of mobile hosts and objects.

Future applications will execute in highly dynamic environments, where communication is not uniform due to changing conditions of network connectivity, reliability and resource availability. In providing services in open distributed environments, interactions between various components as well as system-level correctness must be maintained. Designing communication frameworks that are capable of dynamically adapting themselves to the environment is an important challenge. Furthermore, different applications may demand different properties and guarantees as far as the QoS, security and failure semantics are concerned. Although several frameworks have been designed to support modular and reconfigurable communication, they support complex programming interfaces and their behavior is often expressed via informal descriptions. Clear semantic models capable of expressing dependencies among properties required by a given communication system will help design safe customizable communication frameworks. The composition of multiple resource management services is necessary to guarantee safe, cost-effective Quality-of-Service (QoS) to global multimedia applications.

At UCI (Venkatasubramanian), research in distributed computing has used the concept of reflection to provide modular and adaptive solutions to deal with the problems posed by composition of distributed communication systems and the adaptation of these solutions to mobile environments. Middleware abstracts communication services, allowing the development of network transparent distributed applications. A customizable and composable middleware framework called CompOSE|Q has been developed that allows separate specification of interaction parameters between middleware services and reasoning about the composability of multiple resource management services in ODSs. This framework has been used as a basis for building solutions that address composability issues for access control in insecure environments as well as adaptive, secure group communication.

In providing services in open distributed environments, interactions between various components as well as system-level correctness must be maintained. We aim to incorporate effective mechanisms into a composable middleware framework to ensure safety and QoS enforcement in distributed and mobile environments. Such a framework provides for dynamic network and system customization, dynamic invocation/revocation and installation of services as well as adapts to changes in applications and manages distributed components. Reflection provides a plug and play environment for enabling runtime modification of policies and an efficient technique to build composable middleware. This middleware provides high adaptability, safe flexibility and cost-effective QoS guarantees.

Research in distributing computing and formal methods have used the concept of reflection to provide modular and adaptable solutions to deal with the problems posed by composition of distributed communication services. However, the goal of achieving truly modular and composable communication services, while ensuring correctness in the compositions of such services is quite subtle. For instance, flexible group-communication services require customizable communication among members of the group; this implies integration of customized broadcast and multicast

protocols to objects within the group. Other work in dynamic installation of communication services assume that communication is point-to-point and does not impose formal restrictions on the structure of basic operations. Therefore, multiple protocols may be applied (installed) to a single component by stacking the meta-objects which implement each protocol. An issue of concern is the composition order of these protocols and services; a simplistic implementation can lead to an inconsistent configuration state which may violate the semantics of the basic operations.

Adaptation & Context Awareness: There has been significant work in the development of context sensitive middleware services, including QoS-based resource provisioning, resource/service discovery in Grid environments, quality-aware query processing, adaptive communication, dynamic access control, power-aware middleware etc. These services aim to perform their specific tasks in a more efficient and effective manner by utilizing the available contextual information. To achieve complete context awareness, unobtrusively collecting context information becomes especially important. To support the data-intensive nature of distributed dynamic systems and diverse application requirements, we seek to map application needs of accuracy and timeliness to contextualized data collection strategies via a directory-service (or data repository). The use of directory-based solutions helps de-couple context information between varieties of general purpose middleware services (as oppose to analysis on a per-application basis). In addition, we observe that many middleware services are willing to tolerate information imprecision and bounded delivery latency. Our strategy is to exploit these accuracy and latency margins to ensure that most services receive information at the desired levels of quality and timeliness while minimizing resource consumption incurred in the whole collection process.

- A main goal of this research task is to provide an efficient mechanism for first responders to relay important information (in the form of pictures, video and audio) back to emergency operations centers (EOC) using a wide array of wireless devices, e.g., such as cell phones and PDA's. These data will be automatically timed and location stamped and populated in a GIS database. In this first year, *UCSD (Chockalingam)* found that there was no single device that has an open platform to write applications to time and location stamp multimodal data. There are some phones that have cameras but do not have an open API to access the image data. Others have camera phones but no GPS support. GpsOne is built into some phones but the network is not enabled yet. UCSD is currently exploring a Bluetooth option where the phone is able to retrieve location information via Bluetooth receiver. They are also looking into Qualcomm's BREW environment as a possible platform.
- UCSD (Chockalingam) has developed a next generation mobile Traffic Notification System which allows first responders as well as the general public to get real-time traffic information through their cell phones. The system they have developed allows for on-demand, anytime anywhere access of traffic information through any phone. It provides a user with highly personalized traffic reports including commute time based on the current traffic conditions and fastest route to your destination based on the current traffic conditions. No other system can provide such personalized information on demand, today. This system currently has over 5000 registered users and receives about 30,000 calls a month. The system is capable of dynamically changing voice prompts to accommodate special announcements from the Police Department.

The police have used the system to get access real time traffic information from the field and also to communicate between the fleet through the special announcements feature. The system is available via the toll free number (866) 500-0977 and its associated web site is http://traffic.calit2.net.

The system also has the unique ability to intelligently alert users about traffic congestions via text messages. Current traffic notification systems alert a user whenever there is an incident in their commute route without regards to the severity of the incident and the resulting congestion due to the incident. The notification engine that is being developed by UCSD is able to much better. UCSD is employing the following algorithm, which is a more robust and reliable way of notifying the user: calculate the commute time of a user based on historical averages for various times of the day. They also know the approximate time window of the user's commute based on the time the user calls our system. If during that time window, the commute time exceeds a certain threshold, the notification engine will alert the user of the congestion. Furthermore, the system provides graphical data giving the commuters a time history of their commute times against the time of the day. Simple analysis of this graphical data allows users of the system to empirically determine whether their commute time is shorter at different times throughout the day. The data is compiled based on past historical averages of traffic flow information.

- *UCI (Tsudik)* is investigating admission control techniques in peer groups. Specifically, they are investigating distributed secure techniques for admitting new members into dynamic peer groups such as those formed within RESCUE. Membership of such groups is often hard to enumerate a priori. Consequently, the group members themselves need to make a distributed decision regarding new member admission and securely implementing it. UCI's approach is utilizing various types of threshold cryptography, proactive cryptography, secret-sharing, identity-based cryptography as well as distributed authentication.
- Researchers at *UIUC (Winslett)* are examining under what conditions the various players in disaster response are willing to share information with each other, especially online. As UIUC explores these conditions, it will assess whether trust negotiation is able to handle those kinds of conditions. Learning about these conditions has been a top priority, because they will determine many of this team's activities over the next five years. An initial activity has focused on the identification of usability issues with TrustBuilder that will make the system more flexible and more adaptable to rapidly changing conditions. These have included user-friendly information regarding negotiations that fail or succeed, convenient ways to override decisions that cause negotiations to fail, and logging of relevant data for later auditing. In parallel, UIUC researchers are working to address a deficiency in certain forms of trust negotiation that were identified in last year's PI meeting in Irvine. This deficiency allows one party to extract irrelevant information from the other during negotiation, under certain circumstances.
- During the past year, *UIUC (Winslett and her students)* focused on attacking trust negotiation to determine what an adversarial party can learn about another party while they are establishing mutual trust. This is important for the Rescue project because potential adversaries will know that eventually a disaster will happen in Los Angeles, and can plan in advance how to take advantage of the disaster once it occurs. In particular, if there are automated ways to open up information flow in crises, then an adversary could take advantage of the increased flow to obtain information that they would not normally be able to obtain. UIIC plans to address this

situation by creating audit trails that can be scrutinized after the fact for inappropriate access to information. In their current effort, they have been focusing on the extraction of irrelevant information during the process of negotiating trust. They have used game theory to identify a broad class of attacks, called fishing attacks, which allow the extraction of irrelevant information. Researchers are currently investigating potential means of fending off, detecting, and/or preventing fishing attacks. They anticipate that this work will be ready for conference paper submission in the fall.

- During the past year, *BYU (Seamons)* has focused its efforts on content-triggered trust negotiation. Content-triggered trust negotiation is a variant of trust negotiation that is suitable for use when information is pushed to recipients who may or may not be eligible or willing to receive it. Content-triggered trust negotiation is suitable for use in any communication protocol. As a simple example, a recipient of an email containing an emergency order to shut down and evacuate a city building can use content-triggered trust negotiation to verify that the order really was sent by its supposed sender. This ability offers an additional layer of protection, beyond digital signatures, for highly sensitive content. As another example, content-triggered trust negotiation can be used to prevent the inadvertent inappropriate disclosure of information. For example, the Champaign County Disaster Response plan is not publicly available. If a copy of the plan is attached to an outgoing email, content-triggered trust negotiation can be used to automatically enforce a policy associated with the release of the plan (e.g., require that the Director of Emergency Response have already entered the recipient's name in a database of authorized recipients) and/or establish an audit trail record showing that the plan has been released to a particular party. BYU's work on content-triggered trust negotiation has been accepted for publication in ACM's TISSEC journal. As mentioned above, audit trail facilities are particularly important for documenting atypical information flows during crises. At BYU this year, researchers have been working on LogCrypt, a facility to provide tamper-evident audit logs at low cost. With LogCrypt, any attempts to cover up inappropriate activities by changing audit records will be detected. BYU expects its work on LogCrypt to be ready for conference publication in the fall.
- Crisis situations generate demand for coordination both within and across organizational borders; such coordination, it has been argued, is sufficiently extensive to allow the entire complex of crisis response organizations to be characterized as a single "Dynamically Evolving Virtual Organization" (or DEVO). In this project, *UCI (Butts)* is examining organizational networks associated with a major crisis situation, applying new methods to analyze structural features associated with communication and coordination. In particular, radio transcripts of responder communications during immediate aftermath of the World Trade Center disaster have been obtained, and coding of the transcripts has been performed to extract data on the structure of communication events. Further, in order to compare centralization of communication structures in a uniform manner across networks of varying sizes and densities, a number of new analytical results have been proven regarding the connection between size, density, and degree centralization. These results have been used to construct a new family of centralization measures, which quantify biases towards degree centralization net of size and/or density effects. Use of these and existing measures has shown that radio communications among the WTC responders tended to occur in minimal, tree-like networks; these networks varied substantially, however, in the extent to which they were well-connected (some being comprised of many tree-like components, and others of single trees) and

hierarchical (some being dominated by reciprocal communication ties, and others being highly asymmetric).

These results are expected to provide important insights into the ways in which responders (particularly those working outside the traditional emergency response community) utilize radio communications in the critical period immediately following a crisis event. Current work in this area is focused on extending these results by inclusion of information on task performance, communication content, and organizational boundaries. The methodological advances developed in conjunction with this study are expected to be applicable to network comparison problems in a range of substantive domains; further work on this project will seek to make related advances on other structural features of interest.

- One goal of the RESCUE project is the development of tools for the evaluation of organizational and interorganizational (i.e., DEVO) structures in the context of crisis response. To evaluate such structures, it is necessary to have statistical tools for structural comparison; since organizational/DEVO structures are relational entities (i.e., networks), this is a nontrivial problem. Standard statistical methods are known to be problematic in the context of network comparison (e.g., due to complex autocorrelation structures in the underlying data), and specialized tools are required. During the past year, *UCI (Butts)* has developed an exponential family of permutation models for the comparison of multiple network structures. This innovation extends past work in this area in several respects -- most importantly, it allows for likelihood-based inference on the strength and direction of association between graph sets, while conditioning on all possible sub-graph statistics. Such conditioning is an important tactic for obtaining inferences which are robust to common forms of measurement error, as well as to spurious association arising from artefactual structural properties (e.g., artificially induced density constraints). Past modeling efforts have either not allowed such conditioning, or have employed it only in the hypothesis testing stage; the latter techniques were not likelihood-based, and did not admit principled methods of model comparison or characterization of uncertainty (e.g., standard errors). Algorithms to efficiently fit the permutation model (using MCMC-MLE and pseudo-likelihood methods) have been developed and implemented -- this also constitutes an innovation, since the likelihood function for models in this family contains a normalizing factor whose direct computation is factorial in network size. Monte Carlo quadrature methods (based on recent work on efficient estimation for exponential family random graph models) and an efficient algorithm for the calculation of sufficient statistics for the permutation model (developed as part of this project) now allow likelihood calculations which are linear in network size.

  In addition to direct application in the evaluation of crisis response organizations (and DEVOs), this family of models is expected to be of value in a wide range of contexts (as it can be used to compare arbitrary dyadic relational structures on a shared vertex set). The model has been tested on both simulated and real organizational data, and current work is focused on developing improved heuristics for assessing model fit in the organizational context.

Information Dissemination

This final thrust area focuses on research activities that study how information can be dispersed quickly and efficiently to various entities and organizations. The research will

focus on how various forms of social behaviors emerge during disasters and how knowledge of these behaviors can help customize and personalize information delivery to save lives and property. Specific research areas include:

- Structured Approach to Disseminating Information - to gain deeper insights into the communication process as it relates to information dissemination during disasters. We will explore how dissemination strategies depend upon knowledge concerning source, message, channel, and receiver effects from a social science perspective.
- Emergent Social Behavior within the Context of a Disaster – to identify important social phenomena that must be considered in managing a disaster; to develop behavioral models for these phenomena, and to test models by incorporating them into existing decision-support systems.
- A System for Customized Information Delivery - to build a system that can deliver needed information (voice, text or visual) to targeted audience.

Research Priorities: Classification of dissemination scenarios and modalities; Determine requirements for information dissemination based on relevant subgroups via a detailed field study of crisis behavior and Taxonomy of information products and properties to be disseminated.

Major Activities and Findings:

- *UCI (Li)* is conducting research to support distributed queries on dynamic data in order to minimize communication costs. This solution involves a technique referred to as Data Gerrymandering. The goal is reduce the cost for range queries, such as "finding all current accidents between two known exits on Highway 5." The main objective of this technique is to partition the domain of the querying attribute into intervals, and decide the PUSH or PULL for each interval depending on the query and update distributions. This technique was inspired by the political practice of redrawing electoral districts to benefit one party, although the present framework promotes the greater common good by reducing overall communication costs. UCI has developed a family of algorithms for solving this problem, including a dynamic programming that can find an optimal solution. UCI is also considering different communication cost models, and show how the algorithms work under these models. Intensive experiments have already done conducted, and the results demonstrate the efficacy of the technique. A technical paper has been written on this topic and has been submitted for publication (VLDB 2004).
- P2P systems are now quite popular as a means of disseminating and sharing content in open distributed environments where nodes dynamically join and leave the network. Due to their distributed architecture, P2P systems offer many advantages, including robustness to failures (due to lack of centralized components), scalability of service as more users/peers join the system and greatly reduced administration costs (for any single organization). These same advantages can be used to build sharing and dissemination systems for emergency response. For example, different organizations may have different databases of information (e.g. maps of buildings, live video feed of road conditions, current locations of emergency resources) that may need to be shared across them. The time to set up, disseminate and share information from these databases must be quick, easy and efficient. Additionally, redundancy of data may be needed in case of failures (e.g. power, network outage)

of participant(s). While a P2P approach fits these requirements quite closely, several issues must be overcome in order to realize the full potential of P2P systems. Primarily, P2P networks can be highly dynamic (as nodes can potentially join and leave the network at any point of time). Secondly, all peers may not be equal. Some nodes are typically more capable in terms of resources and data than others. The challenge then, is how to provide steady service in a dynamic network while fully exploiting the more capable peers.

At UCI (Venkatasubramanian), researchers have addressed techniques for providing steady service in a dynamic network. This work specifically addresses the various dimensions of node dynamicity and their impact on the resulting network structure. We also proposed a new measure of dynamicity called persistence that is useful in determining the fraction of the network that is made up of stable nodes. This work has been accepted for publication in the IEEE International Conference on Peer-to-Peer Networks. Also at UCI (Mehrotra, Li, Venkatasubramanian), we have developed a protocol called "SPINE" for distributed metadata management in P2P networks. In the SPINE framework, stable nodes are elected (in a distributed manner) to form the 'backbone' of the P2P network. The stable nodes maintain meta-data about the network and help make searching for resources efficient and scalable. Our current work focuses on how data distribution information can be disseminated in a P2P network in an efficient manner and how a consistent view of a situation can be maintained across all peers in a distributed fashion.

- As part of this project, *ImageCat* is exploring the development of GIS-based solutions for situation assessment and information dissemination. One product that has been developed and is now being deployed as part of this thrust area is VIEWS (Visualizing Impacts of Earthquakes with Satellites). VIEWS is a portable, notebook-based reconnaissance system that links before and after 60cm Quickbird satellite imagery to a real-time GPS feed. The imagery provides city-wide coverage, and enables the visualization of damage sustained by individual structures. Integration with an underlying database allows a post-disaster reconnaissance team to catalog digital photos and observations of damage by map location for later retrieval. Additionally, the results of automated damage detection algorithms allow first responders to focus on the hardest hit areas. VIEWS begins to address many of the issues central to project RESCUE, such as the integration of IT solutions into disaster response. ImageCat is currently focusing on issues related to the use of VIEWS in the field, attempting to glean important lessons learned regarding its ease of use, its visualization efficiency, and concerns regarding software configuration. Tablet PCs, web deployment and integrated digital photography are all identified as possible extensions to the program.
- *UCI (Shinozuka)* is developing the analytical framework for assessing a community's capacity to treat impacted populations after a major disaster. So far, they have developed significant insights into whether communities have sufficient hospital capacity (e.g., number of beds, ambulances, etc.) to effectively respond to a large, regional disaster. UCI has also examined whether sufficient information on emerging technologies is available to first responders to affect actual implementation. To assess this, UCI is developing a platform that will be shared with first responders that estimates (in near real-time) the post-event state of the emergency response system (i.e., hospital and emergency care system).

- During the summer (2004), *UIUC (Winslett)* is investigating emergency response procedures in Champaign-Urbana. While their motivation is to determine how trust negotiation could be deployed to aid resource and information sharing between organizations during crisis response, expectations are to learn additional information that will be helpful to researchers elsewhere in the project. They are currently studying Champaign County's disaster response plan, and will then interview key players in the county for responding to three different types of disasters, including both natural and man-made. At the end of the summer, they plan a visit to Los Angeles to determine how what we have learned carries over to emergency response in Los Angeles. *Tierney (Colorado)* is helping UIIC in planning and executing this effort, and UIUC's activities will be coordinated with Colorado's.
- When first responders arrive at a disaster situation, they may initially saturate their senses of vision and hearing with real-time information or may have their functional vision and hearing reduced in a smoky or loud environment. These responders also must stay on track while following a route on foot despite distraction and disorientation. *UCSD (J. Miller, R. Rao)* has developed a prototype for the Navitron-Go system, which demonstrates how a first responder would use sense-of-touch to follow a pre-defined route. Navitron-Go requires the first responder to rely on his own senses for collision avoidance and personal safety. Navitron-Go provides a sense-of-touch guidance system that directs the first responder along the route only using the sense of touch. A pointer on a dial (like a hand on a clock) rotates clockwise and counterclockwise to guide the first responder left or right. The system gives a short buzz for go and a long buzz for stop. The system slides a knob right and left to show the first responder if he is closer or farther from his destination. The knob's position also may show the approximate time left to complete the route. The prototype consists of a guiding device connected via an RF link to a tactile guide. The tactile guide should be held in the hand. The prototype requires a human guide who has line-of-sight to the user. The prototype has applications for computer-guided systems.
- First responders to a disaster situation may have to depend on other senses than their vision in a smoky environment or while wearing a hazmat suit. These responders also need to stay on track while following a route on foot despite distraction and disorientation. The demonstration platform is a laptop computer running Windows 2000 and using screen reading software to voice audio cues. *UCSD (J. Miller, R. Rao)* has developed a system which shows how a GPS system and audio cues via a cell phone could be used to guide a first responder. Cal-GIS allows the creation and preview of non-visual information describing a pedestrian route. A first responder can use Cal-GIS in real-time while walking a route to speak the distance and bearing of the nearest waypoint. The software speaks the distance between neighboring waypoints and corresponding estimated trip time and estimated number of steps between waypoints.
- *UCSD (Chockalingam, R. Rao)* has created a Mobile Command and Control (MCC) Center for Crisis Mitigation. The MCC is an end-to-end architecture that aids first responders in crisis field monitoring. It helps them gather critical information from the crisis scene in the form images, video and audio using mobile devices cell phones on the field, automatically time and location stamp them and relay it back to the control center. The events are automatically populated in a GIS database. The control center agents can view these events coming in from the crisis scene based on priority and location. The architecture allows for bi-directional communication

between the control center and the first responders. The agents can message the first responders in the form of text messages or voice calls in groups or on an individual basis.

- Within disasters and other large-scale crisis situations, individuals attempt to obtain information from both formal (e.g., disaster warnings) and informal (e.g., rumors) sources. In this first year, *UCI (Butts)* has modeled the propagation of crisis information within social networks, using extrapolative simulation based on data drawn from various archival sources. Analysis of sequential communication data shows substantial differences in the retention and spurious appearance rates of different terms, consistent with past theories predicting the "sharpening" and "leveling" of informant accounts over multiple iterations. While these theories have often been held to run counter to ethnographic observations of complex (and often wildly inaccurate) rumors during times of crisis, simulation of message passing chains suggests that this is not the case: while reduction in signal complexity is common in early iterations of the chain, long-running chains (as can arise during periods of heightened tension, particularly within densely clustered networks) eventually give rise to signals containing numerous spurious elements. These simulations are bolstered by analytical results showing the expected information loss over time, as well as the long-run convergence of signals to a "noise barrier" of background chatter.

  The results obtained as part of this project are expected to advance our understanding of the information diffusion process within large populations -- an important consideration in the design of effective disaster warning systems. Current efforts are directed toward the modeling of more complex network structures, and to population-level analysis.

Testbeds

Transportation Testbed

The goal of this testbed is to provide a platform for testing and validating information technology and social science research within the context of regional crisis response. In facilitating this goal, four major research thrust areas are identified: 1) information collection; 2) information analysis; 3) information sharing; and 4) information dissemination. Some of the key considerations that are being addressed include:

1. Testbed must allow a real-world evaluation of the efficacy of information technologies in crisis response.
2. To test, evaluate and validate information technology research, the testbed has been setup to include two major components: an information technology and social science (IT-SS) component, and a simulation component.
3. The purpose of the IT-SS component is to develop methodologies and tools that will allow for more rapid evaluation of damage in large disasters, for better communication of data and information between critical response organizations (e.g., first responders, decision-makers) and the public. The ultimate goal of these technologies is to mitigate the secondary impacts of large regional disasters, i.e., preventing cascading failures or incidents.
4. The purpose of the simulation component is to serve as a surrogate for real-world conditions in a disaster. This component must be able to simulate results

with and without the use of improved information technologies in order to estimate their efficacies.

5. Information Technology and Social Science research shall include:
   - Dynamic data collection, e.g., loop sensors
   - Event extraction
   - Damage detection using remote sensing
   - Social networks, unreliable information analysis
   - Publish-subscribe based event integration
   - Real-time DEVO (Dynamic and Evolving Virtual Organizations) middleware
   - Trust management
   - Contextualize dissemination and robust ABC networking
   - Information diffusion models
   - Social factors and information release (panic modeling)
   - Evacuation and response
6. Simulation models will be used to approximate the following conditions or physical states: a) regional earthquake damage to buildings; b) casualty levels from building damage and exposure to hazardous materials; c) the fragility of critical bridge structures; d) traffic patterns – in a metropolitan context - before and after a large disaster, e.g., earthquake; e) the behavior of mass populations after large disasters; f) driver behavior in mass evacuations, g) incident reports from emergency response organizations, e.g., police, fire and ambulances; and h) the release and spread of gaseous hazardous materials.

Figure 2-2 shows key milestones for the transportation testbed. The figure separates the two major components of this testbed: simulation models and information technology research.

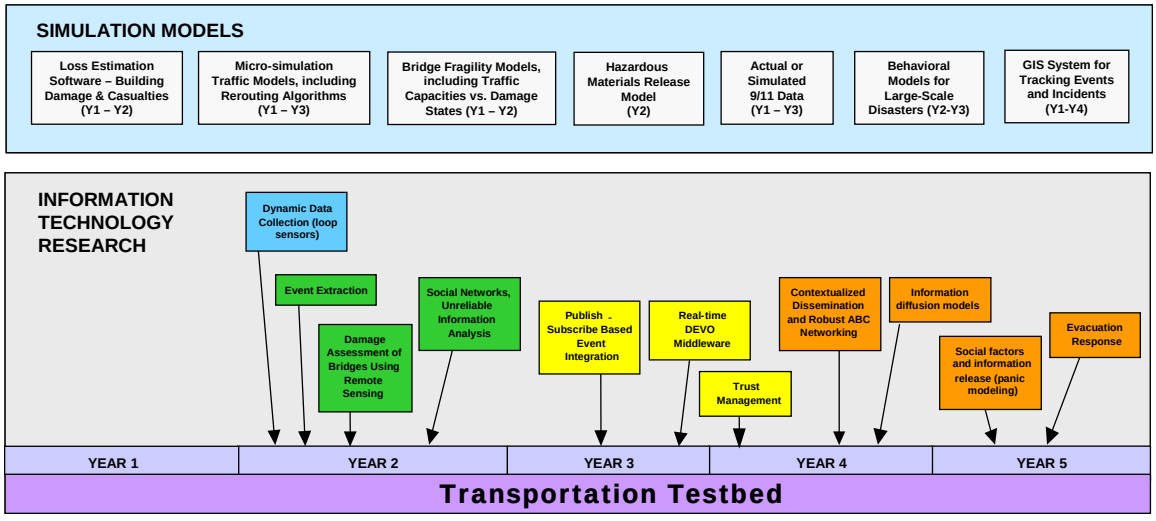

Figure 2-2. Key Milestones for Transportation Testbed

CAMAS Testbed

An initial CAMAS framework has been developed for campus level trouble reporting. It is enabling users to provide input via a web interface thus allowing the research team to monitor of a few key university facilities. Event classification and categorization techniques are being used to organize collected data. Collected data are currently being used to evaluate the event extraction and assimilation techniques developed.

The CAMAS project embodies the concept of "human as sensor" in the context of crisis response and recovery. The goal of the CAMAS system is to create the situation awareness by analyzing community input during crisis response. The testbed will provide a framework for testing and validating our research on multimodal event extraction, event representation, filtering, querying, analysis, mining and visualization. It will also facilitate social science research on information reliability and accuracy.

To drive the development of the system architecture, we have made use of a large body of UCI Facilities problem reports. This corpus represents more the normal day to day reporting of problems, rather than a crisis situation, but such a normal mode is important to establishing a baseline on which a crisis situation can subsequently be overlaid.

Demo System

The demo system provides a web-based interface for submitting a facilities problem, including a textual description of the problem. The problem can be one of 25 facility problem types (e.g., lock-and-key, plumbing, electrical, elevator, clean up, carpentry). Once the user submits a problem, the Extractor parses the problem text to extract events of interest. The extracted events are presented to the user, who can then select properly extracted events for submission to an event database. Visualization, query, and adaptive filtering tools then enable the user to examine events that have been entered into the database.

Database

The database currently holds about 7,000 of the 84,000 facilities reports available to us. This provides a substantial development, training, and testing corpus. Once work is completed to a sufficient extent with the subset, we will test, evaluate, and enhance system performance on the remainder of the corpus in stages. The database primarily represents problem reports and events extracted from them. Additional tables cover location (building, floor, and room number), date & time, event type, event attributes, and other pertinent information (such as the person assigned to fix a problem).

Extractor

The Extractor uses natural language processing methods to parse and extract pertinent events from a facilities problem report. While buildings are assumed to be part of the problem input, room numbers are typically contained in the problem report text and must also be extracted. The Extractor is also tasked with data sanitizing and pointing out spelling errors. The subset of 7,000 problem texts were used to help formulate lists of words and patterns relevant to each of the 25 facilities problem types.

One Extractor implementation focuses on primarily manual NLP-based methods for increasing accuracy and completeness in processing the corpus. This serves as a baseline for more research-oriented approaches. This method relies on the commercial VisualText development environment and the TAIParse general parser provided with it. A second Extractor focuses on more research-oriented methods (such as TF/IDF) to automate the extraction to the extent possible.

Visualization & Query

The events visualization tool for CAMAS is built using 3D-GIS software called ArcScene. The entire GIS data for the UCI campus is obtained in different formats such as vector, raster, and CAD and are integrated together to form a sophisticated completely geo-referenced framework for visualization. The events are pulled from the events database and visualized as points on top of the existing framework. For example, an event in the ICS building will be shown as a point on top of the ICS building. The system can handle multi-granular levels of location information such as building, floor, room, etc.

User query interfaces are built to help the user visualize events according to multiple criteria such as event type, location, time, etc. The user can also have access to multi-media resources concerning an event such as photos, videos, etc. In reality these resources could be live video feed or live photographs from the disaster site. This helps the first responders in assessing the situation better. CAD maps of buildings are integrated into the system, which helps the user pull the detailed floor level plans of an event. This will be very useful while charting evacuation plans during fires.

The main challenge in building the system is the integration of GIS data. The co-registration of different GIS data is a difficult task and cannot be automated easily. Hence, a major share of the time was spent on performing this task. Another major challenge has been visualizing large numbers of events. When the number of events become large, we need more efficient models to summarize the events to the user. In reality, multi-resolution models can be built which will help visualize events at different spatial resolutions.

Adaptive Filtering

The adaptive filtering prototype demonstrates the concept of personalized event dissemination. It employs a HP iPAQ PDA with a GPS receiver to relay location and time stamped multimodal data to the control center. Clients use ARC View/Pad to display events in real time, and use TCP/IP stream sockets to relay user feedback to the server. The server monitors the event database and dynamically pushes events to clients based on the client profiles and dynamic refinements by the clients.

This work employs database technology, emphasizing adaptive filtering, similarity-based retrieval, and query refinement based on relevance and dynamic user refinements.

Software

ArcScene - Visualization and query of facilities events.
ArcMap - Visualization and adaptive query of facilities events.
ECW - Visualization plug-in.
IBM DB2 - Database for one version of the CAMAS demo. Facilities data and events.

JSP (Java Server Pages) - For construction of a web-based interface.
Java - For code underlying the web-based interface.
MS Visual Studio .NET - Underlies other required tools.
MySQL - Database for one version of the CAMAS demo.
TomCat - Server software for web-based interface.
VB (Visual Basic) - For visualization code.
VisualText & TAIParse - For information extraction, sanitizing, data cleaning, database load.

Datasets

UCI Facilities data
Use: Primary input and development corpus for the CAMAS system.
Size: 84,000 problem reports covering years 2000-2004. 24MB. 25 major problem types.
Source: http://www.fm.uci.edu

UCI Building and room data
Use: Location knowledge for the CAMAS system.
Size: 500 buildings, 18495 rooms.
Source: http://datawarehouse.uci.edu (restricted access)

UCI map data
Use: Visualization and query.
Size: 46 MB
Source: UCI Facilities Management

CAD data
Use: Visualization and query.
Size: 46 MB
Source: UCI Facilities Management

GPS data
Use: Visualization and query.
Size: 1 KB
Source: Self survey.

GLQ Testbed

The Gas Lamp Quarter (GLQ) testbed consists of a rapidly deployable mobile networking, computing, and geo-localization infrastructure in the context of incident-level response to spatially localized disasters such as the World Trade Center attack. The testbed focuses on situations where the crisis site either does not have an existing infrastructure, or alternatively, the infrastructure is severely damaged. This testbed focuses on supporting basic services essential to the first responders that can be brought over to crisis sites for rapid deployment. Such services include communication among the first responders, accurate geo-localization both inside and outside of buildings, in urban as well as rural areas, computation infrastructure, incidence level command center, and technology to support information flow from/to crisis sites to/from regional emergency centers.

The primary demonstration study will be in the context of localized incident management in the Gas Lamp district in downtown San Diego. The Gas Lamp Quarter will be

instrumented in partnership with the civic authorities and the San Diego Police Department. This 10 block historic region adjoins the San Diego convention center, sports stadiums as well as city, county and federal facilities and is described as Southern California's premier dining, shopping and entertainment district. Some of the key issues that will be addressed in this testbed are discussed below.

Deploying a Network as a Living Lab

For this testbed, there is a need to have a reliable and controlled wireless network that covers the Gas Lamp Quarter area in downtown San Diego. Although there are several wireless ISPs in that area, most of them provide patchy coverage and their systems are not always reliable.

The RESCUE project is in a good position to design and deploy its own network to cover that area. This will give researchers the opportunity to have a more reliable network that is fully under their control. The following issues are being addressed as we study possible solutions for this deployment:

Frequency Band: The system can be deployed in an unlicensed band and use standard off-the-shelf equipment. This will reduce costs significantly. Our approach is to have a *hybrid network* design. While using the standard 802.11b for reaching end-users, 5.2 GHZ and 5.7 GHz will be used for backhauls to increase capacity. The other opportunity is using Ensemble (a San Diego based company)/XO partnership. Recently, Ensemble and XO announced that they can provide equipment and spectrum to support any wireless deployment in the Downtown San Diego area. This can increase the reliability of the system since this system can be operated in the license band.

Site Acquisition: Sentre Partners, one of the leading real estate companies in San Diego, has already committed itself to a related project to promote the city. They have three of the tallest buildings in downtown area. By using their rooftops, it will be easy to have a large footprint and cover the downtown area.

Backhauls: The cost of the backhaul is the most important factor that should be considered for the long-term. It is possible to involve some of the telephone companies, i.e., Verizon or SBC, to provide the backhaul. However, there is also a possibility for using under-utilized bandwidth in the buildings above to connect our base stations to the network. Sentre Partners, the owner of NBC building, is committed to providing access and enough bandwidth for this testbed.

Network Architecture**:**

As it is shown in Figure 2-3, the GLQ is divided into three different zones. Each zone has its central post that has LoS to the top of NBC building. The transmitter on top of NBC building provides the broadband access to these three lampposts via a 5.2 – 5.7 GHz backhaul (the red points). By using Tropos Networks 5110 outdoor units (the green points), the coverage of three zones will be expanded and we are able to provide the support for standard 802.11b users. 5110 units will find each other and mesh together using standard ISM band and they will also act as an 802.11b access point for the end users. Therefore, it will be possible (by connecting three locations to the network) to cover a large area. Also by having three entry points, the reliability of the system will increase in case of outage for one of the backhauls. Three lampposts with backhaul

connectivity (5th and Market, 5th and E, and 4th and G) will have a Motorola Canopy receiver and a Tropos 5110 unit installed, see Figure 2-4. The others will just have a Tropos 5110 unit installation. Provision of power is the only major requirement for the operation and it has been tested on these same lampposts as part of a Super Bowl experiment. The 802.11b cells communicate with each other wirelessly through a mesh routing algorithm implemented within the access points. The control protocol is part of Tropos Sphere operating and management tool.

The network topology is based on standard centralized routing. All the routing and switching is managed centrally. The backhaul links will act as pure second layer channels, whereas the 802.11b access points will do the DHCP server functionality locally. The system will support mobility based on TCP and VPN session persistent roaming without client software upgrade. The system will be managed remotely through a web-based management tool for the Tropos and standard SNMP.

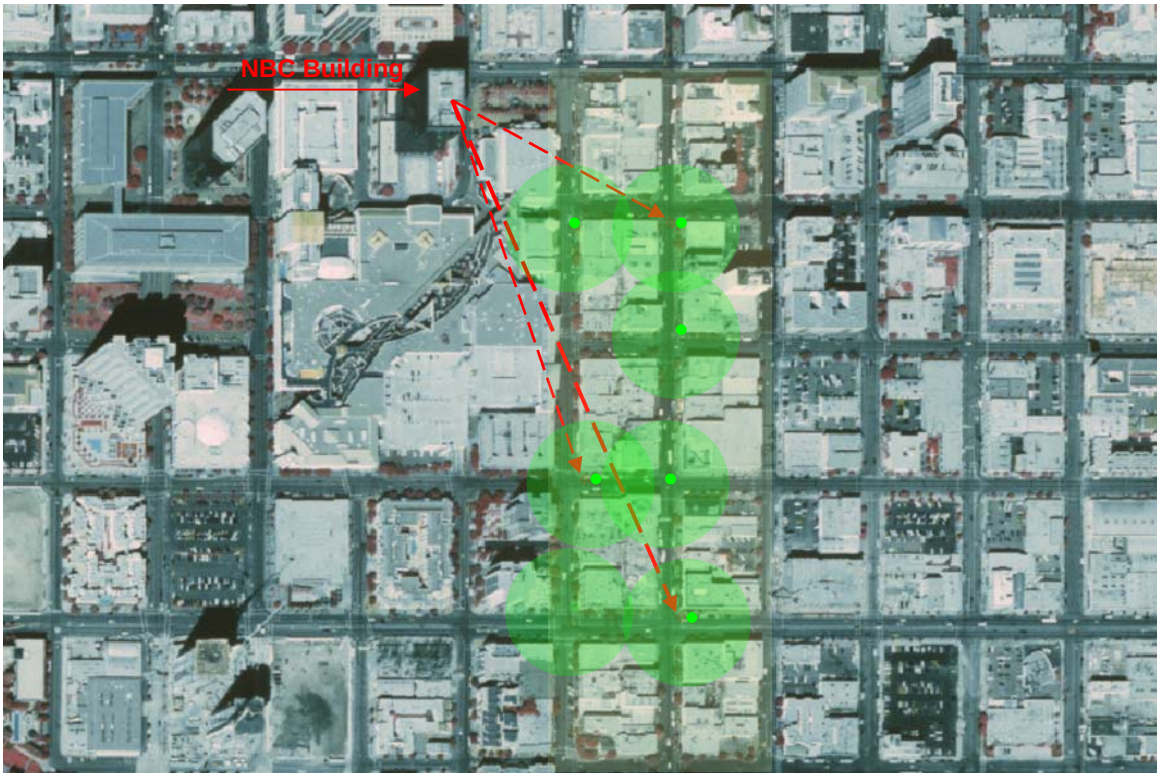

Figure 2-3. GLQ Setup including Location of Three Major Zones

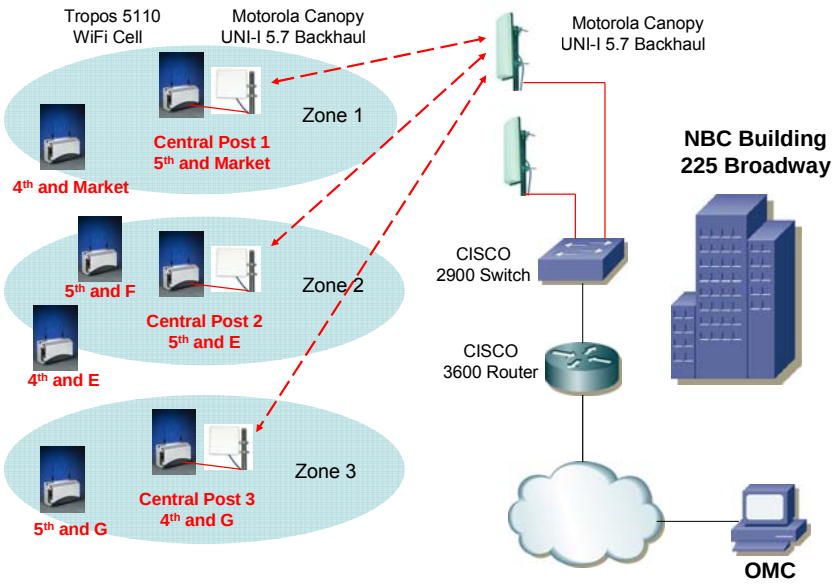

Figure 2-4. Central Posts to be used in GLQ Testbed

The deployment plan is divided into three phases:

- Phase 1 (Proof of concept): In this phase, the inter-operability of the system will be tested in a controlled environment (lab). This includes setting up one zone and using the backhaul radio link and networking gear.
- Phase 2 (Test deployment): In this phase, the tested zone will be deployed and real measurements will be performed to check and confirm the operational parameters of the testbed. The monitoring software will be also tested in the real environment.
- Phase 3 (Final deployment): In this phase, the other two phases will be deployed. Final tests and optimization will be done to adjust the network.

2.2 Opportunities for Training and Development provided by the Project

Because all members of the research team are working on closely-related problems, by necessity, diverse areas of expertise are united by a common task set. We expect students supported by this grant to develop a more diverse skill set, to obtain familiarity with a wider range of scientific literature, and to be better able to bridge disciplines in their own work than their traditionally-trained peers. This group of younger researchers form a community that is held together not only by the high scholarship expected of post graduate researchers but also by a shared bond of applying scientific and technological methods to deal with the universal sense of horror that the events of September 11th unleashed. Outside of their own scientific domains, we expect this unique experience to motivate our students to serve in the community as scholar-citizens who can articulate modern approaches to understanding vulnerability and threats and responding to crisis and in doing so help reduce the public anxiety about, rare, unexpected events. Some of the specific activities which promote training and development opportunities are listed below:

- A summer exchange program involving RESCUE organizations has been initiated. Current plans include: 2 UCI students going to UCSD; 1 University of Illinois student going to University of Colorado; 1 UCI student going to ImageCat; 1 University of Colorado student going to UCI.
- A summer internship program is being initiated with organizations that comprise our Community Advisory Board (CAB). Specifically, 1 graduate student from UCI and 1 postdoctoral researcher from U. of Colorado will be working at the City of Los Angeles to help understand how emerging information technologies can help to improve crisis response and what approaches are effective in improving dissemination of emergency planning information using the Internet.
- Creation of a multidisciplinary laboratory (RESCUE Center) that collocates students and faculty from a variety of disciplines – social science, engineering, and computer science to facilitate meaningful interactions. Furthermore, we have created two courses that all students in the RESCUE project must take. The first course is one which focuses on the social science issues related to crisis response. The second is an IT course which introduces possible roles of IT in emergency planning and response.
- Weekly RESCUE meetings started in October 2003 to allow students, faculty and government partners to share in research findings, to discuss possible implications of research, and to identify additional opportunities to leverage current research to address timely issues or problems. The typical attendance for these meetings has been about 25 people.
- Our instructional approach provides an enriched environment of broad base training that goes well beyond the usual one-mentor, one-lab, one-topic arrangement. Thus, for example, computer science students associated with the project have the opportunity to work on problems relating to social network analysis, information diffusion through human populations, and organizational design -- problems which they would not otherwise be exposed. Similarly, social science students working on grant-related projects are being challenged to consider issues involving the interaction of information technology with large-scale social systems, and the design of data collection and decision support systems. Both groups are interacting with faculty whose interests run the gamut from data analysis and storage systems, to software engineering, to social science, thereby facilitating further cross-disciplinary collaboration.
- To ensure that cross-disciplinary goals are met, we are convening special workshops, seminars, demonstrations, and field trips to bring researchers and public safety personnel together. Close and ongoing interaction between the research team and various public safety and emergency management organizations is essential to discovering the real needs, priorities, constraints and processes followed by crisis management personnel. We will also ensure that the research findings and accomplishments are regularly and systematically shared with our collaborators from these organizations. This will have the effect of educating the research community on the needs that first responders experience and at the same time educate the responders on the kinds of technologies and solutions that are possible.

2.3 Outreach Activities the Project has Undertaken

Outreach to the First Responder Community:

- A PI workshop/kickoff meeting was held on November 24, 2003. The purpose of this meeting was to introduce project goals and objectives to potential researchers on this project, and to provide an opportunity for these researchers to share ideas and discussion on research priorities. This meeting was attended by over 65 participants, including several government partners.. As a result of this meeting, many new collaborations within academia emerged.
- The creation of a Community Advisory Board to help advise and guide research staff. In addition, the CAB will also provide testbeds for many research products. The current members include:

    - Ellis Stanley, City of Los Angeles, CAB Chair
    - Karen Butler, City of San Diego Police Department
    - Dawna Finley, City of Irvine
    - Bob Garrott, Los Angeles County Office of Emergency Management
    - William Maheu, City of San Diego Police Department
    - Paulette Murphy, SPAWAR
    - Eileen Salmon, City of Irvine
    - James Watkins, Governor's Office of Emergency Services

- First Community Advisory Board meeting held on February 23, 2003. The purpose of this meeting to seek input on research priorities and potential collaborations (e.g., testbeds, internships, provision of datasets, etc.)
- Establishment of student internship program with the City of Los Angeles. Currently, two RESCUE students will be working with the city over the summer of 2004. For example, Mayur Deshpande from UCI will be working on exploring the role of web technologies and the internet in the context of information and advisory dissemination.
- RESCUE has officially established a partnership with UCI emergency officers. Plans have been sketched out for a campus level drill in the 2004.

Outreach to Industrial Partners:

- In 2004, RESCUE will be establishing an Industry Affiliates Group (IAG) to begin attracting potential sponsorship of research in future years. In addition, this collaboration will also serve to identify testbeds that ultimately will lead to widespread adoption or commercialization of research products.
- RESCUE has established a collaboration between AT&T and Cal-IT2 in spoken language understanding. RESCUE has requested supplemental fund in order to enhance this collaboration in the area of crisis management and response.

The following RESCUE students are serving as interns this summer at these companies or organizations:

- Ramakrishnan Hariharan (UCI) – Microsoft Research – will be working on GIS-related data management and web services
- Wenyi Zhang (UCSD) – AT&T Research Laboratory – will work with speech recognition group.
- Qi Han (UCI) – IBM Yorktown.

Outreach to community:

The following keynote addresses and invited talks have been delivered as part of the RESCUE outreach effort:

- Sharad Mehrotra – Keynote address at Cal-IT2 workshop at UCI, November 3, 2003.
- Sharad Mehrotra – Invited talk at Cal-IT2 workshop at UCSD, September 2003.
- Sharad Mehrotra – Invited talk on the RESCUE project at SPIE conference on Internet Imaging, January 18-22, 2004.
- Marianne Winslett, An Introduction to Trust Negotiation. Presented at the University of Illinois at Chicago, April 2004; North Carolina State University, May 2004; the University of Pittsburgh, March 2004.
- Ron Eguchi, The RESCUE Project, Invited talk at the 6th Wireless Internet - Data and Enterprise Applications Conference at UCLA, May 4-5, 2004.
- IT demonstrations at annual Cal-it2 day meetings.
- IT demonstrations at CAB meeting, February 23, 2004.
- Ramesh Rao, House Science Committee briefing on October 24, 2003 on the RESCUE effort. The members included Rep. Vern Ehlers (R-MI) - Chair of the Subcommittee on Environment, Technology and Standards; Rep. Nick Smith (R-MI) - Chair of the Subcommittee on Research; Rep. Jerry Costello (D-IL) - third most senior minority member of the Committee on the Subcommittee on Energy. Representative Smith was particularly interested in discussing NSF research and grants issues, and expressed satisfaction at the sort of support RESCUE had received from NSF. Ramesh has also briefed Dr. Mel Bernstein, DHS Director of University Programs and Fellowships, about RESCUE and WIISARD at a meeting organized by Vice Provost for Research, at the Office of the President of the University of California System.
- Sharad Mehrotra, Invited talk at the UCI/FDA Consortium on Agroterrorism: networks, expert systems, risk communication, and fast tracking diagnostic in response US FDA 19701 Fairchild Avenue, Irvine, Ca June 8, 2004.
- Sharad Mehrotra, Invited panelist in the Technolink Association Technology Trends Forum, 2004 (June 8, 2004).
- Sharad Mehrotra, Invited plenary talk on "Information Technology Challenges in Crisis Response" at the 1st Workshop on Database Issues in Virtual Organization (held in conjunction with SIGMOD 2004), Paris, France, June 17, 2004.

- Nalini Venkatasubramanian, UCI TekTalk Series invited talk on “Multimedia Support for Homeland Defense Applications,” at University Research Park, March 18, 2004.

- Marianne Winslett, Invited plenary talk on "Challenges in Virtual Organization" at the 1st Workshop on Database Issues in Virtual Organization (held in conjunction with SIGMOD 2004), Paris, France, June 17, 2004.

- Ramesh Rao - keynote talk at Cal-IT2 workshop at UCSD, September 2003

- Ramesh Rao - keynote talk at Cal-IT2 All Hands Meeting at UCSD, March 13 2004

- Ramesh Rao - invited talk at UCSD Committee on Academic Personnel meeting, June 3 2004

- Ramesh Rao - participation in NSF ITR PI Meeting, June 10-11 2004

- Ramesh Rao - invited talk at Workshop on Cross-Layer Issues in the Design of Tactical Mobile Ad Hoc Wireless Networks: Integration of Communication and Networking Functions to Support Optimal Information Management, organized under the auspices of Task Group 12 of the NATO Research and Technology Organization's Information Systems Technology Panel, US Naval Research Laboratory, Washington, DC, June 2-3, 2004

- Ramesh Rao - invited demonstration at NSF Digital Government workshop, May 24-26, 2004

- Ramesh Rao - invited talk at DS2: Deep Space 2 Workshop 2004, Jet Propulsion Laboratory, Pasadena, CA, April 26-28, 2004

- Ramesh Rao - invited talk for CalTrans at UCSD on Homeland Security interests, March 11, 2004

- Ramesh Rao - invited talk at Lawrence Livermore National Laboratories, March 5, 2004

- Ramesh Rao - invited talk at University of Pennsylvania, February 2, 2004

- Ramesh Rao - invited talk at Accelerating Trustworthy Internetworking (ATI) Workshop, Atlanta, GA, January 21-23, 2004

- Ramesh Rao - invited talk at NSF Wireless Networking PI Meeting, Charleston, SC, January 14, 2004

- Ramesh Rao - participation in Meeting to Discuss Homeland Security Initiatives at UCSD, with C. Caulfield, L. Lenert, P. Linden, M. Sailor, W. Trogler, January 6, 2004

We would like to also point out that our team created a workshop series called "Database Issues in Virtual Organizations (DIVO)" that was held in conjunction with the SIGMOD conference. ACM SIGMOD is arguably the flagship conference on data management. This year, SIGMOD was held in Paris, France and DIVO was held on June 17, 2004. The program consisted of contributed papers, a panel, and invited talks by specialists in various areas of interest to crisis response. DIVO was attended by approximately 20 researchers from the database community. It featured talks by two of the members of the Rescue team Marianne Winslett and Sharad Mehrotra as well as 4 other talks by specialists. It also included a panel of experts from industry, academia, and government.

In addition, the CAMAS project was chosen to be demonstrated at SIGMOD 2004.

Finally, members of our team organized and hosted the NSF crisis response workshop in 2003 at San Diego and also a similar workshop in Irvine in 2002 which included representatives from industry, academia, and government.

Educational Outreach:

- (UCI) Two new interdisciplinary courses relating to Rescue Project have been introduced: SOCIOL 289 (Issues in Crisis Response) which was taught by Carter Butts in Winter 2004 quarter. The web site for this course can be found at http://eee.uci.edu/04w/69797.

  Course Description (Issues in Crisis Response):

  By their very nature, disasters and other crisis situations represent unusual scenarios which stretch the limits of existing social and physical infrastructure. This course will survey a range of issues involved in the effective assessment of and response to crisis situations. Emphasis will be placed on the intersection of technical and social scientific challenges involved in the crisis response process, including the use of potentially unreliable informant reports, sampling of hard-to-reach populations, modeling of rare/extreme events, and deployment of information systems in unfavorable environments. In addition to reviewing relevant literature, students in this class will develop their own research projects involving crisis response, and opportunities will be provided to present this work to the class as a whole. The course included readings in topics related to crisis response and included student projects.

  ICS 280 (Special topics on information technology to support homeland security) was taught by Sharad Mehrotra in Spring 2004.http://www-db.ic.suci.edu/ics280. This course covered variety of research topics including topics on data collection, analysis, and mining in the context of homeland security. Specifically, topics on privacy challenges, intelligence analysis tasks were discussed. Students also learnt about existing E911 services, localization technologies, as well as sensor database management.

- Research products and findings from RESCUE were also introduced into several other class curricula. For example, Nalini Venkatasubramanian's class on distributed systems middleware led student teams to work on various topics relevant to effective crisis response. One such project is *Privacy Preserving*

Data Collection for Media Spaces. The use of media spaces, and in particular, forms of surveillance are quickly becoming an integral part of crime control policy, crisis management, social control theory and community consciousness. Providing automated techniques in order to preserve the privacy of subjects – as well as aid in detecting anomalous behavior by filtering out 'normal' behavior – is desirable in these environments.

This class project developed an architecture for demonstrating the capability of privacy preservation techniques for media spaces. The idea was to fuse video with other sensor data (namely, Radio Frequency Identification or RFID) and use that information to enforce access control policies within a media space. The work provides an underlying RFID framework and accompanying video processing techniques that in conjunction with our policy language makes decisions on under what conditions and how information is collected in a media space.

- At UCSD, under the direct supervision of Ramesh Rao, RESCUE postdoctoral student John Miller, Ph.D., led a UCSD Electrical & Computer Engineering projects course Winter and Spring quarters of 2004. One of these teams developed a device they called "Navitron-Go," a sense-of-touch guidance system which has relevant applications for first responders in disaster situations. The device is a radio-powered, remote guidance directional device with a tactile interface, accounting for situations in which a first responder's other senses (sight, hearing) may be otherwise occupied or inhibited based on the circumstances of the disaster (for example, an earthquake or fire could cause dust or smoke inhibiting the responder's vision, as well as making previously familiar terrain unrecognizable, requiring other methods for determining location and best path for travel). This research project is ongoing, and intends to eventually incorporate magnetic compass and Global Positioning Satellite (GPS) technologies to geo-locate and direct the first responder without the aid of a remotely located human being. This activity was implemented by a team of undergraduates who interfaced with personnel on the RESCUE project, and demonstrated desire to continue the project (hence continuation over two quarters what was normally a one-quarter project).

- (UCSD) PI Ramesh Rao applied for and received a Research Experience for Undergraduates (REU) supplement to the RESCUE grant, which will support one undergraduate student to work closely with Postdoctoral Researchers on the RESCUE project, as well as with senior research personnel, to supplement and enhance RESCUE research efforts for one summer. The student will be making advances in the area of location-based service applications currently being developed to provide highly accurate location readings in cases when GPS is not able to provide a reading or is inaccurate (indoors or in undeveloped areas where location cannot be accurately triangulated based upon road locations, for example). Student will assist in programming software which will increase the accuracy of such assisted-GPS systems, and furthermore will help develop first responder applications for these technologies.

3. Publications and Products

3.1 Journal publications and conference proceedings

General RESCUE papers:

1. Mehrotra, S., Butts, C.T., Kalashnikov, D.V., Venkatasubramanian, N., Altintas, K., Hariharan, R., Lee, H., Ma, Y., Myers, A., Wickramasuriya, J., Eguchi, R., Huyck, C. 2004. "CAMAS: A Citizen Awareness System for Crisis Mitigation." SIGMOD 2004, June 13-18, Paris, France.

2. Mehrotra, Sharad, Butts, C.T., Kalashnikov, Dmitri V., Venkatasubramanian, Nalini, Rao, Ramesh, Chockalingam, G., Eguchi, R., Adams, B., and Huyck, C. 2003. "Project RESCUE: Challenges in Responding to the Unexpected." *SPIE Journal of Electronic Imaging, Displays, and Medical Imaging*, 5304, 179-192. December, 2003. Invited paper, IS&T/SPIE 16th Annual Symposium. San Jose, CA, January 18-22, 2004.

3. Tierney, K. 2004. "Collective Behavior in Times of Crisis." Invited paper presented at the National Research Council Roundtable on Social and Behavioral Sciences and Terrorism, Meeting 4, "Risk Communication for Terrorism." Washington, DC, National Academies, January 30, 2004.

4. Tierney, K. "Responding Effectively to Extreme Events: Reality Versus Assumptions." Invited presentation at the Biosecurity 2003 conference, sponsored by the Harvard School of Public Health and the Harvard Medical School, Washington, DC, October 22, 2003.

Information Collection:

5. Achler, O. and M. M. Trivedi, "Vehicle Wheel Detector using 2D Filter Banks," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted June 2004.

6. Elgamal, A., J. P. Conte, M. Fraser, S. Masri, T. Fountain, A. Gupta, M. M. Trivedi, M. El Zarki, "Health Monitoring for Civil Infrastructure," *9th Arab Structural Engineering Conference (9ASEC). Abu Dhabi, United Arab Emirates,* November 29 - December 1, 2003

7. Han, Qi, Sebastian Gutierrez-Nolasco and Nalini Venkatasubramanian. Reflective Middleware for Integrating Network Monitoring with Adaptive Object Messaging. *IEEE Network, Special issue on Middleware Technologies for Future Communications Networks*, January/February 2004.

8. Han, Qi, Sharad Mehrotra and Nalini Venkatasubramanian. Energy Efficient Data Collection for Distributed Sensor Environments. The 24th IEEE International Conference on Distributed Computing Systems (ICDCS), Tokyo, Japan, March 23-26, 2004.

9. Han, Qi, Matthew Ba Nguyen, Sandy Irani and Nalini Venkatasubramanian, Time-sensitive Computation of Aggregate Functions over Distributed Imprecise Data. The 12th IEEE International Workshop on Parallel and Distributed Real-time Systems (WPDRTS) (In conjunction with IPDPS 2004), Santa Fe, New Mexico, April 26-27, 2004

10. Han, Qi, and Nalini Venkatasubramanian. Addressing Timeliness/Accuracy/Cost Tradeoffs in Information Collection for Dynamic Environments. The 24th IEEE International Real-time Systems Symposium (RTSS), Cancun, Mexico, December 3-5, 2003.

11. Han, Qi, and Nalini Venkatasubramanian, Information Collection Services for QoS-based Resource Provisioning for Mobile Applications. *IEEE Transactions on Mobile Computing,* in revision.

12. Han, Qi, and Nalini Venkatasubramanian, Real-time Collection of Dynamic Data with Quality Guarantees. Technical Report TR-RESCUE-04-22. 2004. Submitted for publication.

13. Hore, Bijit, Sharad Mehrotra, and Gene Tsudik. Privacy-Preserving Index for Range Queries. Technical Report TR-RESCUE-04-18. To appear, VLDB 2004.

14. Huang, K. and M. Trivedi, "Robust Real-Time Detection, Tracking, and Pose Estimation of Faces in Video Streams" *Proceedings of International Conference on Pattern Recognition 2004,* Accepted June 2004.

15. Lazaridis, L., Qi Han, S. Mehrotra and Nalini Venkatasubramanian. Fault-Tolerant Evaluation of Continuous Selection Queries over Sensor-Generated Data. Technical Report TR-RESCUE-04-17. Submitted for publication, March 2004.

16. Lazaridis, L., Qi Han, Xingbo Yu, Sharad Mehrotra, Nalini Venkatasubramanian, Dmitri Kalashnikov and Weiwen Yang, QUASAR: Quality Aware Sensing Architecture, *ACM SIGMOD Record*, March 2004

17. Lazaridis, L., and Sharad Mehrotra. Approximate Selection Queries over Imprecise Data. International Conference on Data Engineering (ICDE 2004), Boston, March 2004.

18. Rao, B.D.; Engan, K.; Cotter, S.F.; Palmer, J.; Kreutz-Delgado, K. Subset selection in noise based on diversity measure minimization. *IEEE Transactions on Signal Processing*. Volume: 51, Issue: 3, March 2003. Pages:760 – 770.

19. Srinivasan, V.; Chiasserini, C.-F.; Nuggehalli, P.S.; Rao, R.R. Optimal rate allocation for energy-efficient multipath routing in wireless ad hoc networks. *IEEE Transactions on Wireless Communications.* Volume: 3, Issue: 3, May 2004. Pages:891 – 899.

20. Trivedi, M. M., K. Huang, and I. Mikic, “Dynamic Context Capture using Distributed Video Arrays for Intelligent Environments,” *IEEE Transactions on Systems, Man and Cybernetics, Special Issue on Ambient Intelligence,* Submitted October 2003.

21. Wickramasuriya, J., M. Datt, S. Mehrotra, and N. Venkatasubramanian. Privacy Protecting Data Collection for Media Spaces. Technical Report TR-RESCUE-04-21. Submitted for Publication 2004.

22. Wu, J. and M. M. Trivedi, "Resolution Enhancement by AdaBoost" *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

23. Yu, Xingbo, Sharad Mehrotra, Nalini Venkatasubramanian, and Weiwen Yang. Approximate Monitoring in Wireless Sensor Networks. Technical Report TR-RESCUE-04-16. Paper under submission.

24. Yu, Xingbo, Koushik Niyogi, Sharad Mehrotra, and Nalini Venkatasubramanian. Adaptive Target Tracking in Sensor Networks. The 2004 Communication Networks and Distributed Systems Modeling and Simulation Conference (CNDS'04), San Diego, January 2004.

Information Analysis:

25. Adams, B.J., C.K. Huyck, R.T. Eguchi. Post-Earthquake Reconnaissance using Satellite Imagery: Boumerdes Case Study, by (2003), EERI Reconnaissance Report on the May 21, 2003 Boumerdes, Algeria Earthquake, EERI.

26. Adams, B.J., C.K. Huyck, R.T. Eguchi, F. Yamazaki, M. Estrada, and C. Herring. QuickBird Imagery of Algerian Earthquake used to Study Benefits of High-Resolution Satellite Imagery for Earthquake Damage Detection and Recovery Efforts (in press), by *Earth Imaging Journal*.

27. Afrati, Foto, Chen Li, Prasenjit Mitra. On Containment of Conjunctive Queries with Arithmetic Comparisons. EDBT, Crete, Greece, March 2004.

28. Butts, C.T. An Exponential Family of Permutation Models for Comparison of Adjacency Structures. 26th Sunbelt Network Conference (INSNA), April 2004. Portoroz, Slovenia.

29. Butts, C.T. Exact Bounds for Degree Centralization. Institute for Mathematical Behavioral Sciences Technical Report MBS 04-09, University of California, Irvine. 2004.

30. Butts, C. T. Latent Structure in Multiplex Relations. North American Association for Computational Social and Organizational Science Meeting, June 2004, Pittsburgh, PA.

31. Butts, C.T. and Leite, F. Bayesian Inference from Continuously Arriving Informant Reports, with Application to Crisis Response. Technical Report MBS 04-08, Institute for Mathematical Behavioral Sciences, University of California, Irvine. 2004. Also has been accepted for presentation at the American Sociological Association conference, San Francisco, CA, August 2004.

32. Dharanipragada, S., U. Yapanel, B.D. Rao. Robust Feature Extraction for Continuous Speech Recognition using the MVDR Spectrum Estimation Method. Submitted to the *IEEE transactions on Speech and Audio processing.*

33. Duni, E. R., Subramaniam, A. D. , Rao, B. D. Improved quantization structures using generalized HMM modelling with application to wideband speech coding. 2004 IEEE International Conference on Acoustics, Speech, and Signal Processing. Part vol.1, 2004, pp.I-161-4 vol.1. Piscataway, NJ, USA.

34. Fidaleo, D. and M. M. Trivedi, "Manifold Analysis of Facial Gestures for Face Recognition," *ACM SIGMM Multimedia Biometrics Methods and Applications Workshop,* November 8, 2003

35. Gandhi, T., and M. Trivedi**.** Motion Analysis for Event Detection and Tracking with a Mobile Omni-Directional Camera. *ACM Multimedia Systems Journal, special issue on Video Surveillance*. Accepted January 2004.

36. Gandhi, T. and M. M. Trivedi, "Motion Analysis of Omni-Directional Video Streams for a Mobile Sentry," *First ACM International Workshop on Video Surveillance,* November 7, 2003.

37. Gandhi T. and M. M. Trivedi, "Motion Based Vehicle Surround Analysis Using Omni-Directional Camera," *Proc. IEEE Intelligent Vehicles Symposium, 2004,* Accepted

38. Gustafsson, T.; Rao, B.D.; Trivedi, M. Source localization in reverberant environments: modeling and statistical analysis**.** *IEEE Transactions on Speech and Audio Processing.* Volume: 11, Issue: 6, Nov. 2003. Pages:791 – 803.

39. Jin, Liang, Nick Koudas, Chen Li. NNH: Improving Performance of Nearest-Neighbor Searches Using Histograms. EDBT, Crete, Greece, March 2004.

40. Kalashnikov, D. and S. Mehrotra. An algorithm for entity disambiguation. University of California, Irvine, TR-RESCUE-04-10.

41. Kalashnikov, Dmitri V., and Sharad Mehrotra. RelDC: a novel framework for data cleaning. RESCUE-TR-03-04.

42. Krotosky S. and M. M. Trivedi, "Occupant Posture Analysis using Reflectance and Stereo Images for "Smart" Airbag Deployment" *IEEE International Symposium on Intelligent Vehicles, Parma, Italy* To Appear 2004

43. McCall J. and M. M. Trivedi, "Pose Invariant Affect Analysis using Thin-Plate Splines" *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

44. Ma, Yiming, Sharad Mehrotra, Dawit Yimam Seid, Qi Zhong. Interactive Filtering of Data Streams by Refining Similarity Queries. Technical Report TR-RESCUE-04-15.

45. Ma,Yiming, Qi Zhong, Sharad Mehrotra, Dawit Yimam Seid. A Framework for Refining Similarity Queries Using Learning Techniques. Submitted for publication, 2004.

46. Murthy, C., Roh, J. C., Rao, B. D. Optimality of extended maximum ratio transmission. Sixth Baiona Workshop on Signal Processing in Communications. Servicio de Publicacions da Universidade de Vigo. 2003, pp.47-50. Vigo, Spain.

47. Srinivasan, Vikram, Pavan Nuggehalli, Chiasserini C. F., Rao, R. R. Cooperation in wireless ad hoc networks. IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428). IEEE. Part vol.2, 2003, pp.808-17 vol.2. Piscataway, NJ, USA.

48. Trivedi, M., K. Huang, T. Gandhi, B. Hall, and K. Harlow. Distributed Omni-Video Arrays and Digital Tele-Viewer for Customized Viewing, Event Detection and Notification. *Proceedings of International Conference on Information Technology 2004*, April 2004.

49. Trivedi, M. M., K. Huang, T. Gandhi, B. Hall, and K. Harlow, "Distributed Omni-Video Arrays and Digital Tele-Viewer for Customized Viewing, Event Detection and Notification" *Proceedings of International Conference on Information Technology 2004,* Accepted April 2004.

50. Wu J. and M. M. Trivedi, "High Frequency Component Compensation based Super-resolution Algorithm for Face Video Enhancement" *Proceedings of International Conference on Pattern Recognition 2004,* to appear.

51. Zorzi, M.; Rao, R.R. Geographic random forwarding (GeRaF) for ad hoc and sensor networks: energy and latency performance**.** IEEE Transactions on Mobile Computing. Volume: 2, Issue: 4, Oct.-Dec. 2003. Pages: 349 – 365.

52. Zorzi, M., Rao, R. R. Energy and latency performance of geographic random forwarding for ad hoc and sensor networks. WCNC 2003. 2003 IEEE Wireless Communications and Networking Conference Record (Cat. No.03TH8659). IEEE. Part vol.3, 2003, pp.1930-5 vol.3. Piscataway, NJ, USA.

53. Zorzi, M., Rao, R. R. Multihop performance of geographic random forwarding for ad hoc and sensor networks. GLOBECOM '03. IEEE Global Telecommunications Conference (IEEE Cat. No.03CH37489). IEEE. Part vol.7, 2003, pp.3948-52 vol.7. Piscataway, NJ, USA.

Information Sharing:

54. Cheng, S. and M. M. Trivedi, "Occupant Posture Modeling using Voxel Data: Issues and Framework" *IEEE International Symposium on Intelligent Vehicles.* Parma Italy. To Appear 2004.

55. Gavriloaie, R., W. Nejdl, D. Olmedilla, K. E. Seamons, and M. Winslett. No Registration Needed: How to Use Declarative Policies and Negotiation to Access Sensitive Resources on the Semantic Web. *1st European Semantic Web Symposium*, Heraklion, Greece, May 2004. To appear.

56. Hore, Bijit, Hakan Hacigumus, Bala Iyer, Sharad Mehrotra. Indexing Text Data under Space Constraints. Technical Report TR-RESCUE-04-23. 2004. Submitted for review.

57. Iyer, Bala, Sharad Mehrotra, Einar Mykletun, Gene Tsudik, and Yonghua Wu. A Framework for Efficient Storage Security in RDBMS. E. Bertino et. al. (Eds.) *EDBT 2004, LNCS 2992*, pages 147-164. Springer-Verlag: Berlin Heidelberg, 2004.

58. Mykletun, E., M. Narasimha and G. Tsudik. Authentication and Integrity in Outsourced Databases. ISOC Symposium on Network and Distributed Systems Security (NDSS'04), February 2004.

59. Narasimha, M., G. Tsudik and J. Yi. On the Utility of Distributed Cryptography in P2P Settings and MANETs, IEEE International Conference on Network Protocols (ICNP'03), November 2003.

60. Roh, J.C.; Rao, B.D. Multiple antenna channels with partial channel state information at the transmitter. *IEEE Transactions on Wireless Communications*. Volume: 3, Issue: 2, March 2004. Pages:677 - 688.

61. Saxena, N., G. Tsudik and J. Yi. Admission Control in Peer-to-Peer: Design and Performance Evaluation. ACM Workshop on Security of Ad Hoc and Sensor Networks (SASN '03), November 2003.

62. Saxena, N., G. Tsudik and J. Yi. Experimenting with Peer Group Admission Control. International Workshop on Advanced Developments in Software and Systems Security (WADIS'03), December 2003.

63. Seamons. K., TrustBuilder: Automated Trust Negotiation in Open Systems. CERIAS Security Seminar, Purdue University, February 11, 2004. Invited presentation.

64. Smith, B., K. E. Seamons, and M. D. Jones. Responding to Policies at Runtime in TrustBuilder. To appear in: *5th IEEE International Workshop on Policies for Distributed Systems and Networks (POLICY 2004)*, Yorktown Heights, New York, June 2004.

65. Van der Horst, Timothy W., Tore Sundelin, Kent E. Seamons, and Charles D. Knutson. Mobile Trust Negotiation: Authentication and Authorization in Dynamic Mobile Networks. *Eighth IFIP TC-6 TC-11 Conference on Communications and Multimedia Security*, September 2004. To appear.

66. Wang, Kang, Chiasserini, C. F., Rao, R. R., Proakis, J. G. A distributed joint scheduling and power control algorithm for multicasting in wireless ad hoc networks. 2003 IEEE International Conference on Communications (Cat. No.03CH37441). IEEE. Part vol.1, 2003, pp.725-31 vol.1. Piscataway, NJ, USA.

67. Wickramasuriya, J., N. Venkatasubramanian. Middleware-based Access Control for Ubiquitous Environments. Technical Report TR-RESCUE-04-24. 2004. Submitted for publication.

68. Yan, M. and; Rao, B.D. Soft decision-directed MAP estimate of fast Rayleigh flat fading channels. *IEEE Transactions on Communications*. Volume: 51, Issue: 12, Dec. 2003. Pages:1965 – 1969.

69. Yang, Xiaochun, and Chen Li. Secure XML Publishing without Information Leakage in the Presence of Data Inference. VLDB 2004.

Information Dissemination:

70. Bagchi, Amitabha, Amitabh Chaudhary, Michael T. Goodrich, Chen Li, and Michal Shmueli-Scheuer. Data Gerrymandering: Efficient Push-Pull Partitioning to Support Range Queries on Dynamic Data. Submitted to VLDB 2004.

71. Chiasserini, C. F., Rao, R. R. Improving energy saving in wireless systems by using dynamic power management. *IEEE Transactions on Wireless Communications,* vol.2, no.5, Sept. 2003, pp.1090-100. Publisher: IEEE, USA.

72. Cheng, S. Y. and M. M. Trivedi, "Human Posture Estimation Using Voxel Data for "Smart" Airbag Systems: Issues and Framework" *IEEE International Symposium on Intelligent Vehicles.* Parma, Italy. To Appear 2004.

73. Deshpande, Mayur and Nalini Venkatasubramanian. The Different Dimensions of Dynamicity. The Fourth IEEE International Conference on Peer-To-Peer Computing. August 25-27, 2004.

74. Deshpande, Mayur, Haimin Lee, Chen Li, Sharad Mehrotra, and Nalini Venkatasubramanian. SPINE: Scalable Approximate Global State Maintenance in Peer-to-Peer Networks. In Revision. 2004

75. Lawson, G.C. and Butts, C.T. Information Transmission Through Human Informants: Simulation. North American Association for Computational Social and Organizational Science Meeting, June 2004, Pittsburgh, PA.

76. McCall, J. and M. M. Trivedi, "An integrated, robust approach to lane marking detection and lane tracking," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted June 2004.

77. McCall, J., O. Achler and M. M. Trivedi, "Design of an Instrumented Vehicle Testbed for Developing Human Centered Driver Support System," *Proc. IEEE Intelligent Vehicles Symposium,* Accepted June 2004.

3.2 Books or other non-periodical, one-time publications

Smith B. Responding to Policies at Runtime in TrustBuilder. M. S. Thesis, Brigham Young University, March 2004.

3.3 What websites or other Internet sites have been created

www.itr-rescue.org

http://adaptive07.ucsd.edu:83/mcc/web/default.html
http://www.ics.uci.edu/~kemal/bibliography/bibliography.htm
http://dais.cs.uiuc.edu/trustbuilder/
http://isrl.cs.byu.edu
http://sagehen.ucsd.edu/RESCUE
http://www-db.ics.uci.edu/pages/research/quasar/

3.4 Specific products developed (databases, physical collections, educational aids, software, instruments)

The following software, databases and other products have been produced thus far in the RESCUE project. Many are in prototype phases and will be tested and validated in later stages of this project. Also, listed under each product are the primary developers or researchers.

Privacy Preserving Data Collection for Media Spaces

Students: Jehan Wickramasuriya, Mahesh Datt, Momo Alhazzazi, Nitesh Saxena
Faculty: Sharad Mehrotra, Nalini Venkatasubramanian

The use of media spaces and in particular forms of surveillance are quickly becoming an integral part of crime control policy, crisis management, social control theory and community consciousness. Providing automated techniques in order to preserve the privacy of subjects as well as aid in detecting anomalous behavior by filtering out 'normal' behavior is desirable in these environments. This project develops an architecture for demonstrating the capability of privacy preservation techniques for media spaces. The idea is to fuse video with other sensor data (namely Radio Frequency Identification or RFID) and use that information to enforce access control policies within a media space. The work provides an underlying RFID framework and accompanying video processing techniques that in conjunction with our policy language makes decisions on under what conditions and how information is collected in a media space.

CAMAS: A Citizen Awareness System for Crisis Mitigation

Students: Kemal Altintas, Haimin Lee, Jehan Wickramasuriya, Ramaswamy Hariharan, Yiming Ma
Faculty: Other Researchers: Sharad Mehrotra, Carter Butts, Dmitri Kalashnikov, Nalini Venkatasubramanian, Ron Eguchi, Charles Huyck

The goal of this work is to enhance the mitigation capabilities of first responders in the event of a crisis by dramatically transforming their ability to collect, store, analyze, interpret, share and disseminate data. CAMAS is a system designed to allow a variety of users, including the average citizen to report incidents and potentially hazardous situations, analyze and evaluate these reports and notify appropriate personnel for further action. The multidisciplinary approach incorporates a variety of information technologies: networks; distributed systems; databases; image and video processing; GIS; and machine learning, together with subjective information obtained through social science. As part of this testbed, specific experiments will be performed that illustrate issues of event extraction, ranking, access control and visualization.

Mobile Command and Control Center for Crisis Mitigation

Researchers: Ganz Chockalingam, Nick Hill, Brian Braunstein

The mobile command and control center is an end-to-end architecture that aids first responders in crisis field monitoring. It helps them gather critical information from the crisis scene in the form images, video and audio using mobile devices cell phones on the field, automatically time and location stamp them and relay it back to the control center. The events are automatically populated in a GIS database. The control center agents can view these events coming in from the crisis scene based on priority and location. The architecture allows for bi-directional communication between the control center and the first responders. The agents can message the first responders in the form of text messages or voice calls in groups or on an individual basis.

Adaptive Filtering on CAMAS & 911 Call Center Data

Students: Qi Zhong, Yiming Ma
Faculty: Sharad Mehrotra

In this demonstration, a location map with geo-referenced information has been mapped to mobile devices (HP iPAQ) used by field agents. Our event server is able to receive new events and disseminate the events to individual mobile devices based on individual profiles stored on the server. Field agents can use the mobile devices to feedback the relevance of events back to the server, and the server will update the profile accordingly.

RelDC: a Novel Framework for Data Cleaning

Researcher/Student: Dmitri Kalashnikov, Stella Chen
Faculty: Sharad Mehtrotra

In this research, we explore a systematic approach based on exploiting relationships among objects for the purpose of disambiguation. Such a problem arises in a variety of contexts – e. g., in data cleaning context where the same object may be represented differently. Our approach is based on the hypothesis that if two representations refer to the same entity, there is a high likelihood that they are strongly connected to each other through multiple relationships implicit in the database. We view the database as a graph in which nodes correspond to entities and edges to relationships among the entities. Any one of the existing conventional approaches is first used to determine possible matches among entities. Graph analysis techniques are then used to disambiguate among the various choices.

Complex Queries over Attributed Entity/Event Graph Databases

Student: Dawit Seid
*Faculty:*Sharad Mehrotra

Uncovering relationships among events or entities constitute a large portion of data analysis tasks in numerous applications including intelligence link analysis, social network analysis, spatio-temporal event data analysis. This work aims to enable the querying, analysis and mining of event/entity relationships by using attributed graph

based data models to represent event/entity data. In particular, we have developed a language to enable the expression of complex analytical queries on attributed graphs. We also have developed a multi-relational data cube computation algorithm that aims to scale up relational data mining like the discovery of multi-relational association rules.

Video Data Analysis Using Stochastic Motion Models

Student: Sridevi Parise
Faculty: Padhraic Smyth

The project involves modeling and analyzing pedestrian motion in a general outdoor scene, as seen in video, using stochastic motion models. These are useful in many applications, for example, in realistic trajectory generation for video simulations, atypical behavior detection for video surveillance and analyzing patterns of path usage for planning and design. The various steps involved are the extraction of trajectories from raw video using object detection and tracking, defining appropriate model families to handle pedestrian motion, learning the parameters of such models automatically from historic data using machine learning approaches and, finally, the use of such learned models for the various application tasks. The demonstration illustrates some of these steps, the various issues involved and some possible solutions.

The Early Post-Earthquake Damage Assessment Tool (EPEDAT)

Researchers: Charles Huyck, Hope Seligson, Ronald T. Eguchi, M. Shinozuka

EPEDAT is a GIS-based program that calculates damage and population impacts after an earthquake based upon earthquake magnitude and location or GIS ground motion files such as ShakeMap. Estimates of building damage are presented as a dollar figure for structure and contents, as well as the number of red or yellow-tagged buildings for both residential and commercial structures. Additionally, damage to water, power, and natural gas infrastructure are estimated, as well as the number of casualties and persons displaced from their homes. EPEDAT was initially developed for the California Office of Emergency Services (OES) and incorporates detailed tax assessor data for five southern California counties, including Los Angeles and Orange. It is currently being modified to work as an on-line system within the RESCUE project.

RACCOON: A Peer-Based System for Data Integration and Sharing

Students: Qi Zhong, Jia Li
Faculty: Chen Li

Many database applications see the emerging need to support distributed, peer-based data integration and sharing, where participating organizations (peers) exchange and share their information without any central control. We have built a system, called “RACCOON," to study research problems in such an application. In the system, each peer in an overlay network publishes its metadata for data-sharing purposes. A visualization tool ("PeerViewer") allows users to browse the network of neighbor peers and issue searches and queries. In a search, the system finds relations in other peers that are related to a relation given by the user. Schema mappings can be generated in the process to link the information from different peer relations. Furthermore, users can pose SQL queries on specific peers to retrieve information in a "Focused Querying

Mode." In addition, users can also choose an "Extended Querying Mode" to submit a query, where the system will use the mappings to rewrite the query to queries on other relevant peers to retrieve more information.

Cal-GIS Audio Cues Guidance System For First Responders

Students: Kathryn Becker, Hoang Anh Nguyen, Danny Picar, Mike Ramirez, Tuan Anh Vo
Researcher: John Miller

First responders to a disaster situation may have to depend on other senses than their vision in a smoky environment or while wearing a hazmat suit. These responders also need to stay on track while following a route on foot despite distraction and disorientation. The demonstration platform is a laptop computer running Windows 2000 and using screen reading software to voice audio cues. The demonstration software shows how a GPS system and audio cues via a cell phone could be used to guide a first responder. Cal-GIS allows the creation and preview of non-visual information describing a pedestrian route. A first responder can use Cal-GIS in real-time while walking a route to speak the distance and bearing of the nearest waypoint. The software speaks the distance between neighboring waypoints and corresponding estimated trip time and estimated number of steps between waypoints.

BuddyFinder (A Location Based Service Framework)

Researcher: John Zhu

A LBS (Location Based Service) framework is developed for applications like Buddy Finder, Mobile Force Management, etc. The framework manages the map rendering for both mobile and web browser, the logging of position and position management of mobile, the security issues of users, group messaging, etc. Buddy Finder is an application developed based on our LBS framework. It supports Where am I, Where is my friend, the trace of a member for the last couple hours, get the latest position of a friend, group position, manual GPS upload when GPS is not available. It also supports the group messaging and location based POI (point of interest). The same features are offered for WEB also. Buddy Finder is enhanced to send location based alert to server. The mobile can also view the alerts displayed on the map, e.g., UC Irvine's map.

511: San Diego Wireless Traffic Report

Researchers: Ganz Chockalingam, Nick Hill

Current access modes of traffic information include the TV, radio and the internet. However, when you are in the car, the only medium that is accessible is the radio. Traffic reports on the radio are usually vague and not tailored to your commute. Most traffic reports do not provide detailed traffic flow information (i.e. the speed of the traffic flow). Our system overcomes these limitations by providing real time traffic flow information to the commuters through their cell phones. This allows for on-demand, universal and personalized access to traffic information.

ABC: Always Best Connected

Faculty: Ramesh Rao, Pamela Cosman, Rene Cruz, Sujit Dey, Geoffrey Voekler
Researchers: Rajesh Mishra, Per Johanssen, Cahit Akin, Salih Ergut

Seamless interoperability among various network infrastructures to maintain constant - and the most powerful - connection to the Internet for mobile users using both licensed (e.g., cellular networks) and unlicensed (e.g., IEEE 802.11b) spectrum. This work is making it possible for user devices to seamlessly roam among varying network access technologies, including IEEE 802.11b, CDMA2000, GPRS, and Ethernet, with controlled adaptation of applications' performance to the network capabilities at hand.

MMS: Enhanced Multimedia Messaging Services

Faculty: Nuno Vasconcelos, Ramesh Rao
Researchers: Kai-Chieh Yang, Luke Barrington, Dr. Babak Jafarian

The aim of the project is to enhance the Multimedia Messaging Service by adding capabilities to classify the incoming images sent to the server by users. We would ideally like to know whether each image has good quality and correct orientation, whether it is a duplicate or not, what event it depicts, etc. This would enable the cell phone operators to remove all the spurious data that is clogging their servers. The service could essentially make each mobile user into a photographer whose reports would be available to the whole world. However, the received data would undoubtedly be much unstructured and of widely varying quality. The server-side processing applied by the cell phone operators simply dumps all the incoming data into a single directory. Images of many different events and all of the events would be grouped together in a single depository and the bad quality images will be classified into another category or eliminated as well.

Navitron-Go: Sense of Touch Guidance System For First Responders

Students: Kathryn Becker Hoang Anh Nguyen, Danny Picar, Mike Ramirez, Tuan Anh Vo
Researcher: John Miller

First responders to a disaster situation may saturate their senses of vision and hearing with real-time information or may have their functional vision and hearing reduced in a smoky or loud environment. These responders also must stay on track while following a route on foot despite distraction and disorientation. The Navitron-Go system demonstrates how a first responder would use sense-of-touch to follow a pre-defined route. Navitron-Go requires the first responder to rely on his own senses for collision avoidance and personal safety. Navitron-Go provides a sense-of-touch guidance system that directs the first responder along the route only using the sense of touch.

A pointer on a dial (like a hand on a clock) rotates clockwise and counterclockwise to guide the first responder left or right. The system gives a short buzz for go and a long buzz for stop. The system slides a knob right and left to show the first responder if he is closer or farther from his destination. The knob's position also may show the approximate time left to complete the route. The prototype consists of a guiding device

connected via an RF link to a tactile guide. The tactile guide should be held in the hand. The prototype requires a human guide who has line-of-sight to the user. The prototype has applications for computer-guided systems.

4. Contributions

4.1 Contributions within Principal Disciplines of the Project

The central focus of the RESCUE project is to radically transform the efficiency (speed and accuracy) at which information flows through disaster response networks. These networks span a multitude of response organizations as well as the public. The primary disciplines of research are information technology and social science. We summarize our contributions (current, ongoing, and future) along both of these disciplines; however, we note that this research is multidisciplinary and thus transcends the traditional boundaries of these disciplines.

4.1.1 Contributions: Information Technology

The goal of our IT research is to provide seamless access to the right information by the right people at the right time. In this context, the *right information* refers to information, suitably customized/aggregated, that significantly enhances the decision-making capability of responding organizations/agencies/people. The *right people* refers to decision-making entities that triage information across organizational and system boundaries and to entities that utilize this information in making critical decisions regarding crisis response. The *right time* refers to time periods where effective decisions can either prevent the occurrence of secondary disasters, such as release of hazardous materials or minimize the initial impacts of the disaster through rapid and effective response, e.g., efficient deployment of emergency response resources.

To achieve the above goals, we envision information technology solutions that dynamically capture and store crisis relevant data as it is generated, interpret and analyze these data in real-time, and triage critical information derived from these data to decision makers in forms that can easily be interpreted or used in making critical emergency response decisions. Challenges in realizing such IT solutions arise due to the scale and complexity of the problem, the diversity of data and data sources, the state of the communication and information infrastructure through which information flows, and the diversity and dynamic nature of the responding organizations.

Diversity of Information Sources: Information needed for effective decision-making may be dispersed across a hierarchy of storage, communication, and processing units – e.g., sensors (in-situ sensors, satellite imagery, other remote sensing technologies) where data are generated to form diverse and heterogeneous databases belonging to largely autonomous organizations. Critical information may reside across various modalities – e.g., field-observations communicated via voice conversations among emergency workers, video data transmitted from cameras carried by first responders, sensor data streams, and textual and relational information in databases.

Diversity of Information Users: Information may need to be shared across loosely coupled, diverse, and emergent multi-organizational networks in which different entities play different roles in response activities, have different needs and priorities, have different cultures, and may have vastly different capabilities with respect to technology utilization. These organizations may or may not have policies in place for data sharing and collaboration. Furthermore, these organizational networks may rapidly reconfigure in order to adapt to the element of surprise in a crisis event. Finally, different people/organizations have different needs and urgencies for the same information.

State of the Infrastructure: Information must be transferred across highly-distributed, mobile infrastructure consisting of heterogeneous communication channels and systems that are prone to failures and may be vulnerable to further damage or attacks during a crisis.

The RESCUE project is exploring both fundamental and applied research in information technology to overcome the challenges described above. We are making contributions to existing state-of-the-art IT areas at two different levels: systems-centric research and information-centric research.

In systems-centric research, we are exploring challenges in networking under extreme situations, technologies to maintain always best network connectivity, data management and middleware solutions for quality-aware dynamic data collection, data management approaches to store highly dynamic databases, technologies for representing and querying spatio-temporal events, approaches to seamlessly integrate databases "on the fly", open-distributed systems for trust establishment and management, systems to facilitate data sharing, and push-pull technologies for information dissemination.

With respect to information-centric research, we are exploring techniques for multimodal data analysis including mechanisms for speech recognition in noisy distributed environments, video analysis – object recognition and tracking, models/methodologies for event extraction from multimodal data, techniques for event and entity disambiguation/resolution, methods for event tracking across multiple modalities, data interpretation techniques including probabilistic models for determining reliability of information, spatial and temporal localization of events, models for occupancy from various information sources, and visualization of spatio-temporal event-oriented data

These diverse research activities are coordinated/organized along four inter-related activities that together capture the information flow process during a crisis.

Information Collection: The objective of information collection is to bring relevant crisis-related information from a variety of information sources to decision makers in a timely and efficient manner. Our research addresses how large volumes highly dynamic, multimodal information generated at various information sources can be effectively collected and stored over networks that might be unreliable and possibly insecure. Information sources include instrumented sensors, video cameras either embedded in civil infrastructures or dispersed at crisis sites for situation monitoring, remote sensing systems, field-based sensors such as seismic sensors, and sensor and video probes carried by first responders. We are exploring integrated distributed systems, data management and networking research that enable information to seamlessly flow in real-time from these information sources to collection points over heterogeneous network channels that may be only sporadically available and are vulnerable to further hazards or attacks. In designing such a system, we focus on two novel aspects of the information collection problem. First, our research explores technological solutions to enable humans to act as vital information sources in a crisis. We believe that first responders' observations and interpretations from the scene (given the benefit of human cognizance) can provide among the most vital and dependable sources of ground reality information. Leveraged properly, it can result in much more accurate situation awareness and hence better response. Yet, existing crisis response systems do not systematically exploit such human input. We will therefore seek scalable and robust IT solutions that enable crisis workers to play the role of human as sensors. To gather data in an unobtrusive manner,

we will capture and analyze voice input from conversations among in-field rescue workers. We will then rely on IT solutions to extract meaningful events/information in real-time from transcriptions (possibly with the help of positioning technologies such as GPS, other sensor data, and video feeds) and utilize the extracted information as input into damage and impact assessment systems. Such an approach raises fundamental research questions in speech recognition, data management and information fusion which will be addressed in our research.

The second novel aspect of our research is the exploration of privacy in the context of information collection with the objective of developing customizable solutions that explore a tradeoff between functionality and the (loss of) privacy. Spaces instrumented with video cameras, sensors, tracking systems based on RFID or similar technologies, while they facilitate surveillance and situation monitoring, they leave a trace of people behind whether this is acceptable to them or not. We envision data collection mechanisms that are privacy-aware and adaptive. Such mechanisms will empower the users - to the extent possible - to control the acceptable loss of privacy, and adapt to the varying needs of the situation.

Information Analysis: A set of related research activities focus on extracting useful information (from the perspective of first responders) from raw data (sensor data, text, voice, and video streams) and assimilating or fusing data across multiple modalities to develop higher-level understanding. The information analysis component bridges the gap between raw data and semantically richer representations that are useful to humans in the context of their tasks (damage assessment, planning, situational awareness). A fundamental abstraction that permeates various aspects of information analysis is that of an "*event*". We define an event as a significant phenomenon or occurrence embedded in space and time. Events can occur at multiple spatial and temporal scales. For a field worker (e.g., a firefighter requiring fine-grained situation awareness), change in location of his team members at a given time might be an event. At a higher layer, relevant events may correspond to more aggregated information. For example, incident commanders monitoring the response at the city EOC (emergency operations center) may choose to focus on the total number of deployed firefighting or police units at a given region at a given time instead of detailed information about each individual/resource. Our research on information analysis is focusing on extracting meaningful events from multi-modality data streams (transcribed voice conversations in the context of human sensors, video feeds, various types of sensor data), techniques to assimilate events, fuse information, and integrate it with (possibly static) information -- e.g., maps of the crisis site.

Information Sharing: This area focuses on a set of related research activities that facilitate seamless sharing of information amongst decision-makers across organizational boundaries, especially across highly dynamic, emergent, virtual organizations. The crisis response environment is characterized by Dynamic and Evolving Virtual Organizations ***(DEVOs)*** in which participating organizations collaborate in the context of a variety of tasks related to disaster mitigation or response (e.g., rescue and evacuation, maintaining law and order). Seamless mechanisms to inter-organization information sharing can revolutionize how such emergent collaborations are established resulting in dramatic improvements to crisis response. Such information may have been dynamically collected and analyzed, or preexisting in organizational knowledge and databases. Challenges in information sharing across DEVOs arise due to frequent structural and functional changes (e.g. expansion, extension) within

organizations, emergence of complex inter-organizational relationships, *lack of centralized control*, and an element of the surprise resulting in unexpected inter-organization relationships and data needs. Disaster response networks are characterized by heterogeneity in the nature of network relationships (e.g., command and control vs. voluntary coordination, formal or contractual vs. informal relationships) and shifting composition, as new organizational entities join the network in response to changing conditions and response to disaster-related demands. To address the information sharing challenges in such virtual organizations, we will explore an integrated approach to understanding information sharing needs and optimizing organizational structures in the context of response coupled with technological innovations that facilitate their formation and functioning. From the IT perspective, we will develop an open distributed system with adaptive and scalable mechanisms for rapid and secure sharing of information. Such a system must incorporate mechanism for dynamic trust negotiation between organizations.

Information Dissemination: This final area focuses on a set of related research activities that study how information can be dispersed quickly and efficiently to various entities and organizations. The research will focus on how various forms of social behaviors emerge during disasters and how this knowledge can help customize and personalize information delivery to save lives and property. This research area will focus on the challenges associated with the timely dissemination of information to entities participating in disaster response activities, to other organizations (e.g., mass media organizations), and to the general public. For over five decades, empirical social science research has focused on issues related to the dissemination of hazard-related information in both pre- and post-disaster contexts. We now have a good understanding of how crisis-relevant information can be effectively disseminated, as well as, a wide range of challenges and difficulties associated with communicating in turbulent, rapidly-evolving, and uncertain environments. This research has conceptualized information dissemination as a communication process consisting of four elements: *origin of information; messages; dissemination channels; and receivers of information*. Effective information dissemination strategies (that ensure timely delivery to recipients in the form most useful to them) require a deeper understanding of each of these elements and their interactions. Our focus in this research will be two fold: (1) developing a structured approach to understand interactions between the above listed communication elements in the context of crisis response, and (2) designing advanced IT solutions that customize both dissemination strategies and message content to meet needs of diverse organizational actors and segments of the public.

4.1.2 Contributions: Social Sciences

Project-related activities in the social sciences focus on a number of basic and applied topics. One key research area centers on network emergence and adaptation under emergency conditions, which couple extreme environmental demands with intense time constraints. Network analysis is an extremely large field that spans a range of disciplines (see, for example, Powell, 1990; Knoke and Guilarte, 1994; La Porte, 1996; Podolny and Page, 1998). The extensive literature on networks focuses on a variety of topics, including structural features of networks, the consequences of structural position for individual network actors, network evolution and change, and the advantages of the network form of organization over other organizational forms—advantages that include the ability to foster adaptation and innovation. Among the many empirical studies on social and organizational networks, there has been almost no work on networks in

disaster response. This gap in the literature exists despite the obvious applicability of network concepts, methodologies, and research findings to crisis response activities. The research that does exist on the topic of emergent multi-organizational networks (EMONS) in disasters (see Drabek, 2003) makes important conceptual and practical contributions but does not take full advantage of either advanced network-analytic methods or information technologies.

A second key social science research area focuses on facilitating and constraining factors influencing the extent to which groups and organizations that participate in disaster-related preparedness and response activities can adopt and implement advanced IT solutions and to share information across organizational boundaries. RESCUE-related research activities are predicated on the assumption that response activities will be more effective if accurate information is delivered to the appropriate organizational actors in a timely manner. However, yet to be determined is the extent to which such information flows will be facilitated or impeded by social and organizational factors. A partial list of such factors could include organizational cultures; resource constraints, including barriers related to both funding and available expertise; lack of interoperability among IT tools; security concerns for certain types of disaster events, such as terrorist attacks; legal constraints on information-sharing; issues of privacy and civil rights; proprietary attitudes toward data; and other factors. Social science researchers will conduct research within RESCUE testbeds to assess the impact of these real-world organizational considerations.

A third area of emphasis concerns collective behavior in times of crisis. Both impending disaster threats and actual disasters generate a variety of collective behavior responses among the public and responding organizations (Tierney, Lindell, and Perry, 2001; Tierney, 2004). Such behaviors range from the highly altruistic and positive, such as mass volunteering, to more problematic behaviors, such as rumoring, large-scale convergence resulting in organizational "over-response," to crises, and spontaneous evacuations that may actually increase rather than reduce vulnerability. RESCUE-related social science research seeks to better understand and model these responses, with an emphasis on investigating how IT and network modeling techniques can assist with the early detection and amelioration of potentially dangerous and disruptive collective behavior responses.

4.2 Within Other Disciplines of Science or Engineering

Project-related activities in engineering focus on three distinct areas: monitoring the response or performance of critical infrastructure (such as bridges and highways), regional damage detection, and modeling of post-disaster traffic flows. These areas either support the various testbeds or provide methodologies for information collection, analysis, or dissemination.

Monitoring the Performance of Critical Infrastructure: Condition monitoring for bridges is traditionally performed using accelerometers. The advantage of this approach is that only a few sensors are needed at each location. Experience has shown that changes in the global characteristics of the bridge, however, are not sensitive to damage. Past research findings have shown that significant damage can manifest itself in changes that are smaller than those produced by noise in the signals. Alternative approaches have so far encountered problems that have yet to be resolved.

The approach taken by this project is to use long continuous strain gauges. If the type of deformation that contributes to deflection is known, then strain measurements can be used to determine the deflection of the bridge. Strain measurements based on point-wise measurement, however, is not altogether reliable since damage may not occur where the strain gauges are located. To mitigate this problem, a strain gauge that is designed to measure the cumulative strain over a distance is being contemplated. In this approach, any damage within the instrumented span can be captured.

The research above is part of the Transportation Testbed that has been created to evaluate the efficacy of information technology solutions to reduce or mitigate the effects of unreliable or unavailable information on the performance of large-scale infrastructure systems.

Regional Damage Detection: In a major disaster, effective response depends on quick and precise estimates of damage extent and magnitude. Loss estimates are key in prioritizing the allocation of limited resources, as well as preventing cascading events that can exacerbate the initial effects of a disaster. With the recent emergence of loss estimation tools like HAZUS (Hazards US, a FEMA-sponsored effort, FEMA, 2003) and EPEDAT (Early Post-Earthquake Damage Assessment Tool, Eguchi, 1997), cities and communities are able to simulate the impacts of large disasters such as earthquakes, floods and hurricanes. These tools typically utilize large databases on hazards (location, extent, and relative frequency), exposed populations and structures (detailed inventories), hazardous facilities (e.g., chemical processing plants), and critical infrastructure (e.g., highways and other lifeline systems). Hypothetical scenarios routinely provide results for emergency response training exercises, response plans, and resource assessment. Advanced users use quantitative loss projections for planning purposes, including cost-benefit analysis of building codes and proposed mitigation efforts. After an event, loss estimation programs provide answers at the critical time when damage extent and distribution is unclear.

Although these tools provide information that is useful for planning and response, they currently require expert users and are not very accessible after a disaster. Highly customizable and computation intensive, they require GIS specialists or engineers to work with seismologists and geologists to create "study regions" where supplementary data are required for an accurate portrait of loss. Recent earthquake response efforts have brought this modeling paradigm into question. After the 2001 Nisqually earthquake in the State of Washington, several different local, state, and federal entities took it upon themselves to produce estimates, which varied widely based on how the event was modeled. In the recent San Simeon earthquake in California, the sparse default data available in the rural area was not adequate to model the event accurately. These events illustrate the need for a web-based modeling environment, where important decisions concerning how the results are produced and presented can be controlled. Centralized and widely disseminated loss estimates will benefit response and planning efforts and will dovetail into various RESCUE products.

Development of a loss estimation tool for the internet (a major focus of this research study) poses several technical and research challenges. Spatial database objects are being moved from a PC environment to a distributed database environment. Models that were initially developed in a single-tier, are being moved to a "three tier" web-based environment. This web-based program must integrate tools for complex spatial data processing tasks. Each loss estimation module is being re-thought, restructured, and

reprogrammed to generate results quickly with SQL queries. Complex models are being simplified and presented in a web environment. Currently, building loss and casualties are being calculated from predefined ground motions and building inventories. Next steps include query optimization, the coding of an attenuation function and integration of various transportation modules. Since GIS programs based on commercial software must frequently to modified for compatibility with new versions and new programming languages, all modules are being developed in freely available and OpenGIS compliant tools.

Modeling of Post-Disaster Traffic Flows: Many studies have focused on the flow of traffic during large-scale disasters (Werner, et al., 2004). In most of these efforts, what is generally modeled is the efficiency in moving people from one area or region to another, often bypassing major areas of impact or disruption. In these cases, research issues that are addressed include: efficient construction of network models, adjustment of origin-destination algorithms accounting for traffic congestion and damage to buildings and infrastructure, and the fragility of key transportation components such as bridges, on- and off-ramps, and highway pavements. In this study, our focus is on the rapid evacuation of people/drivers away from areas that have the potential for hazardous materials (chemical and biological) release. In this regard, a whole new set of research questions must be addressed. These include:

- Quantifying the number of drivers (and thus people) in highly concentrated areas, e.g., downtown and industrial areas, at any particular time. This information is critical in understanding the scope and magnitude of an evacuation effort. Current research is focused on innovative techniques for "counting" daytime traffic into these areas using "loop sensor" data.
- Modifying conventional transportation models to address evacuation conditions. Important factors that will be addressed include: modification of micro-simulation models to more accurately reflect driver aggressiveness and driver awareness, adjustment of transportation models to include accurate and inaccurate assessments of highway damage, and modeling of driver's patterns with and without accurate traffic information.

This research is part of the transportation testbed which is aimed at testing the efficacy of information technology solutions on a large regional scale. The improvements that are made to the transportation models described above will also help to improve the modeling of traffic flows under smaller incidents or events that occur on a more frequent basis.

4.3 Within the Development of Human Resources

The RESCUE project provides support for 32 faculty and senior personnel, and five full-time, as well as five part-time staff members, at five institutions. The project also supports 34 graduate students, whose involvement is central. Student engagement is facilitated by weekly group meetings, at which project members (both students and faculty) present current RESCUE-related research and discuss new directions. This collaborative environment provides a forum for mentoring and professional development while facilitating communication among research groups, in the best tradition of the research university.

RESCUE's contribution to education extends beyond mentoring of students in a research setting. RESCUE PIs Butts and Mehrotra have each designed and taught graduate seminars in the past year in the area of crisis response. These seminars featured coursework related to RESCUE research, but were available to students in the University of California generally; each combined practitioner materials from FEMA and other agencies with current scientific research in related fields. A major benefit of this educational effort has been the development of expertise in the areas of crisis management and disaster research among graduate students within the project, thereby facilitating the connection of basic research activities to real-world problems. Several students are following up on these initial experiences by field study with response organizations in Los Angeles, thanks to agreements with our community partners. Such progress is in line with RESCUE's broader goal of serving as a catalyst for the integration of information technology research, social science, and the crisis/disaster response fields.

In addition, RESCUE has committed to developing a long-term framework for this research project by ensuring the following activities:

- At UCI, the RESCUE project has hired Lynn Harris to serve in the role of an Administrative Project Coordinator who is tasked to support the Principal Investigator for this research study (Mehrotra) and to facilitate interactions between key researchers and the first responder community, the Community Advisory Board, and industry representatives.

- Cal-IT2 has cost shared part of this research study by assigning Helena Bistrow to work part time in a similar capacity at UCSD. In addition, (as specified in the original proposal), the Cal-IT2 office is performing the task of financial managing the grant. Cal-IT2 is also providing support in seminar organization and publicizing RESCUE functions and activities.

4.4 Within the Physical, Institutional, or Information Resources that form the Infrastructure for Research and Education

With the resources that form the infrastructure for research and education, we have created a cross-disciplinary research laboratory at UCI that houses about 20 RESCUE students, faculty, and staff from various disciplines. Weekly meetings generally attract over 25 participants from UCI, UCSD and ImageCat; these meetings facilitate multi-disciplinary/cross-disciplinary interaction which help to address technical, social and economic issues. As a result of these interactions, a number of joint research papers have emerged which demonstrates this commitment for multidisciplinary research.

A live campus-based testbed (CAMAS) for accurate situational awareness and monitoring by collecting, analyzing and triaging data in the context of a problem reporting system is an example of a long-term commitment to form the type of infrastructure required to test various research innovations or solutions. The next generation of CAMAS will be integrated into a campus level emergency drill at UCI to study the impact that such information processing systems have on enhancing awareness in crisis response planning. The testbed also provides opportunities to enhance education by creating course projects that relate to the testbed. Specifically, IT courses such as data management, networks, middleware, and multimedia will

challenge the students to develop software artifacts that are tied to this testbed. Students taking data mining and social science courses (such as network analysis) will benefit from the data collected within this testbed. Similar research and educational benefits are expected in the other two testbeds: Transportation and GLQ.

A web site has been created (http://www.itr-rescue.org) that not only provides information about RESCUE but also links to other crisis response related information.

4.5 Within Other Aspects of Public Welfare beyond Science and Engineering, such as Commercial Technology, the Economy, Cost-efficient Environmental Protection, Solution of Social Problems

The fundamental goal of the RESCUE project is to transform the ability of responding organizations to collect, analyze, share and disseminate information during large disasters, resulting in real-time and accurate situational awareness. Enhanced awareness, in turn, can significantly improve the decision-making ability of first responders making crisis response more effective and timely. Furthermore, our research explores IT innovations to facilitate multi-organization virtual teams that form during a crisis. We believe that the technologies developed will significantly improve information flow between key emergency response organizations and the public.

Besides contributing to the improvement of crisis response systems, we believe that our approach to building situational awareness tools using multimodal data that includes speech, event extraction data, data on spatio-temporal events will significantly contribute to other systems that operate in a non-disaster situation, e.g., next generation 911 emergency system.

4.6 References

Drabek, T.E. 2003. Strategies for Coordination Disaster Responses. Boulder, CO: Institute of Behavioral Science, Natural Hazards Research and Applications Information Center, University of Colorado.

Eguchi, R.T., J.D. Goltz, H.A. Seligson, P.J. Flores, N.C. Blais, T.H. Heaton and E. Bortugno, 1997, "Real-time Loss Estimation as an Emergency Response Decision Support System: The Early Post-Earthquake Damage Assessment Tool (EPEDAT)," *SPECTRA*, Volume 13, No. 4, November.

FEMA (Federal Emergency Management Agency), 2003, *HAZUS MH Manual*. See also www.fema.gov/hazus/ or www.hazus.org.

Knoke, D. and Guilarte, M., 1994. "Networks in organizational structures and strategies." Pp. 77-115 in Current Perspectives in Social Theory, Supplement 1. Greenwich, CT: JAI Press.

La Porte, T. R., 1996. "Shifting vantage and conceptual puzzles in understanding public organization networks." Journal of Public Administration Research and Theory 1: 49-74.

Podolny, J. M. and K. L. Page., 1998. "Network forms of organization." Annual Review of Sociology 24: 57-76.

Powell, W. W., 1990. "Neither market nor hierarchy: Network forms of organization." In B. Staw and L. L. Cummings (eds.) Research in Organizational Behavior. Greenwich, CT: JAI Press.

Tierney, K., 2004. "Collective behavior in times of crisis." Paper prepared for the National Research Council Roundtable on Social and Behavioral Sciences and Terrorism, Meeting 4, "Risk Communication for Terrorism," Washington, DC, January 30.

Tierney, K., M. K. Lindell, and R. W. Perry, 2001. *Facing the Unexpected: Disaster Preparedness and Response in the United States.* Washington, DC: Joseph Henry Press.

5. Budget Justification

FY 2003 Budget
The RESCUE project is a large collaborative agreement between UC Irvine and UC San Diego with subcontract projects under UC Irvine.

The RESCUE project at UC Irvine was funded at 80% of the original requested amount for YR 1. A total of $1,726,716 was awarded to UC Irvine with $557,420 of the total budget allocated to five subcontract projects. Allocations to participating sites were as follows:

Brigham Young University	$82,093
ImageCat Inc.	$274,880
University of Colorado at Boulder	$80,839
University of Illinois at Urbana-Champaign	$79,534
University of Maryland College Park	$40,073

The RESCUE project at UC San Diego was funded at 83% of the original requested amount for YR 1. $700,000 was awarded to UC San Diego.

UC Irvine FY 2003 Expense Justification
At the time of the award to UC Irvine, the building assigned to permanently house the project was under construction. Due to the unavailability of the assigned space, the physical location for the project has temporarily been housed at an off-campus location, specifically the University Research Park (URP) located immediately adjacent to the UCI campus. In order to accommodate the cost of being located off-campus, UCI has authorized the application of UCI's approved off-campus indirect rate (26%) in lieu of the campus's approved indirect rate (51.5%) during the time the project is located in the off-campus space. It is estimated that the project will be located in the URP space through September 30, 2004 when the new building is expected to be available for occupation. The effect of the reduction in the indirect rate has allowed for the coverage of direct costs including monthly lease, space maintenance, utility and telephone costs, minor renovations to the space, as well as additional students needed for the project. It is estimated that approximately $230,642 from the difference between the approved on-campus and off-campus indirect rates will be available during this period to be rebudgeted to cover the above stated direct costs.

It is anticipated most of YR 1 funds will be spent out and carry-forward will not exceed 10%. The project is continuing to hire personnel and if all positions are filled then a very small amount of carry-forward can be expected to YR 2.

This year the campus has provided the project $50,000 in cost-sharing funds for use on the project. At this time funds have not been expended from this contribution, however, these funds may be used for salary supplementation once all positions have been filled. The Department of ICS has provided support through graduate student fellowships and appointments.

Brigham Young University FY 2003 Expense Justification
It is anticipated the entire YR 1 funds will be expended as originally budgeted.

ImageCat Inc. FY 2003 Expense Justification
It is anticipated the entire YR 1 funds will be expended as originally budgeted.

University of Colorado at Boulder FY 2003 Expense Justification
There has been a delay of final awarding of funds for the project at U. of Colorado led by Dr. Kathleen Tierney due to an issue with human subjects approval. Originally, the work plan did not call for any activity involving human subjects using YR 1 funds; however the opportunity to conduct field studies to gather data came sooner than originally expected. A meeting will be held in early July to clarify the situation, after which the necessary applications will be submitted to the human subjects board at the U. of Colorado. The situation is expected to be resolved in a matter of days. However, it should be pointed out that other tasks as outlined in the statement of work for year 1 are ongoing. In the original U. of Colorado YR 1 budget, two graduate students were to be hired; however, a post-doctoral scholar will be hired instead to work on the project in their place. It is anticipated the entire YR 1 funds will be expended at the end of the YR 1 project period.

University of Illinois at Urbana-Champaign FY 2003 Expense Justification
It is anticipated the entire YR 1 funds will be expended as originally budgeted.

University of Maryland College Park FY 2003 Expense Justification
Per the request of Dr. Peter Chang, PI for the project at the University of Maryland College Park, approximately $13,900 in funds have been rebudgeted into the categories of travel, supplies and equipment to better support the needs of project. The original budget supported salary support for the PI, a technician, and a graduate student. It is anticipated that a majority of the YR1 funds will be expended at the end of the project year. Remaining funds will be used towards graduate student salary support in YR2.

University of California at San Diego FY 2003 Expense Justification
There has been a delay in hiring personnel on the project at UC San Diego because of difficulties with University Human Resources and job classification/job card creation issues, as well as finding suitable candidates for the positions. The administrative coordinator for the project was not hired until February of 2004. UCSD is currently in the process of interviewing and hiring for the staff technical lead (Programmer/Analyst IV). One postdoc worked on the project for a period of approximately six months, and another for one quarter. UCSD is currently in the process of recruiting and interviewing candidates to fill these postdoc positions, and expects to have them filled before the end of YR 1. Only one of the three students budgeted has been funded on the project for the entire duration of YR 1, and an additional student spent one quarter on the project. Two students from UC Irvine will be spending the summer working full time at UCSD, which will further expend GSR salary funds not spent during the first part of YR 1.

Due to the delay in hiring personnel, we have rebudgeted into the categories of supplies and equipment to support our high startup costs. YR 1 equipment and supply expenditure will be greater than anticipated in the original allocation.

It is expected that the majority of YR 1 funds will be expended by the end of the YR 1 project period. Any funds remaining to be carry- forwarded to YR 2 are not expected to exceed the NSF limitation of 20%.

FY 2004 Budget Request

There is no change to the budget request for YR2 funds at UC Irvine. The current YR2 budget requests a total of $1,877,208 in funds awarded to UC Irvine with $609,629 of the total budget being awarded to five subcontracts. Allocations to participating sites are as follows:

Brigham Young University	$82,093
ImageCat Inc.	$275,175
University of Colorado at Boulder	$80,324
University of Illinois at Urbana-Champaign	$77,883
University of Maryland College Park	$41,985

There is no change to the budget request for YR 2 funds at UC San Diego. The current YR2 budget requests a total of $700,000 in funds awarded to UC San Diego.