Potential of Satellite and Aerial Remote Sensing Technologies for Earthquake Disaster Management

by

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ABSTRACT

The paper focuses on potential payoffs and the importance of exploring innovative technology applications using remote sensing capabilities for earthquake hazard and disaster management. New tools are presented for potential application to earthquake disaster management from the result of a national program on remote sensing and spatial information technology application to transportation, a joint program with the National Aeronautics and Space Administration (NASA) managed by the Research and Special Programs Administration (RSPA) of the U.S. Department Of Transportation. The paper discusses the potential application of remote sensing technologies for disaster management in the following critical areas:

1) Application of Synthetic Aperture Radar (SAR) technology for detection and measurement of ground strains in large land masses associated with strain energy accumulation and releases leading to earthquakes.

2) Remotely sensed imagery analysis for assessment of critical infrastructure vulnerability to transportation service disruptions and for community planning of emergency preparedness.

3) Development of new sensing platforms for near real time and readily deployable imagery capability using Unmanned Airborne Vehicles (UAVs) for applications to emergency management of transportation, after an earthquake event.

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1.0 INTRODUCTION

During the past three decades, earthquake hazard mitigation research in the U.S. and Japan, has made significant advances in technical understanding and analysis of earthquake mechanisms and predicting damage to structures. Viable tools for measuring precise ground movements in large land mass structures generated by strain energy accumulation that lead to earthquakes are not currently available. This limitation presents a barrier for achieving responsive earthquake pre-event recognition and disaster mitigation processes. Space or aerial based sensing and measurement of ground strain in large land areas associated with earthquake energy accumulations would have the potential for recognizing earthquake events before their occurrence and provide new tools for disaster management. The advances in satellite and aerial based sensing, information and communication technologies offer a range of potential 'leap frog' technologies for application to earthquake event recognition and disaster management. During the next decades, earthquake R&D programs for hazard mitigation should focus on exploring the potential application of these remote sensing technologies and concepts to predict earthquake events and plan for the safety and evacuation of communities in regions prone to earthquakes.

2.0 SYNTHETIC APERTURE RADAR APPLICATION FOR LAND MASS STRAIN DETECTION

Synthetic Aperture Radar (SAR) is a new space geodetic imaging technology that has the potential for enabling precise measurement of changes in the Earth's surface and surface deformation over large land masses before, during, and after earthquakes. Fundamentally, SAR measures the range of reflected radar signals to determine ground alterations and strains from an observing satellite using advanced processing of the reflected signal's amplitude and phase. The sensing range is determined by measuring the time between transmission of a pulse to receiving the echo from a target .

An airborne radar could collect data while flying long distances and then process the data as if it came from a long antenna. SAR measurement is similar to holography in that two SAR images are differenced, revealing changes in the Earth's surface with a resolution of fractions of the radar wavelength. Modern SAR satellites can precisely measure and map hundreds of square miles of land areas in a very short time. Civilian exploration of SAR technology application to infrastructure planning and construction will increase during this decade , because lower cost electronics are just beginning to make SAR technology economical for smaller scale uses.

SAR has the potential to accurately image millimeter level changes in the Earth's surface in response to changes in stress and strain energy accumulation within the Earth's crust. SAR can measure slow accumulation of strain changes in the Earth's surface and provide views of micro changes in land mass surface at resolutions adequate for performing ground strain measurements leading to earthquakes. The analysis of imageries using SAR has the potential to lead to revolutionary change in our understanding of the strain build up and forces leading to earthquake events.

Sequences of SAR images could detect the land mass changes and weakness in the overburden as an early sign of incipient ground failure. Recent technological advances in space born radar interferometry permit observation of mm-level surface deformation. The National Research Council, National Science Foundation, NASA and the United States Geological Survey have identified SAR as an essential tool in developing and extending our ability to warn of impending natural hazards and disasters.

3.0 APPLICATION OF REMOTE SENSING IMAGERIES FOR ASSESSEMENT OF TRANSPORTATION NETWORKS AND PLANNING FOR EARTHQUAKE EMERGENCIES

Remote sensing technologies enhance the decision process on critical transportation infrastructure service condition for emergencies by providing a visual perspective of critical links to highway networks such as highway bridges, rail lines and critical intersections. Custom software and analysis methods are now available for augmenting existing centralized national databases such as National Highway Planning Network (NHPN) and Highway Performance Monitoring System (HPMS) that 'tracks down' highway bridges and critical links from remotely sensed imagery and facilitates information on condition and serviceability in transportation networks after an earthquake event.

Figure 1 shows an example of an illustration of the working one of the custom software developed in a DOT study (2) for damage and vulnerability assessment of critical transportation infrastructure network using SPOT imagery. The imageries reveal structural characteristics that simplify the interpretation of serviceability for emergency response, following a disaster. Comparison of the imageries taken before the event with 'After' event images using a centralized geospatial information system provides comparative damage assessment and serviceability evaluation for evacuation. The serviceability condition of critical networks and the extent of disruption are immediately ingested into a network-modeling program to generate critical intelligence for emergency managers on serviceability status of traffic networks for emergency planning and evacuation.

Evacuation of communities during unplanned and unexpected disaster events place a congestion burden on existing transportation networks. Transportation network vulnerability event analysis is an important first step for ensuring that the communities in earthquake prone regions have open transportation network systems for emergency evacuation. Congestion evaluation , in the event of a disaster, helps public policymakers and planners in building transportation systems that are robust in the event of unplanned disruption to critical transportation links. The dynamic flow model developed in a U.S. DOT project (3) captures system-wide impacts on congestion and its propagation over space and time.

Residential development in disaster prone regions is occurring at an unprecedented rate. Many threatened areas do not have an evacuation plan. In order to illustrate potential application of remote sensing technology for emergency preparedness decision process, a hazard example is taken from a study completed by U.S. DOT project team in a sample community east of Salt Lake City, Utah , a region highly prone to high fire recurrence levels (3) . Satellite imagery and data from the developer were merged to identify the road network and location of homes in the subdivision. This information was used with traffic simulation software to design and test neighborhood evacuation plans. The method allows an analyst to map the sub-neighborhood variation in household evacuation travel-times and potential transportation bottlenecks during a disaster. It also identifies the location of the bottleneck. Figure 2 depicts the mean household evacuation times for a relatively urgent evacuation where an average of 2.5 vehicles departed each household and the mean departure time following notification of the entire neighborhood was 10 minutes. The Figure also shows the effect of reducing the evacuation time by providing a second exit for this community. It demonstrated to the residents and planners that the new road significantly alleviates traffic problems during an evacuation and supported the decision by the County to build a second exit road.

4.0 NEAR REAL-TIME REMOTE SENSING DURING EARTHQUAKE DISASTER EVENTS USING UNMANNED AIRBORNE VEHICLES (UAVs).

A capability to deploy remote sensing operations immediately after a disaster event is important for an immediate assessment of the damage and serviceability of transportation infrastructure and critical transportation networks in the proximity of earthquake disaster locations . The operations should permit analysis of the impact of events immediately following a disaster event in near real-time.

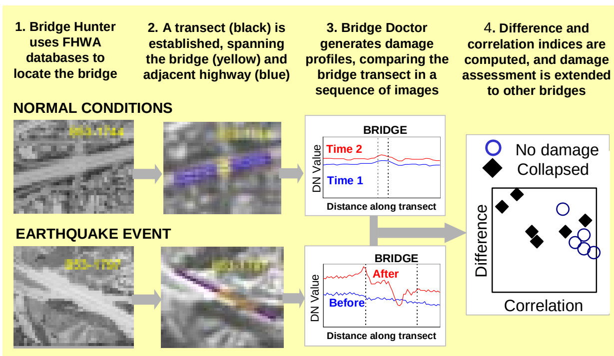
The technology for unmanned vehicles are advancing at a rapid pace adding new capabilities for remote sensing . The U.S. DOT project teams (4, 5)conducted pioneering demonstrations on using UAVs for remote sensing of transportation systems and for obtaining imageries of transportation networks and performing near real-time analysis of results for application. UAVs can be programmed off-line and controlled in real-time to navigate and to collect imageries for transportation network surveillance immediately following a disaster. Small UAVs for transportation application can range in weights from 10 to 60 pounds and can carry a variety of multiple and interchangeable imaging devices, including day and night real-time video, multispectral and hyperspectral sensors, thermal, synthetic aperture radars, moving target indication radar, laser scanners, and chemical, biological and radiological sensors. Figure 3 shows a micro UAV and an Airborne Data Acquisition Systems (ADAS) tested for transportation application in DOT projects. UAVs have been successfully tested for tracking urban and rural transportation networks and multimodal operations and can be deployed for application to emergency management in the event of an earthquake disaster.

5.0 REFERENCES

The following references cited in the paper are from preliminary results from ongoing research by several investigators in a U.S. DOT Joint program with NASA. Copies of the project reports can be obtained by writing to the author at U.S. DOT/RSPA, 400 Seventh Street SW, Suite 7110, Washington, D.C. 20590

1. US DOT and NASA team discussions on SAR technologies for disaster application (RS Work Group of SDR)
2. Disaster damage and emergency response by ImageCat. Inc (Ron Eguchi)
3. Community evacuation Community planning using RS technologies by University of Utah (George Hepner and Tom Cova)
4. Micro UAV Applications to Transit Management by Bridgewater State College (Lawrence J. Harman)
5. Airborne Data Acquisition System by GeoData Systems (Ernest Carrol)

Figure 1. Remote Sensing Imagery Application For Damage And Vulnerability Assessment of Critical Transportation Bridges For Emergency Transportation after an Earthquake (U.S. DOT Project Results by Imagecat Inc)



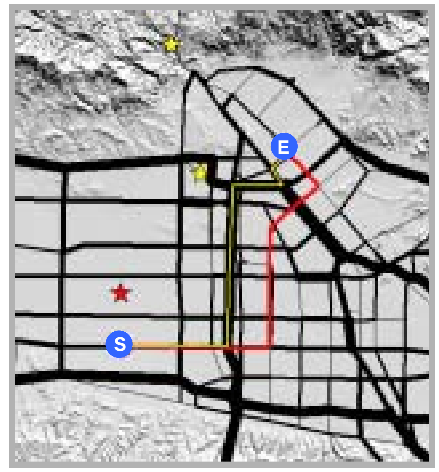
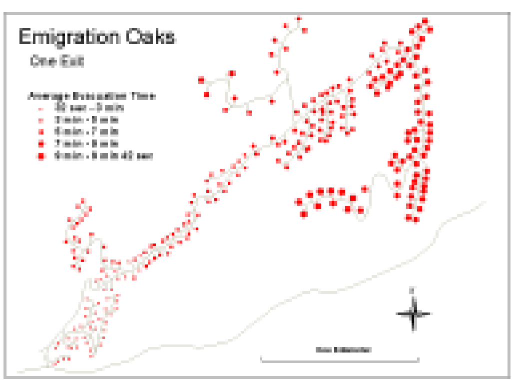


Figure 2. Modeling Emergency Evacuation in Community Planning (U.S. DOT Project Results by University of Utah)



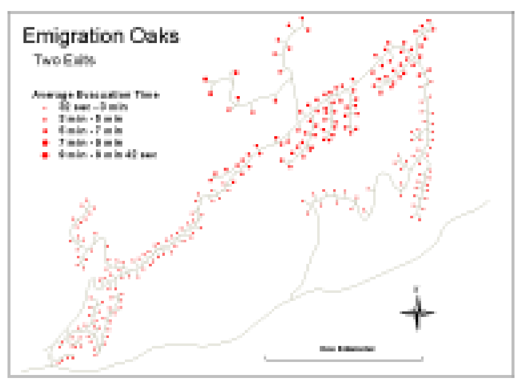


Figure 3. Micro UAVs For Urban Transportation Management (U.S. DOT Project Results by Moakley Center-Bridgewater State College) and Airborne Data Acquisition System (ADAS) for Traffic Management (U.S.DOT Project Results by Geodata Systems Inc.)