Towards a Geospatial Knowledge Discovery Framework for Disaster Management

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Submitted to ESA-EUSC 2008: Image Information Mining: pursuing automation of
geospatial intelligence for environment and security

Extended Abstract

Natural and technological disasters occur can occur with little warning and pose a significant risk for the loss of human life and extensive damage to property and the economy. Although, the generation process underlying the various disaster and emergency scenarios are fundamentally different, the techniques to assess risk, evaluate preparedness, and implement response and recovery are not. In contrast, these techniques have a common logical foundation irrespective of their fields of application and are supported by similar earth observation data and analytical capabilities. Geospatial information is essential for quick and effective response during disaster and emergency situations. Because disasters and emergencies are always geographically defined and addressed, the decision making capability in emergency management requires spatiotemporal visualization of our environment, which in turn is empowered by geospatial information that is largely derived from earth observation or remote sensing data and spatial analyses using various Geographic Information System (GIS) based modeling and simulation tools. Consequently, remote sensing technologies are increasingly becoming nucleus to disaster preparedness, response, and recovery missions.

Majority of disaster impact modeling and mitigation analyses programs take advantage of geospatial data and other surrogate data sets that are derived from the large volume of image data being produced and archived. For example, rapid damage assessment is key to time critical decision support in disaster management to better utilize available response resources and accelerate recovery and relief efforts. Enormous volumes of image data are being produced that are not only required for developing spatial or geographic data applications such as land cover, but are also critical for time-sensitive applications. Images are not only critical for situation awareness and assessment purposes, but they are invaluable for detecting changes and providing relevant information to decision makers. But exploiting such huge volumes of image data for rapid damage assessment is a time consuming exercise to do manually or using existing semi-automated techniques. Modeling and analytical tools have been upgraded, or specifically developed to take advantage of complex spatial data structures. Unfortunately, these upgraded tools have not been able to keep up with the pace of data upgrades primarily because of the overwhelming rate of spatial data development and the disparate characters of the data being produced. Modeling and analytical tools take

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advantage of available image data sources that are typically managed in a data archive. For any geographic region, an increasing number of images become available. These images are produced from different and newer sensor platforms (satellites, aircrafts) and consequently these images vary in spatial, spectral, and temporal resolutions, geographic projections, and internal data structures. These data are also distributed from various dispersed sources making it quite difficult to efficiently keep up with the periodic updates and refinements necessary to keep the data archive current and to maximize its usability. Another challenge is how to quickly search and retrieve features of interest from thousands of images. This is an impossible task at present because images are typically catalogued by geographic indexes and not necessarily by the features or information contained in them. This lack of an automated image data management system that allows fast and effective retrieval of information severely weakens the link between the spatial data and the modeling and analytical tools that use that data. This consequently impacts the effectiveness decision support systems that rely on the quality of spatial information generated from spatial data (imagery) as well as the efficiency of the tools that process such information.

The lack of comprehensive framework that allows fast and efficient exploitation of voluminous image data for information extraction leading to knowledge management is well realized. There are several ways to improve the overall performance of disaster preparedness and response collaborations by taking advantage of the progressive Cyberinfrastructure including high performance computing and networks. At an elemental level the goal is to assimilate best available data with analytical capabilities from various nodes of a geographically distributed network to enhance the reliability of information and the speed at which it becomes available to decision makers and first responders during preparedness, rescue, and recovery phases of a disaster. Acknowledging that effectiveness all decisions are bound by operationally acceptable timeframe, another important facet of a dynamic geospatial knowledge discovery framework is to provide the user with the most relevant (space and time) resolutions of data, model, and tools given the resolution of a question being asked and the sensitivity of the resolution of the answer for decision support. Consequently, of disaster impact assessment at different geographic scales should take advantage of different sources of data (and vice versa). For example, images from Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Wide Field Sensor (AWIFS) have high temporal resolution and coarse spatial resolution. These data sources can be used to monitor changes and/or assess damage to vegetation at regional scales over a period of time. Images from Ikonos, Quickbird and aerial images have high spatial resolution and low temporal resolution. These data sources can be used to monitor changes and damages caused to urban buildings and man made structures.

Feasibility of such dynamic knowledge discovery framework has been discussed by Bhaduri et al. (2006) and Tobin et al. (2005 and 2006). Potere et al. (2007) and Fang et al. (2006) investigated on monitoring temporal variations in MODIS data to capture land cover change in vegetation using time series analysis of dynamic geospatial data archives. Moreover, effectiveness and technical challenges of multi-resolution feature extraction with high performance computing have also been discussed by Cheriyadat et al. (2007) and Vijayaraj et al., (2007). This paper will describe ongoing development of
a computationally intensive and efficient geospatial modeling and analysis framework that allows near real time processing and integration of remotely sensed data, derivation of more intelligent data derivatives, and faster than real time modeling and simulations using capability computing. Drawing from our experience in supporting national and international consequence management efforts for recent natural disasters including Hurricanes Katrina and Rita, and historic Tsunami of 2004, we will highlight the practical limitations of traditional disaster decision support structure and criticality of geospatial science and technology in advancing current modeling and analysis approaches. In particular, we will discuss plausible developmental approaches for a rapid damage mapping technique by mining post and pre-disaster event high resolution image data using high performance computing to increase computational performance. The proposed technique has a region based approach in which a set of features are computed for both before and after event set of images. The major challenges are to identify features that are robust to changes in illumination and imaging conditions, to be robust to small co-registration errors and to efficiently and effectively compare multiresolution features. Typically imagery collected after a natural disaster like a hurricane has variations in illumination due to cloud cover and may be at different viewing angle compared to pre-event image. Also the imagery that is available immediately after the event might have a different spatial resolution compared to the pre-event image. A conceptual diagram of the proposed technique is given in figure 1.

![Figure 1: Rapid Damage Assessment from high resolution imagery](image)

The pre-event image data is processed and spatial features are computed. The features are indexed in a database. The information from this spatial database can be used in a content based image retrieval framework to plan disaster preparedness. Similar features are computed from post-event image data as they become available and are compared with the pre-event feature set in the database to identify changes and assess damages. Parallel processing is used to efficiently compute and index features for high resolution imagery covering a large disaster area.
References:


