Using Remote Sensing for Natural Disaster Management

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Abstract

Natural disasters can cause devastating human, property, and economic loss in a region. Predicting the impact of a disaster and creating potential recovery plans can help alleviate these losses. Remote sensing images can be used to provide information about the landscape and environment of the Earth. Recent technological advancements in resolution and image transmission speed have made it possible to have accurate and up-to-date images available during the time of a crisis. Current research is focused on developing an infrastructure to make the data collected with remote sensing more widely available to disaster management authorities.

1. Introduction

In disaster management, many organizations have to coordinate in a stressful environment under time pressure. Decisions are often made based on experience rather than information due to the lack of timely, reliable data [3]. Using remote sensing can provide images that are particularly useful in the field of disaster management. Remote sensing is the collection of information about an object or area through the use of a device that is not in immediate contact with the object, such as an airplane, ship, or satellite. Currently, however, there is no infrastructure to store and distribute the data collected with remote sensing. This paper discusses data and system requirements of a Spatial Data Infrastructure (SDI) and reviews infrastructures that are currently implemented.

2. Data Requirements

The data utilized in disaster management supports the evaluation of the development, impact, and extent of a disaster. This data needs to be accurate, exchangeable consistent, and up-to-date. It should also be easy to input, update, and transfer the data in a quick and efficient manner [5]. The time span of a disaster is about forty-eight hours, so images need to be acquired, processed, and made available very quickly [1]. Emergency forces can save time, money, and effort when sharing the burden of data collection and maintenance [5].
2.1 Acquiring Data

Disaster response is dynamic and time sensitive. Some data needs to be collected prior to the disaster, and some data needs to be updated immediately following the event [2]. These requirements need to be taken into consideration when determining how to acquire necessary data and images. Currently, satellite scheduling can take up to twenty-five hours. This means that images cannot be acquired on the same day that a disaster occurs. Satellite scheduling needs to be improved so satellites can be rescheduled up to several minutes before the image acquisition. This will shorten the time between the occurrence of the disaster and the acquisition of the first images. High resolution geostationary satellites should also be deployed. This will allow the monitoring of a particular area for anywhere from several minutes to several hours. Images should be acquired systematically for interest areas so that up-to-date images are always available [1].

2.2 Formatting Data

Once images are acquired, they need to be downloaded, formatted and distributed. This process, which can take more than eight hours, creates a significant delay between image acquisition and image availability. Automatic information extraction algorithms need to be developed. This will help analyze the large volume of data that exists, especially in high resolution images [1].

2.3 Storing Data

Data needs to be kept secure and in an easy-to-use format while being made available to multiple organization. Each organization should have their own database with relevant data as well as access to a main database through a web-based system [2]. One proposed solution is to create a web-based catalogue service that could be used to organize information. Data could be described by topic, spatial and temporal reference, generator, quality, etc. Data can then be retrieved by selecting a database, specifying keywords (thematic search), specifying a period of time (temporal search), and specifying a location (spatial search) [4].

3. System Requirements

A Spatial Data Infrastructure (SDI) can be defined as a framework for the coordination of the exchange of static and dynamic spatial data between emergency forces [5]. The SDI needs to handle multiple forms of data, including framework data, environmental or geological data, satellite images, and dynamic data [4]. The SDI should be accessible for both stationary and mobile users and should be implemented through a special secure infrastructure that does not rely on a normal internet connection and electricity [5].

Each phase of the disaster management life cycle encompasses certain activities that the system would need to support. During the mitigation phase, it is important to utilize monitoring, modeling, and simulation systems in order to plan for the minimization of the impact of a disaster. During the preparedness phase, it is important to be able to distribute
the proper information, materials, resources, and plans to prepare for the imminent event. During the response and recovery phases, it is important to have fault-tolerant communication and a robust system that can handle high performance data and information flows [4].

### 3.1 Implementation

A web-based SDI would provide the greatest usability [2]. The SDI should be implemented using Java or XML to provide platform independence [4]. In order to be widely adopted by disaster management authorities, the SDI should be designed with the Technology Acceptance Model (TAM) in mind. The TAM describes factors that will determine the acceptance or rejection of a new technology by users. The first factor is the perceived usefulness, or the degree to which a person believes that a system will enhance his or her job performance. The second factor is the perceived ease of use, or the degree to which a person believes that using a system will not require a lot of effort [6].

### 3.2 System Components

The web-based system would be comprised of a user interface and a variety of servers to process client requests.

![Diagram of System Components](image)

The user interface would be implemented through a web browser. Clients would use the interface to access and analyze data. The client request is sent to a web server, and the web server forwards the request to either a data server or map server via an application server. The data servers retrieve data from a spatial data database and send it to the map server for analysis [2]. The map server should provide a visualization of geographic information in the form of digital maps [4]. There should be several map and data servers so that concurrent requests from different clients can be processed simultaneously [2].

### 3.3 Security

Permissions and security constraints should be implemented so that only eligible users can access the data [2]. Several backups of data should be saved at multiple locations so there is no risk of losing information [5]. For example, mirror databases could store copies of the main database and become active automatically if the main database is compromised. This ensures constant operation of the system [2].
4. Current Systems

4.1 Tangible User Interface

The Tangible User Interface (TUI) is one example of a current system that could be utilized in developing an SDI for disaster management. The TUI is a multi-user interface that can be used to manage information and communication during a crisis. This system has an input layer on top of a table. This table generates electric signals which are sent to a computer connected to the table. Users can interact directly with the table surface, and the system will react to the user’s touch. The DiamondTouchTable, developed by the Mitsubishi Research Labs, is one example of a TUI. The DiamondTouchTable has the capability to recognize when a user touches the table, which user touched the table, where the user touched the table, and the size of the area touched [6].

4.2 Andean Information System for Disaster Prevention and Relief (SIAPAD)

The main goals of the SIAPAD project are to increase the visibility of and access to geographical information and to implement standards for data collection and publishing. This will help to eliminate the technical difficulties with sharing data among different organizations. The cost of the system must be reasonable given the economic conditions of the countries in the Andean community. The system should also be adaptable to future changes or new components. SIAPAD should be easy to use for both general users and users who are familiar with risk management.

SIAPAD is comprised of a web portal which provides tool for data searching and visualization.

![Figure 2 – SIAPAD data visualization [7]](image-url)
The information available in this system is comprised of data that is produced and managed by each individual organization. There are a variety of searches to cater to different types of users including a keyword-oriented search, a thematic search, and a task-oriented search.

The keyword search allows a user to type in one or more words and constrain the search with the aid of certain spatial or temporal reference points. The thematic search allows users who are more familiar with the field to search themes related to disaster management. The task oriented search is for users who are not at all familiar with the field. These users can define their search using a list of pre-fixed typical questions [7].

5. Proposed Work

The high resolution images captured through remote sensing contain a large volume of data. Extracting and analyzing the relevant information can be a time consuming process that creates a significant delay between the acquisition of the image and the availability of the image for disaster management authorities. Image processing techniques can help to simplify complex images so they can be analyzed quickly and easily. These techniques, however, have not been implemented in existing Spatial Data Infrastructures. I intend to research existing image processing approaches and how these techniques can be incorporated into current and future systems.

There are three main approaches in remote sensing image processing: principal component analysis, image differencing, and object oriented classification. The purpose of these techniques is to identify non-damaged and damaged areas in images. Principal component analysis classifies the spectral reflectance of images before and after an event separately and identifies the differences as areas of damage. Image differencing classifies cells based on spectral differences of images before and after an event to determine the area of damage. Finally, object oriented classification segments an image into objects, or
groups of pixels that have similar spectral and spatial properties, to distinguish between
the damaged and non-damaged areas [8].

The goal of my research is to adapt these techniques so they can be implemented in
current and future Spatial Data Infrastructures. The first step of my research would be to
further investigate the different approaches to image processing to understand exactly
how each technique works. The second step of my research would be to create an
algorithm to automatically invoke these image processing methods when a new remote
sensing image is acquired. The third, and final, step of my research would be to develop
the code necessary to implement the new algorithm in existing systems. The following
table shows how this work will be completed in a two-month time frame:

<table>
<thead>
<tr>
<th>Week</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Research Image Processing Techniques</td>
</tr>
<tr>
<td>3-4</td>
<td>Algorithm Development</td>
</tr>
<tr>
<td>5-6</td>
<td>Code Development</td>
</tr>
<tr>
<td>7-8</td>
<td>Testing &amp; Improvements</td>
</tr>
</tbody>
</table>

I believe that many of the courses I have taken as a computer science major qualify me to
conduct this research. I have had experience with algorithms through my Analysis of
Algorithms course. I have had extensive programming experience through my classes as
well. My strongest programming language is Java, which is the primary language of
current Spatial Data Infrastructures. I also plan to assemble a small research team of other
computer science experts. Through our combined efforts, we will be able to complete our
research in a timely and efficient manner.

6. Conclusions

The field of using remote sensing in disaster management is relatively new. The
acquisition and use of this data can still be greatly improved. The current systems that
incorporate remote sensing offer promising solutions to the creation of an SDI to support
disaster management. However, there is still much research to be done before a fully
functioning and efficient SDI can be widely adopted among authorities in disaster
management.

References

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