POST-EARTHQUAKE DAMAGE ASSESSMENT USING SATELLITE IMAGERY

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ABSTRACT

After the Turkey-Marmara earthquake that occurred in 1999, it was realized that this region had a great risk because of its closeness to the North-Anatolian fault line. Going on research showed that another severe earthquake is expected in the following thirty years. These research results brought into agenda not only the precautions that should be considered but also the importance of the rescue management. In rescue management, the damage assessment is a major issue in determining the optimal way in the usage of the rescue sources. This paper proposes a method of damage assessment based on satellite images taken before and after a disaster. This study also includes the synthetical construction of post-earthquake images.

1. INTRODUCTION

Earthquake motion is caused by the quick release of stored potential energy and its conversion into kinetic energy of motion. More than 150,000 tremors strong enough to be felt by humans occur each year worldwide [1]. Most earthquakes are produced along faults, tectonic plate boundary zones, or along the mid-oceanic ridges.

The Marmara earthquake occurred during a time of unprecedented technological development. Post-disaster information that once took months to generate were developed within a matter of days in this incident. Furthermore, the ability to comprehensively understand the meaning of these obtained data was significantly enhanced because of the use of sophisticated database management programs and geographical relational algorithms. In the most general sense, it was possible to literally map the effects of the earthquake in "real time"[2].

When a natural disaster such as a big earthquake happens, the range and severity of the damaged areas should be grasped to organize the rescue operation. It is important to capture the distribution of the damage immediately after an earthquake or any other disaster[3].The satellite images are useful to grasp the damaged areas rapidly and widely.

In this study, the satellite images are used to determine the damaged areas. In the occurrence of an earthquake, pre- and post-earthquake images will be used for the determination of the damage. For this study, an image-based damage construction simulator was also developed to obtain hypothetical post-earthquake satellite images. The amount of damage can be obtained by computing the difference between the two images.

This paper is organized in 5 main sections. After the introduction, an overview of the system implemented is given in Section 2. This section also emphasizes the assumptions that are made for simulation purposes. The two main parts of the system are detailed in Section 3 and Section 4, respectively. Section 6 concludes the paper.

2. OVERVIEW OF THE SYSTEM

The system consists of two main parts as given in Fig. 1. The main part of the system is the damage assessment block. However, in order to show the working of this unit, post-earthquake images are needed. The first part of the system synthesizes virtual post images. The details of these units are explained in detail in the following sections. Here it should be noted that the amount of damage and loss of life depends on a number of factors such as the time of day, magnitude and duration of the earthquake, distance from the focus of the earthquake, the type of the building construction and the population density in the area[4]. In this study, not all of these factors were taken into account and some assumptions are made.

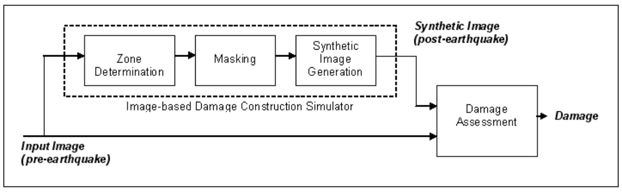

Figure 1. Flowchart of the system consisting of the simulation and the damage assessment units.

Some of the most important assumptions made for the simulation purposes can be listed as follows:

- The weather is assumed to be clear and cloudless. In the case of a cloudy weather, no clear satellite image would be obtained.

- The zones and the earthquake of these zones are determined randomly.
- The types of buildings and their endurance are not considered individually and the buildings in a district is considered to have the same construction properties.
- The position of the satellite for the pre- and post-images are assumed to be identical.
- In determining the damage, the images are compared based on pixel values. The areas with a greater damage is expected to give larger difference values.
- The epicenter of the earthquake is taken randomly and only the distance from this center is taken into account while determining the zone degrees.

3. IMAGE-BASED DAMAGE CONSTRUCTION SIMULATOR

The main aim of this study is determining the damaged areas by considering post-earthquake satellite images and displaying the results on the map. However to test the damage detection algorithm, the satellite images of a probable earthquake should be constructed. The simulator produces virtual earthquakes and enables us to obtain post-earthquake images.

The simulation which constructs damaged images consists of a few steps. These are detailed in the following subsections.

3.1. Zone Determination

The epicenter of the earthquake cannot be determined before the earthquake. But the information about the distance from the fault enables us to make predictions about the probable damage. Also if the degree of earthquake zone is known, we can make clearer predictions.

The first thing for the simulation of post-earthquake image construction is dividing a satellite image into 16 zones. This way, a detailed and precise masking and post earthquake image construction will be done for each zone. The zones of the sample image are shown by Figure 3. In this study the real data of the region is not used and a random degree between 1 and 5 is assigned for each zone. The degrees of the zones are considered for the epicenter selection and for the transmission of the energy that is relieved by the earthquake. In Fig. 2 the degrees of the zones for the sample area are shown.

3.2. Masking

The effects of the earthquake is not only related to the distance from the epicenter but also related to the construction of the buildings. The construction of the buildings may vary in zones but we can assume that buildings in the same district have similar construction properties. The buildings are divided into three categories according to their properties [5]:

- A Type: slight earthquake endurable.
- B Type: medium level earthquake endurable.

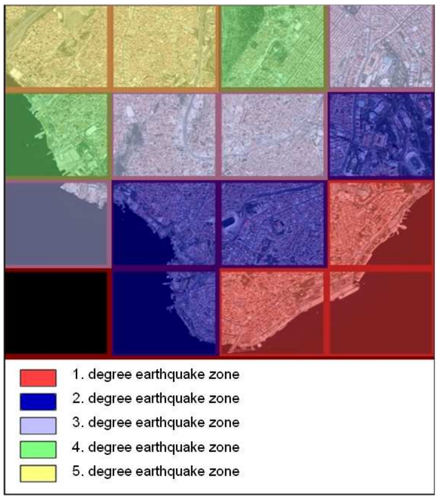

Figure 2. Degree of earthquake zones. These degrees are given randomly for simulation purposes.

- C Type: earthquake endurable.

Masking is done for every zone. The aim of masking is selecting different areas in the zone. In Fig. 3 a mask is shown. The determined districts are divided into three

Figure 3. A sample area and an example of a mask for the given area.

equal groups so that in each zone A, B and C type districts are distributed randomly with equal numbers. In Fig. 4 the A, B, C type district groups are shown for a zone. Table 2 shows the relationship between the magnitude of the earthquake and the amount of damage for different building types. According to this the percentages of the buildings which will be considered as slightly, moderate and heavily damaged in an area are determined. Then the masks are combined to be used in synthetic image generation algorithm.

3.3. Synthetic Image Generation

The final step in the image-based damage construction simulation is producing post-earthquake image by producing synthesized image. For this purpose Ashikhmin's texture synthesis algorithm [4] is used. The purpose of this algorithm is to distort some areas of the region and imitate the texture in those areas. The important thing is that the changed areas should also be compatible with the general image. For this reason, while changing the area the neigh-

Table 1. Relationship between magnitude of the earthquake and the amount of damage in building types.

Earthquake Magnitude (d)	Amount of Damage	Number of Damaged Buildings
$4.0 - 5.0$ $0 < d < 1.0$	slight moderate heavy	$A(0.3 + 0.3d)$ $A(0.2d)$ 0
$5.0 - 5.5$ $0 < d < 0.5$	slight moderate heavy	$B(0.3 + 0.1d)$ $A(0.1 + 0.1d) + B(0.1 + 0.2d)$ $A(0.4 + 0.2d)$
$5.5 - 6.0$ $0.5 < d < 1.0$	slight moderate heavy	$B(0.2 + 0.2d)$ $A(0.1d) + B(0.3 + 0.2d)$ $A(0.5 + 0.4d)$
$6.0 - 6.5$ $0 < d < 0.5$	slight moderate heavy	$C(0.3 + 0.1d)$ $B(0.3 + 0.1d) + C(0.1 + 0.2d)$ $A(0.6 + 0.4d) + B(0.3 + 0.3d)$
$6.5 - 7.0$ $0.5 < d < 1.0$	slight moderate heavy	$C(0.2 + 0.1d)$ $B(0.1 + 0.1d) + C(0.3 + 0.3d)$ $A(0.8 + 0.2d) + B(0.5 + 0.3d) + C(0.1d)$
$7.0 - 7.5$ $0 < d < 0.5$	slight moderate heavy	0 $C(0.1 + 0.1d)$ $A + B(0.8 + 0.2d) + C(0.7 + 0.2d)$
$7.5 - 8.0$ $0.5 < d < 1.0$	slight moderate heavy	0 0 $A + B(0.9 + 0.1d) + C(0.8 + 0.2d)$

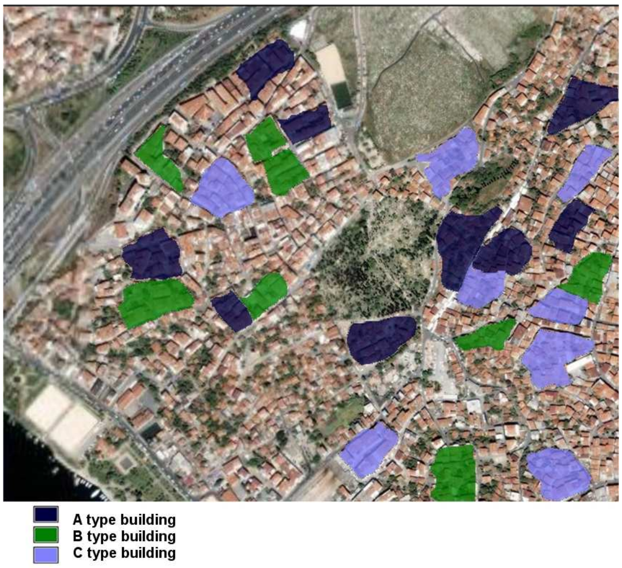

Figure 4. Grouping of the districts of a sample zone as A,B or C type.

bor pixels are considered and remembered so that a better continuation is acquired.

After the masking process the information about which areas will be effected slightly, moderate or heavily is determined. Since the damage levels of the areas are known, the algorithm is applied to these areas according to their damage level. In Fig. 5 we can see the post-earthquake simulation image of a zone with magnitude 6.7. The steps of the algorithm are:

- The array of original pixel positions is initialized to random valid positions in the input image
- For each pixel in the output image, in scanline order, do:
  - in the texture, an L-shaped neighborhood of current pixel of a specific (fixed) size is considered,
  - for each pixel from this neighborhood, use its original position in the input image (taken from the array) to generate a candidate pixel whose location is appropriately shifted
  - remove duplicate candidates
  - search the candidate list for a pixel with a neighborhood most similar to the current L-shaped neighborhood in the texture.
  - the current pixel value in the output image is copied from the position in the input sample identified as the most similar by this search and this position is recorded in the array of original positions.

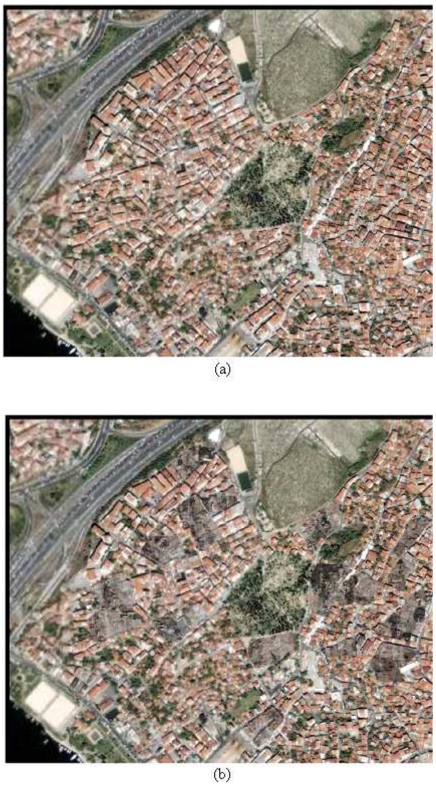

Figure 5. (a) Sample zone, (b) post-earthquake simulation image for the sample zone with magnitude 6.7.

- if necessary, modify the algorithm for the last few rows and go over the top few rows again to improve tileability of the result texture.

4. DAMAGE ASSESSMENT

It is important for emergency management and recovery works to capture damage distribution immediately after an earthquake. In this part of the work, damage assessment is done by comparing the original image with synthesized image. As opposed to the manual damage interpretation given in [3], this study embraces an automatic assessment of damage using satellite images.

In order to find the difference between two images, pixel-based comparison is done and euclidean distance is used. Some threshold values are used to separate slight, moderate, heavy damaged areas. The most realistic threshold values are determined after running the simulation for several times. It is decided that if the distance is above 200 the area is heavy damaged, if between 150 - 200 it is moderately damaged and if between 100 - 150 it is slightly damaged. In Fig. 6 the output of the damage assessment algorithm by using the original image and the synthesized image of a 6.7 earthquake is given. Red, yellow and green points indicate the heavy, moderate and slight damage respectively.

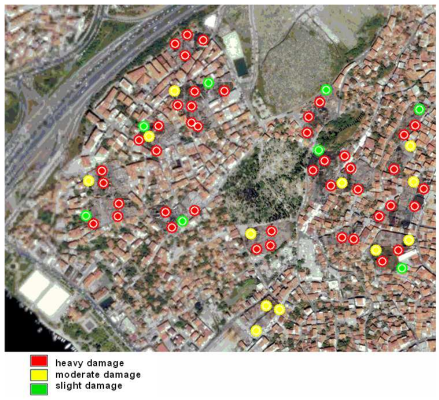

Figure 6. Damage detection on an image synthesized by the simulation for an earthquake with magnitude 6.7.

5. CONCLUSION

In this study by using satellite image of a region, a synthesized post earthquake image is produced. By comparing these two images, we obtain the damage levels of the areas. After an earthquake especially emergency management centers sending rescue and support teams to the earthquake region, require the damage information for regions to optimize the rescue work. If the developed algorithm is used after the earthquake, it can provide useful information for emergency management systems.

6. ACKNOWLEDGEMENT

This study is supported by Metropolitan Municipality of Istanbul. The code for the synthetic image generation part of the simulator was provided by Işık Barış Fidaner, a graduate student in Boğaziçi University, Department of Computer Engineering.

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