

# AUTOMATIC ASSESSMENT OF EARTHQUAKE DAMAGED AREA USING SCALE-SPACE CLASSIFICATION TECHNIQUES

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## ABSTRACT:

Disaster management has got an important facet, viz., disaster mitigation, which in turn depends upon early damage assessment. Remote Sensing is considered as an ideal technique for obtaining early information. This exercise has been carried out for assessing the damaged area, automatically, based on high-resolution post-earthquake images in Gujarat, India and high resolution satellite images of tsunami-affected areas in India and Sri Lanka. The damaged area in the form of rubble manifested as fine structure in the image. The separation of the fine structure from the rest of the image is attempted by scale-space representation approach. This method is found to be very effective for estimation of damaged area automatically in quick time and can be a very useful tool in the disaster management.

## 1.0 Introduction:

In recent years Disasters like Earthquakes and Tsunami's have caused thousands of deaths and severe economic losses. The impact of these disasters are many and varied, ranging from minor structural damages to few buildings to complete annihilation of major urban centers and severe disruption of the social and economic fabric of the nation. In 1994 the Northridge quake in Southern California and the Kobe earthquake in Japan 1995 resulted in thousands of deaths and economic losses estimated at around 200 billion US Dollars. Last Gujarat earthquake in India resulted in approximately 20,000 deaths, 1,66,000 injured with 3,48,000 houses destroyed and 8,44,000 houses damaged. The Indian government estimated that the earthquake affected, directly or indirectly, 159 lakhs people and direct economic losses of 6000 crores of rupees. The devastating tsunami in Indian Ocean in the year 2004, killed more than 2,25,000 people in eleven countries and caused heavy economic losses.

Disaster mitigation is needed to reduce worsening of post-disaster situation by way of taking effective steps to carry out relief work, finding suitable relocation places, etc. Quick information of the damaged areas (badly hit area) is very essential to do the relief work immediately so that the assistance can reach the needy people at the earliest.

In the event of disaster like Earthquake and Tsunami, conventionally, first hand information about the damage affected areas can be obtained earliest through aerial surveys due to obvious reasons. Now with the availability of multiple high-resolution satellite sensors like IKONOS, Quickbird etc. and increasing frequency of coverage satellite remote sensing can be considered as a viable source of early information.

The availability of high-resolution satellite/aerial imagery will make a profound contribution to earthquake damage assessment and disaster mitigation. Quite often it is realized, although data can be acquired reasonably quickly, it takes far longer to process/analyze and create spatial information of relevance due

to the large amount of data to be analyzed manually. Manual processing of data becomes so time consuming, tedious and it varies individually.

To make the process faster, simpler and robust we need to have an automatic method, which gives us the knowledge of the areas damaged by these disasters. Damaged area assessment can be easily carried out when pre- and post-event images are available. It can be assessed, using simple change detection techniques. But events like earthquakes and tsunamis are usually unpredictable in nature hence pre event data may not be available.

In this paper we are using a multi-scale approach to assess the damaged area with the help of a single post-disaster image. From the image point of view the signature of damages was found to be the similar for the earthquake and Tsunami disaster. Hence the same method is applicable in both the cases.

## 2.1 Scale-Space theory:

Scale is inherently tied up with information. Optimal information extraction can be carried out at certain scales. For example extraction of 20-meter wide road by 1-meter resolution image data will show not only the road but also features like dividers, markers, vehicles, shadows, etc. making the road extraction a complex process. At the same time if the scale of the image is reduced, i.e., effectively finer structures/information is eliminated then the problem becomes simpler. By the same reason, some of the features will appear over certain range of scale. Scale Space theory provides a well-defined frame- work for dealing with image structures at different scales [Lindeberg, 1994].

The basic idea behind a multi-scale representation of signal is by generating one-parameter family of derived signals, where fine-scale information is successively suppressed. This operation, which will be termed scale-space smoothing, must be available at any level of scale. The major reason for this is to

explicitly represent the multi-scale aspect of real world images or simply by removing unnecessary and disturbing details, such that later stage processing tasks can be simplified more technically.

‘Multi-scale’ analysis is a family of transformation  $[T_t(x)]$  defined as

$$I(t,x) = \begin{cases} T_t(x) & \text{if } t > 0 \\ I_0 & \text{if } t = 0 \end{cases}$$

$I_0$  is the original image and  $T_t(x)$  is the image after transformation at scale ‘t’.

### 2.2 Representation of Scale-Space:

There exists a large number of possible ways to construct a one-parameter family of derived signals from a given signal this is referred to as “multi-scale representation”.

In this paper we concentrated on scale-space representation based on the diffusion equation. Diffusion filtering diffuses edges based on fine-tuning of the Diffusivity ( $D$ ) in the diffusion equation, when moving from fine to coarser scales, so that structures which are identified at a coarser scale, have to be traced back to the original image.

Diffusion equation:

$$\frac{\partial I}{\partial t} = \nabla(D\nabla I)$$

Where ‘D’ is the Diffusivity

$$I(x;0) = I_0$$

$$\nabla = \partial / \partial x + \partial / \partial y$$

$I$  is the image at scale  $t$ ,  $I_0$  is the original image

#### Different types of Diffusion processes:

There are two types of diffusions employed in Scale-Space representation

1. Linear Diffusion
2. Non-linear Diffusion

#### Linear Diffusion:

In Linear Diffusion the Diffusivity ‘D’ is constant through out the image. If  $D = 1$  the output is same as convolution with the Gaussian kernel. If we take  $D = 1$  directly, useful information is also eliminated along with the noise. Then the images become blurred.

#### Non-linear Diffusion:

In order to avoid the blurring and localization problem of linear diffusion filtering Perona and Malik proposed a non-linear diffusion method [Perona, Malik, 1990]. The non-uniform process reduces the diffusivity at those locations that have a larger likelihood to the edges, which have larger gradients.

Of the different non-linear methods [Weickert], anisotropic diffusion is used in the present context. It is an edge preserving process, which favours diffusion of intra-region over inter-region. This is needed for the separation of rubble from built-up area.

### 3.0 Algorithm / Implementation:

Our approach of assessing the damaged area is based on the scale-space events. If we successively degrade the resolution then the coarser scale of one pixel value happens. At some scale some of the features just appear / disappear. These are called scale-space events. Texture is spatial variation of gray tone. Finer feature implies high spatial variation. In the scale space methods, when one proceeds from fine to coarser scale, the fine texture disappears first followed by coarser texture.

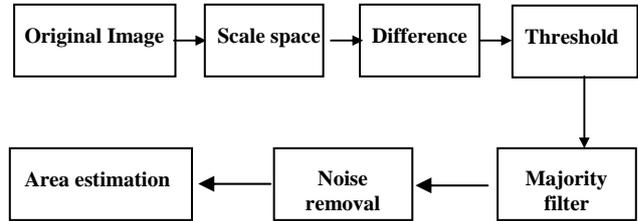


Figure 1 . Block Diagram

The rubble present in the image is a fine texture, which can be separated by the use of scale-space representation. The area under rubble is used as a measure of damaged area. Block diagram in Fig.1 shows the process of extraction of damage (rubble). The extracted portion is having noise as well as holes so the low level image processing technique like morphological operations are used to form a continuous cluster of rubble, and using some area threshold to remove spurious noisy regions. The whole process appears to have potential for operationalizing the damaged area assessment.

### 4.0 Results / Analysis:

A High-resolution aerial image of the Bhuj and Anjar (in India) was acquired after the Earthquake. Scale space classification is applied to extract rubble region in the image as explained in section 3.0. The extracted rubble regions are seen as dense cluster of points, although there are few isolated points in the image, which does not belong to the rubble region. The dense cluster points are converted to continuous regions by the use of morphological dilation operator followed by the erosion operator. The isolated points are removed by area base filter.

In order to assess and validate the damaged area, the original image is divided into blocks of 200x200 pixels. The percentage of damaged area in each block is obtained by visual interpretation. Similar blocks are considered in the damaged area extraction by our method. **The comparison of damaged area estimation by manual and automatic method has found to have correlation of 0.96.**

In order to prove operationalization of the methods another portion of the damaged area of Anjar was taken which had many road and clean ground features, which gave similar encouraging results. This shows the adopted technique is fast and efficient in assessing the damaged area quickly and automatically.

In a similar way, high resolution Quickbird images of Banda Ache were used to assess the damaged area with the same technique and the results were correlated with the manually interpreted values. Both the results were highly correlating. To verify the technique pre event images are also used to find out the commission errors, results shows that the automatically

detected damaged areas reported in pre event images is negligible.

Results are shown in appendix-1.

### 5.0 Conclusion:

Results show that this new technique of assessing the damaged area is very fast and efficient. The main advantage is the quickness and automation of the procedure. As soon as the data comes one can find out the areas, which are badly hit and the rescue work can be organized accordingly.

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### References:

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### Appendix-1

#### 1. Banda Aceh - Indonesia (28-12-2004)

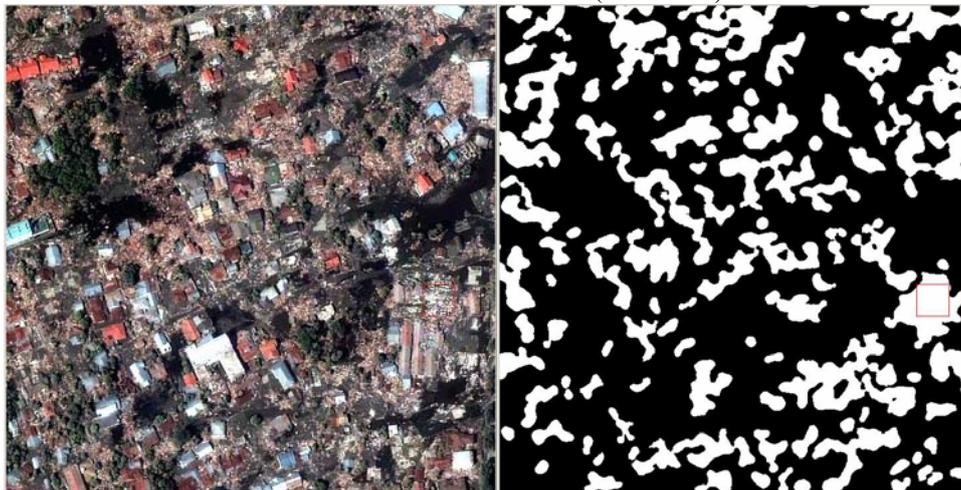


QuickBird Imagery: Post Event

Detected Damaged Area

Area under debris estimated : 40%

#### 2. Banda Aceh - Indonesia (28-12-2004)



QuickBird Imagery: Post Event

Detected Damaged Area

Area under debris estimated : 28%

**3. Banda Aceh - Indonesia (Pre Tsunami Images)**



QuickBird Imagery: Pre Event

Commission errors (<1%)