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Earthquake Damage Assessment of Buildings Using Pre-event and Post-event Imagery

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Abstract The serious natural disasters such as flood and earthquake result in great loss to human every year. The natural disasters cannot be eliminated completely, but it can be minimize the sufferings through proper awareness of the likely disasters and its impact by developing a suitable warning system, disaster preparedness and management of disasters and assessment. Rapid damage assessment after natural disasters (e.g., earthquakes) and violent conflicts (e.g., war-related destruction) is crucial for initiating effective emergency response actions. For rapid impact assessment, remote sensing data sets can provide important information since they can map the extended areas quickly and in an uncensored manner. In this project, a novel method is introduced, that detects buildings destroyed in an earthquake using pre-event and post-event detected imagery. The method operates at the level of individual buildings and assumes that they have a rectangular footprint and are isolated. Several procedures were followed and finally features are matched. The similarity between the predicted image and the actual image is analyzed. If the similarity is high, the building is likely to be still intact, whereas a low similarity indicates that the building is destroyed.

1. INTRODUCTION

The reported occurrence of natural disasters, such as earthquakes, floods, and cyclones, is on the rise leading to increased public awareness of the impact of catastrophic events. In the short term, the occurrence of such events cannot be reduced by immediate human actions, whereas long-term trends may be influenced for events that are tentatively linked to climate change. To understand and possibly mitigate the impact of such catastrophic events on human beings and their environment, research is being carried out for each of the characteristic phases of such events, i.e., before the event (early warning systems, risk assessment, preparedness), the moment the event occurs (disaster-alerting systems), and after the event (emergency response, impact assessment).

Rapid impact assessment after a catastrophic event is crucial for initiating effective emergency response actions. The acquisition of field data, supporting the aforementioned impact assessment, in areas hit by severe earthquakes is indeed a hard task, mainly due to the restricted physical accessibility of the affected areas (i.e. unpredictable road conditions, landslides and soil fractures, panic, growing of diseases, lack of food and water, hazards due to instable buildings). To cope with the accessibility and time constraints issues, data in earthquake contexts, especially for damage assessment purposes, has been widely proposed and a number of results have been presented after every event. Other damage assessment case studies include the 2004 Central Indian Ocean tsunami and the 1999 Izmir, Turkey, 2003 Bam, Iran, and 2006 Java, Indonesia, earthquakes.

Information on the impact of an event can be derived from suitable satellite imagery by comparing data from a chosen reference before the event (pre-event) to imagery acquired shortly after the event (post-event). Optical VHR sensors (such as IKONOS, QuickBird, EROS-B, WorldView-1, and the recently launched GeoEye) have spatial resolutions finer than 1 m. Some of these sensors have existed for almost a decade and have already imaged large parts of the earth. The increased availability of this type of sensor and their growing image archives that are frequently updated make VHR optical data well suited as the pre-event reference data source. If post-event VHR optical data are also available, general unsupervised change detection methods can be used to investigate the impact of the event. Methods focused on the detection of damage to built-up structures are proposed, but rely on a rapid supply of high-quality optical VHR data, thus requiring nearly cloud free weather conditions and suitable solar illumination. Consequently, useful data of this type are not guaranteed shortly after an event.

2. PROPERTIES OF BUILDINGS IN PRE-EVENT AND POST-EVENT IMAGES

In this paper, the input pre-event and post-event image is resized into a size of 256×256 and converts it from RGB to Gray image for further processing. If it processed with RGB image format, it can’t able to recognise the image. The edge component from the coarse wavelet for each decomposition has been detected and stored. Then it is used to preserve the edge components the soft threshold process takes place by leaving those pixels and put the same value of that pixel place. The over smoothening is also avoided because of the thresholding value is calculated from the image pixel value itself. Describe here a simple version of the algorithm applicable to binary images. The algorithm may be easily generalized for segmented colored images. "Segmented" means that the image must be subdivided into a not too large number of connected subsets each of which contains pixels of only one color. In usual colored images there are thousands of small subsets, each consisting of a single pixel. It is of course possible to encode such an image by the presented algorithm, but this has no practical sense. we consider the image as a two dimensional complex containing besides the pixels also cracks and points.

A. Sharpening Spatial Filtering

The principle objective of sharpening filter is to highlight fine detail in an image or to enhance detail that has been blurred, either in error or as a natural method of particular method of image acquisition. Uses of image sharpening vary and include applications ranging from electronic printing and medical imaging to industrial inspection and autonomous guidance in military systems.

B. High Pass Filter, High Boost Filters, Unsharp Masking

The first method is Basic high pass filtering technique. The shape of the impulse response needed to implement a high pass (sharpening) spatial filter indicates that the filter should have positive coefficients near its center and negative coefficients in the outer periphery. This filter eliminates the zero frequency term which reduces significantly the global contrast of the image. The result is characterized by somewhat enhanced edges over a rather dark background. Significantly better result can be obtained by using high-boost filtering. A process used to sharpen images consists of subtracting a blurred version of an image from the original image itself. This process is referred to as unsharp masking.

This process is exclicksed as

$$fs(x, y) = f(x, y) – f\hat{}(x, y) \quad (2.1)$$

Where fs(x, y) denotes the sharpened image obtained by unsharp masking, and f ^(x, y) is a blurred version of f(x, y). A slight further generalization of unsharp masking is called high boost filtering.

A high boost filtered image, fhb, is defined at any point (x, y) as

$$fhb(x, y) = A*f(x, y) – f\hat{}(x, y) \quad (2.2)$$

Where A>=1. When A=1, high boost filtering becomes “Standard” Laplacian sharpening filtering.

C.Object Segmentation

Segmentation is a term used very commonly in computer vision and refers to several kinds of image decomposition/classification techniques. For example, segmentation is used in the extraction of contours and regions of an image or a scene, boundary detection, and voxel image analysis. Generally, the first step in image analysis is to segment the image under consideration. Segmentation subdivides an image into its constituent parts or objects. The level to which this subdivision is carried depends on the problem being under processing. In general, autonomous segmentation (unsupervised segmentation) is one of the most difficult tasks in image processing. This task is the process that determines the eventual success or failure of the analysis. In fact, effective segmentation rarely fails to lead to a successful solution. Thus, considerable care should be taken to improve the probability of rugged segmentation. Numerous opportunities exist for application of segmentation in various stages from input image until segmentation and recognition. One of the interesting techniques that are used in segmentation is the chain code technique.

Various image segmentation algorithms have been proposed to achieve efficient and accurate results. Among these algorithms, watershed segmentation is a particularly attractive method. The major idea of watershed segmentation is based on the concept of topographic representation of image intensity. Meanwhile, Watershed segmentation also embodies other principal image segmentation methods including discontinuity detection, thresholding and region processing. Because of these factors, watershed segmentation displays more effectiveness and stableness than other segmentation algorithms.

D. Edge Detection

Edge detection is one of the most commonly used operations in image analysis, and there are probably more algorithms in the literature for enhancing and detecting edges than any other single subject. The reason for this is that edges form the outline of an object. An edge is the boundary between an object and the background, and indicates the boundary between overlapping objects. This means that if the edges in an image can be identified accurately, all of the objects can be located and basic properties such as area, perimeter, and shape can be measured. In this project, we have compared several techniques for edge detection in image processing. we consider various well-known measuring metrics used in image processing applied to standard images in this comparison. One of the desired features of the speckle filters is to preserve the edges. That is, the sharpness and the position of an edge should be maintained after filtering denoising.

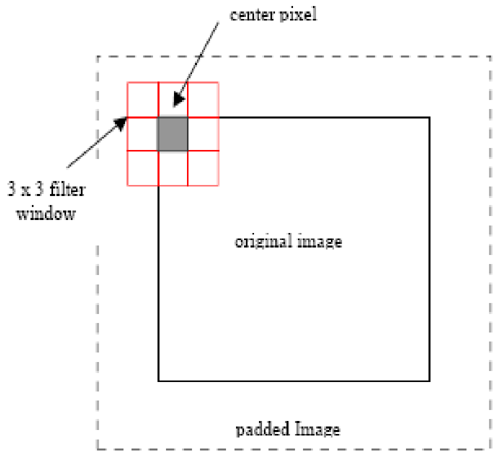

Fig 2.1: Window analysis for edge detection

According to the paper, the approach attempts to look for the neighborhood area of a coefficient, in the detail images of the wavelet decomposition, using a 3x3 moving window, and considering spatial relationship on the coefficients belonging to an edge. The reason is that a wavelet coefficient representing an edge will probably have wavelet coefficients of similar amplitude representing the same edge at its neighbors. For this goal, the absolute local average of the coefficients in the moving window is calculated. Here sobel is preferable. Because sobel is the operator which have to threshold value i.e., upper and lower threshold value. Sobel is preferred for image processing of image capture at long distances. So sobel operator is best.

E. Feature Selection

The main purpose of feature selection is to reduce the number of features used in classification while maintaining acceptable classification accuracy. Feature selection is a preprocessing technique, commonly used on high-dimensional data, that studies how to select a subset or list of attributes or variables that are used to construct models describing data. Wide data sets, which have a huge number of features but relatively few instances, introduce a novel challenge to feature selection. Among the fifteen features extracted, the most five significant features were chosen.

F. Feature Extraction

The detection process consists of matching of the extracted features from the image under inspection with those of the predefined models. The detection process becomes very complex if the image to be detected is noisy and features could occur at random positions and orientations. This can be utilized by pixel gradients instead of by only pixel values, emphasizing the structure of the image instead of the texture.

G. Chain Code

A chain code is a lossless compression algorithm for monochrome images. The basic principle of chain codes is to separately encode each connected component, or "blot", in the image. For each such region, a point on the boundary is selected and its coordinates are transmitted. The encoder then moves along the boundary of the image and, at each step, transmits a symbol representing the direction of this movement. This continues until the encoder returns to the starting position, at which point the blot has been completely described, and encoding continues with the next blot in the image. This encoding method is particularly effective for images consisting of a reasonable number of large connected components. Some popular chain codes include the Freeman Chain Code of Eight Directions (FCCE), Vertex Chain Code (VCC), Three Orthogonal symbol chain code (3OT) and Directional Freeman Chain Code of Eight Directions (DFCCE).The chain code is a way to represent a binary object by encoding only its boundary. The chain code is composed of a sequence of numbers between 0 and 7. Each number represents the transition between two consecutive boundary pixels, 0 being a step to the right, 1 a step diagonally right/up, 2 a step up, etc. In the post measuring boundary length, We gave a little more detail about the chain code.

Worth repeating here from that post is the figure containing the directions associated to each code:

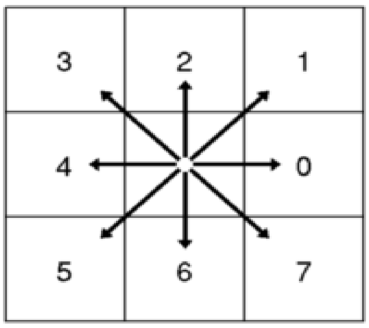

Fig 2.2:Directions associated to each code

The chain code thus has as many elements as there are boundary pixels. Note that the position of the object is lost, the chain code encodes the shape of the object, not its location. But we only need to remember the coordinates of the first pixel in the chain to solve.

H. Image to Chain Code

Let's assume we have a binary image with a single object in it. Using DIP image, we could generate a suitable test image thus:

img = rr<30;

The algorithm also needs an array with the definition of each of the chain codes. Call this a "cipher" if you will. Indexing in this array with one code from the chain gives the change in coordinates as you go from one pixel to the next. Thus, directions(cc+1,:), where cc is one code from the chain, yields the [x,y] increment for the coordinates. The +1 is necessary because MATLAB indexing starts at 1, whereas the first code is 0.

The algorithm starts at any pixel that is on the object's boundary. We will use MATLAB's function find to find the first "on" pixel in the image:

indx = find(dip_array(img),1)-1;

MATLAB is column-major, meaning that indices increase downward first. The function find returned the first object pixel using this column-major indexing, meaning that none of the columns to the left have any object pixels, and in this column, none of the pixels above have any object pixels. The boundary possibly continues downward on one side, and up/right on the other side. That is, from this point the possible steps are chain codes 0, 1, 6 and 7. Codes 3, 4 and 5 all point to the column to the left, which we know is empty, and code 2 points up. Where we also know the object cannot be. we choose to follow the boundary clockwise (though it is equally valid to define the chain code counter-clockwise if one so wishes), and thus we need to try the possible steps in this order: 1, 0, 7, 6. If the step 1 yields an object pixel, this is the pixel that continues the boundary in the clockwise direction. If this pixel is empty, we try to see if we find the object using step 0, etc. Once the next pixel is found, this step is repeated again and again until we have travelled all the way around the object and return to the initial pixel at coordinates start. However, each next step has different limits for which directions are possible. The first direction to try (the "most clockwise" neighbor, if you will) is the one that is two codes up from the previous step. That is, the boundary makes a 90° left turn. It cannot make a 135° left turn, because that pixel is also a neighbor to the previous pixel, and if the object is there, the previous step would have pointed to it instead. As before, we first try the "most clockwise" step first, then continue down the codes until we find an object pixel. We have a starting coordinate and a starting direction. Inside the loop, we test the pixel pointed at by this direction. If it contains an object pixel, we add this direction as a code in the chain, set the current pixel to the newly found boundary pixel, initialize the starting direction to the 90° left turn, and continue on with the loop. This algorithm is very simple, though it might be difficult to understand and it recommend you take a paper and a pen and draw out the steps of the algorithm, until you are satisfied that it always works as intended. Also note, for example, the special case of an object with a single pixel: The algorithm looks in all directions once, then meets the finishing requirements and quits. Thus, a single pixel object has 0 elements in the chain code.

I. Chain Code to Image

The inverse algorithm, walking over the codes in the chain and drawing the boundary back in the image, is much more trivial. The final command, join channels, overlays the two binary images in color, the original one in red and the newly drawn boundary in green. Where the two overlap, the pixels appear yellow. As you can see, the whole boundary is yellow, indicating that the pixels represented by the chain code are the boundary pixels of the object.

Chain code techniques are widely used to represent an object because they preserve information and allow considerable data reduction. A chain code approximates a curve with a sequence of directional vectors lying on a square grid considered a detailed discussion of the properties of contour codes. Chen and Chen proposed a simple recursive method for converting a chain code into a quad tree with a lookup table. However, this leads to an increase in the storage requirements.A related blot encoding method is crack code. Algorithms exist to convert between chain code, crack code, and run-length encoding.

3. Proposed Methodology for Damage Detection from Pre-Event and Post-Event Images

The goal of this paper is to detect buildings destroyed in an earthquake using pre-event and post-event detected imagery that allow to carry out earthquake damage assessment in a very short time.The main issues faced will be discussed and possible solution to improve the adopted approach will be proposed. Till date, prevention of natural disasters is only rarely achieved, and such events continue to pose an increasing threat to life and property.

Especially following earthquakes, there is a need for rapid and reliable damage assessment in the critical post event hours. Observations concerning the magnitude and distribution of building damage after a destructive earthquake are of primary importance for post-event emergency response, and later on, for understanding the effects of shaking on buildings and other key infrastructure. Damage assessment and exploration of the causes of the damage other then ground shaking are crucial, as this provide the basis for the future rehabilitation of the affected people. GIS and Remote sensing technologies can provide valuable information for response activities due to potentially high spatial temporal resolution and synoptic coverage. For damage assessment caused by this earthquake an extensive field is carried out the affected areas soon after the earthquake. Another reason might be due to its litho logical and geomorphological setup.Due to which it faced more ground shaking during the earthquake and caused more damaged comparatively. Balakot City is being divided into different zones based on homogeneity in building damages on quickbird Satellite Image in the field and for each zone different attributes were collected from the field.

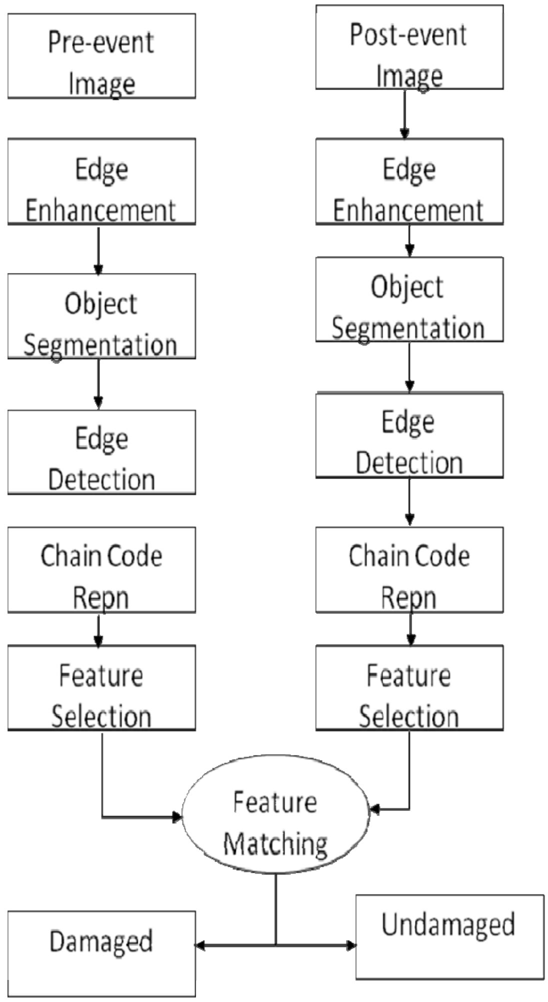

Fig. 3.1. Block scheme of the proposed method for building damage detection from Pre-event and Post-event images. The procedure is applied to each building, which shall be investigated for damage separately.

For rapid impact assessment, remote sensing data sets can provide important information since they can map the extended areas quickly and in an uncensored manner. In this project, a novel method is introduced, that detects buildings destroyed in an earthquake using pre-event and post-event detected imagery. The method operates at the level of individual buildings and assumes that they have a rectangular footprint and are isolated. Several procedures were followed and finally features are matched. The similarity between the predicted image and the actual image is analyzed. If the similarity is high, the building is likely to be still intact, whereas a low similarity indicates that the building is destroyed. A similarity threshold is used to classify the buildings.

4. Results

After analyzing the pre-event and post-event imagery, we selected for each class in **Ω** a set of 15 individual candidate buildings. All are flat-roof buildings because this is the prevailing building type in the area under investigation. The selection of candidate buildings is driven by the need to test the methodology in an accurate way and was mainly limited by the following issues.

1) The town is not very large; thus, the number of candidate buildings is limited.
2) The pre-event image was acquired about three years prior to the event; thus, in our analysis, we had to exclude those areas of the town for the analysis that could be identified as already changed prior to the event (e.g.,newly developed areas, changes in road outlay).
3) The earthquake itself was very destructive so that only few undamaged buildings could be found.
4) According to the present assumptions of the proposed method, buildings should be isolated; thus, structures in the dense part of the town were not considered.
5) After a destructive earthquake, the affected area typically experiences many significant changes in a short period.

5. Discussion and Conclusion

In this paper, we have presented a novel damage assessment method for single (isolated) rectangular buildings using prevent and post-event images. The method is tuned to work at the individual building level and determines whether a building is completely destroyed (collapsed) after a catastrophic event or whether it is still standing. First, a reference pre-event image is used to extract the 3-D parameters of a building that is tested for damage. This information is combined with the acquisition parameters of the actual post-event data to simulate the signature of the undamaged building. The predicted signature is compared quantitatively to the actual scene. Based on the Bayes rule, the resulting comparison determines whether the building is destroyed or still standing. Similarity between the simulated and the actual scene indicates an undamaged building, whereas dissimilarity results in classifying the building into the damaged class. We have demonstrated the effectiveness and the properties of the proposed approach using pre-event and post-event data from Yingxiu, China, which was heavily damaged in the Sichuan earthquake in May 2008.The results show that the method is able to distinguish between damaged and undamaged buildings with high overall accuracy of about 90%. The analysis was based on a set of 20 buildings of various sizes and heights.

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