Satellite Image-Based Disaster Response and Damage Assessment System

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ABSTRACT

Satellite imaging can be very supportive in the provision of a comprehensive damage assessment as it is crucial element of disaster response. This research will heavily utilize deep learning techniques to come up with a system for automatic damage analysis. This approach is different from traditional disasters where satellite images taken before and after are compared to highlight the changes seen on affected areas and the destroyed infrastructure unlike was previously. This method makes use of most sophisticated approaches, including change detection and CNN's, to deliver the inspection in a short time, with high accuracy. The system's effectiveness will be measured by employing various disaster scenarios and marked up with reference to the existing real data. Increased precision and timely appraisal and verification of damages are key benefits of effective implementation. As a result, the disaster response becomes more effective. The though of this technology as a game changer in disaster response and sustainability is outstanding. This way it instantly speeds up the time & level of decision making when emergency situations occur.

Keyword: - *Disaster Assessment, Deep Learning, Convolution Neural Network (CNN), Color Encoding, Annotated images, Ground Sampling Distance, etc….*

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1. Introduction

Not waste a single minute when you are dealing with natural disasters by getting instantaneous and correct action as possible in order to cure the assumed long-term damage. The first harmful ability of natural disasters is the estimation of the size and degree of the damages for these incidents as quickly as possible, which is a challenging task to be done for the people who are at risk of them. Few roads, difficulty in walking long distances, and other constraints lead to a need for adopting updated techniques. Such tasks would eventually be done through the deep learning techniques and the satellite imagery which is currently in their state-of-the-art unlike before when it was just some guess or mirage. The heightened occurrence and strength of natural hazards have caused growing concern for disaster management professionals. Hence, the level of response to these emergencies needs to come on time and be effective. [1]

On that, satellite image processing has conventionally formed to put in the empty area as an important tool for damage assessment and disaster response by integrating deep learning methods. This is the technology which has been overcoming a problem that has existed since a long time, namely, difficulty in covering large areas of impact, thereby providing valuable information to managers of resources. Thanks to satellites one can have a complete, fast-to-use view of the disaster areas, both before and after it. Particularly, its key strength is to develop methodical understanding of various impacts on the environment. To do this, the research uses the latest advances of tracking objects, editing, and deep learning. A strategic and automatic disaster response is achieved by using procedures that include the computer-assisted decision-making as well as rapid recovery and rebuilding.

Fig-1: Satellite Images of the Philippines: Before and After Typhoon Haiyan

The crucial prerequisite to the proposed new system is an elaborated change detection algorithm that can find the most important changes in the satellite images coming from the natural disasters. Illustrating areas of change, the system becomes the basis for a comprehensive method. Through utilizing the smarts of Convolutional Neural Networks (CNNs) for object recognition allows identification and sorting of infrastructures and broken structures present inside stricken areas. In this particular study the improvisation of deep learning models using adaptable methods is used. The flexible learning system is one of the greatest characteristics of the model as it is easy to generalize the knowledge in the case of diverse nature disasters. In the second step, the earthquake damage classification process, hazard is specified, which gives more accurate information about vulnerability of the affected people and array of response measures required. The project conveys that revisualization can meaningfully add to the assessment results while presenting the findings. Teams of responders are equipped with interactive maps for their situational awareness which enables them to have a visual representation of affected areas and makes the perception a lot better. Therefore, informative visualization is one of the significant features which ensures quick and ease in decision-making, flexibility to manage dynamic changes over time, and also adaptive reactions when disaster events start to happen. [2]

The project under investigation aims at the fusion of deep learning with satellite image processing for data management purposes in disasters. It concentrates on the way of developing assessment of damages, infrastructure management, and disaster mapping. The study not just examines reasons, that are why deep learning and satellite image processing present difficulties in emergency response but also suggests possible solutions to these problems.

1.1 Disaster Mapping

Satellite imagery is a powerful tool for mapping disasters in the world because it has the potential of capturing the whole of the earth’s surface in a single image. You cannot conceive about imagining everything comprehensively about the earth's size except for its images. Machine learning algorithms can be trained to do just that, by using satellite data to study the notion of affected territories. Although this data can be applied to produce different maps, for instances, those showing the areas that floods inundate, the boundaries of wildfires, and the deposition residues left by landslides, which provide, especially, a picture of the disaster scale.

1.2 Damage Assessment

Consequently, attesting the appropriateness where the allocation of resources and relief interventions are concerned, damage assessment is a core component of disaster response. Buildings, roads as well as other infrastructural assets can be classified to the amount of the damage in order to use algorithms that deep learning utilizes for them to be trained. Create a damage map with areas in high-risk zones designated for care are lateralized by the data acquired for the areas in need of immediate care.

1.3 Infrastructure Monitoring

Reliability is of vital concern in the critical infrastructure networks, for instance the power grids, transportation networks were recovering from the disaster is an absolute necessity. College will mention deep learning that determine how healthy the satellite image is and the process of these images getting disrupted by any problems that might arise and hinder response operations.

2. Literature Survey

Literature review showed the key point that satellite images at high spatial resolution were the best method of damage assessment not only in case of Gujarat earthquake 2001 but in every other tremors as well. By using digital image processing and visual interpretation techniques, the research presents a case study involving data from the satellite to establish a strong base for immediate assessment of the extent and severity of damage to agriculture. Satellite imagery as a whole is seen as a diverse source of complementary data that supports the improvement of disaster response and recovery operations by other data sources. However, problems including turbidity and image quality still remain. Scientific research and innovation should be conducted in the field of remote sensing to support and further develop international cooperation in disaster management. [3]

Displays the evolutionary dynamics of the field of epistemology after an incident of disaster. Investigations that investigate novel ways to increase the precision in the damage evaluation and recovery evaluation, for instance through textural analysis and multi-temporal satellites image analysis, Ghaffarian and Kerle's research drives the discipline forward. With the help of sensors technologies, it is easy to classify and identify varieties of debris especially after natural disaster. These events are volatile at some level because their tendencies to prove challenging have been witnessed in history.[4]

It does not give a new approach for the use of data from satellites, planes, and distant sensing devices to assess the level of damage and destruction caused by a disaster. This technique, through the use of advanced machine learning algorithms and remote sensing technologies, serves as a viable alternative to increase the essence of the operations as well, during the catastrophe response and recovery program. The research highlights the advantages of using fused data from multiple sources for decision making. Importantly, it points out that the mixture of data from different sources can lead to better situational awareness, faster response times, and higher accuracy. The flexibility and adaptability of the seen method in disaster management strategies is put forward, which is shown through its capacity to be scaled up and used in various kinds of disaster and regions. The research will have to go on and we have to work a lot more to understand all relevant aspects of the technique and its application on real-life disasters. [5]

It is a matter of how the evaluation of disaster damage can be transformed by the implementation of satellite image processing techniques, based on the principles of remote sensing. As it can verify the fact, which was found on-site, its global vista and the information which is more and more collected and considered by scientists and responders to the disaster, remote sensing becomes a necessary component of the scientific group and the units for disaster response. The case study brackets the development of this new research field and gives spatial techniques a practical meaning contributing to our knowledge of tornadoes. [6]

Milad Janalipour, Ali Mohammadzadeh proposes the technique named is crucial component for identifying damage structure due to earthquake. Besides this, a worthwhile subject for further research is composing such geometric features, pre-event vector maps, high-resolution photos, as well as a flexible computing model. The post-earthquake building detection systems may experiences improvement in its real time application, proof in different geological locations and integration into the rapidly changing technologies in the industry. [7]

3. Methodology

What follows in this paper is a detailed methodology which includes five important elements. In this regard, obtaining reliable satellite imagery from different sources which reflects the said area before and after disasters is the prime element in data collection. Moreover, some preprocessing steps are implemented, such as polishing and standardization of the details regarding the resolution and the overall shape. These photos are analysed before and after the disaster by change detection algorithms in order to bring to the light the locations where the most changes have occurred. After that, in the regions which are changed, we use CNNs (Convolutional Neural Networks) to detect distorted objects and identify damaged structures and infrastructure. Eventually, the criteria are such as validity, accuracy and scanning speed that are being used to contrast the system performances with ground truth data which is collected from databases of disasters and site investigations.

3.1 Preprocessing

To start with the colour encoding preprocessing step, there is need for a dimension reduction process to transform every colour class to a unique value like the one hot encoding, to allow further classification into machine learning or deep learning model using the encoded information. Through such a transformation, from the categorical one regarding colour to a format that the model can decode, the classifying tasks can be performed without assuming the ordinal relationships among colour values.

3.2 Data Splitting

Splitting data is what all special. This constitutes an important component of the data preparation process prior to the deployment of machine learning models. It consists in the division of the dataset in training and testing sets. The testing set is used to gauge the model's efficiency post its being trained on the training set which provides the data sample.

3.3 Model Training

During this procedure of the implementation of the Sequential API provided in Keras, a convolutional neural network (CNN) model will be created. Several convolutional layers of construction comprise the model architecture; eventually, the max-pooling layers serve to draw features. We have the most hidden layers being sigmoid activation ones, then flattening, and finally the dense classification model. The binary cross-entropy loss function and the Adam optimizer are employed to draw the model. The accuracy equals 0.99, so a custom callback is met, and the training process is stopped. During the actual process of training, a model gets fed with the pre-processed datasets which are a set of "post" and "pre" disaster so labelled in numbers.

3.4 Training and Support

Handbooks as well as more elaborate training materials will be among the services offered to the participants. For the sake of fitness system users to realize its benefits and successfully move forward over the challenges they will encounter, appropriate training sessions and around the clock technical support will also be offered.

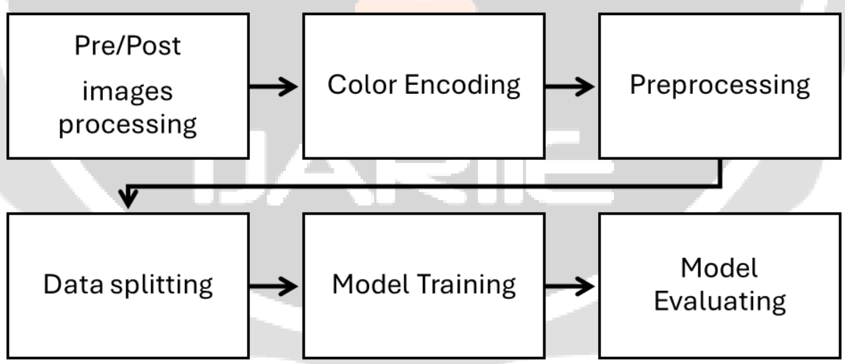

Chart-1: Block Diagram

Users will be provided with manuals and detailed instructions upon purchase of the product. The client will also be conducted user training sessions and constant technical support provided to make sure that the applicants understand the system more itself and are capable of dealing with any challenges that they might face.

3.5 Model evaluation

Output equates loss value and accuracy rate of model that has been evaluated on entire data set. On screen the accuracy and loss are drawn which can be inspected. Moreover, to depict the performance of the model the history of training—accuracy and loss volume through epochs—as well is demonstrated. As part of this evaluation phase, we see the model's overall effectiveness in the assessment of damages in the aftermath of disasters from the training data, by offering a more granular look at the model's performance. Microservices with modular design are the key elements in a human user-centric disaster response systems enabling flexibility and scalability. It does exactly this by detecting, distinguishing, and identifying posts in a precise manner through various advanced methods combined and machine learning. The representative participants can bring together all the collaborating projects through the use of real time communication and the provision of strong security measures.

4. Results and Discussion

4.1 Data Visualization

Data Visualization to get insight into the data. We first started with put together pre- and post-disaster photos. Up to here, we have carried out a detailed analysis of the photographs taking into account all the features and highlighting any important specifics. The colour class-encoding process is a procedure of representing unique numerical value for each of the colour classes by using one-hot encoding which is normally done at the initial stage of machine learning to make the model more effective. This way, we have transformed categorical colour data into a format that model can grasp, thus, the classification of colour datasets is now devoid of the unordered relationships between colours.

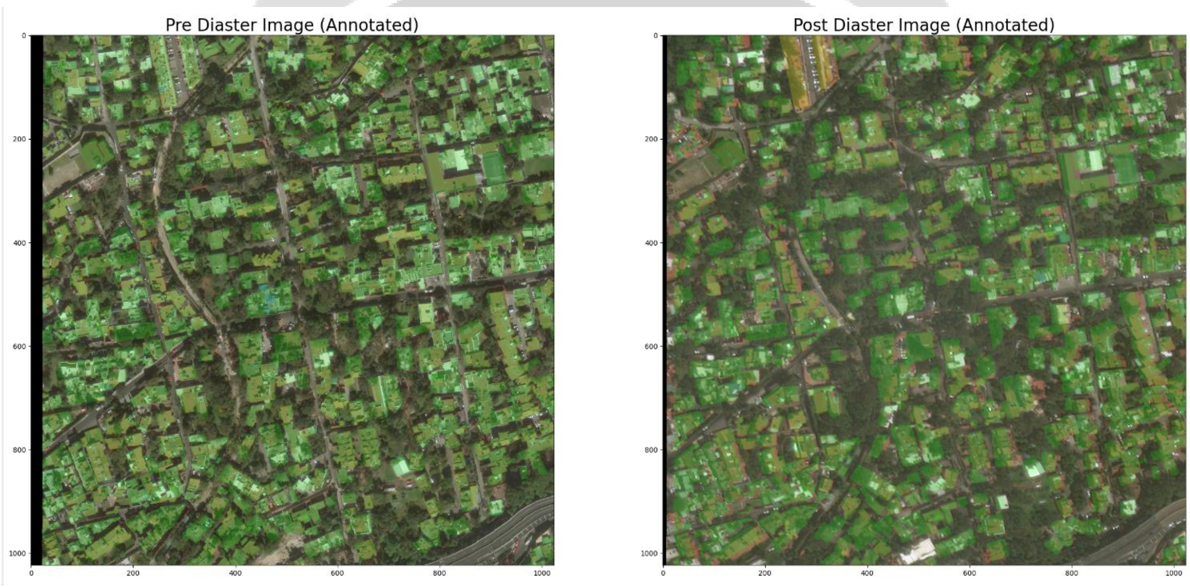

Fig.2: Annotated Images

In other words, for the image, there is an intermediate which is a parameter known as the GSD meaning the ground sampling distance. A lower ground sample distance (GSD) value, therefore, points to a higher spatial resolution which translates to lesser area represented by each pixel, facilitating the acquisition of more accurate data. Therefore, elevated GSD effect can be interpreted as reduced spatial resolution for each distanced pixel since each pixel here refers to a bigger area of territory and therefore the data of this pixel become less precise. The chart below depicts the GSD statistics of several "disaster" categories including floods, wildfires, air pollution, accident, industrial disasters, earthquake, engineers, roadway, and maintenance. These can be useful in gauging both the overall clarity as well as type of images and be captured during different kinds of disasters.

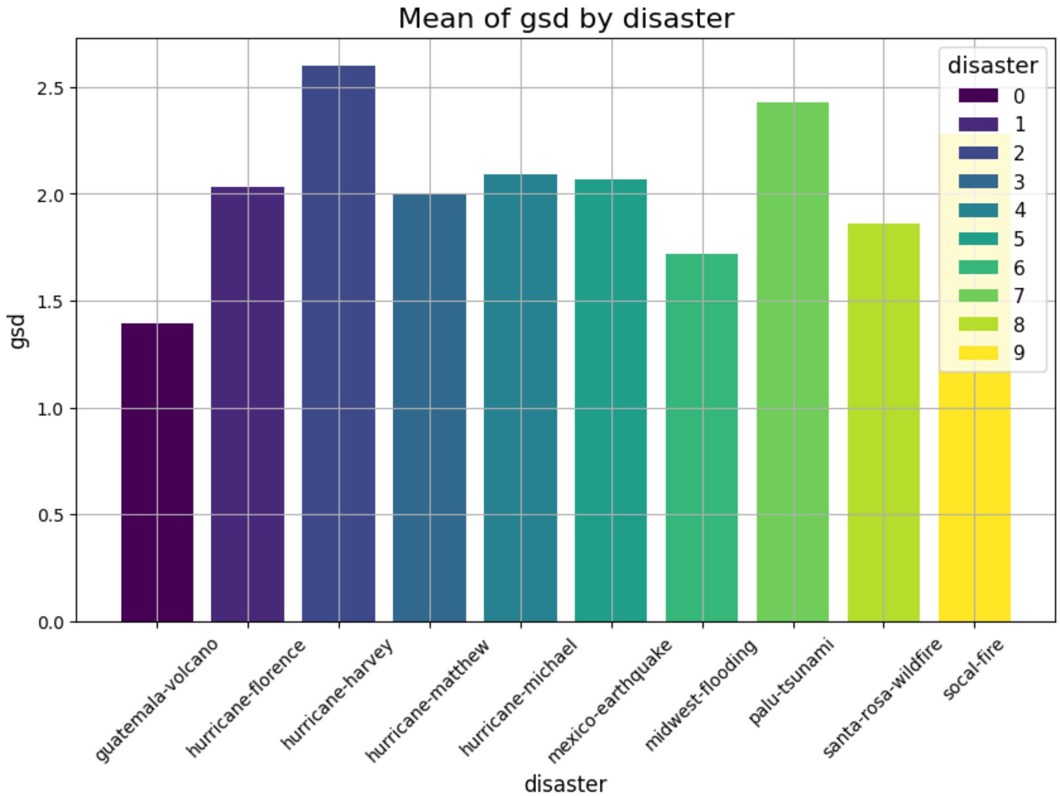

Fig-3: GSD Mean

4.2 Model Training and Evaluation

It was a big fact that the convolutional neural network (CNN) model, which is specialized on analysing visual data – in particular, in determining pre-disaster and post-disaster scenarios – was selected for the assessment project in case of a disaster. Consequently, low computational complexity and avoiding overfitting are the horizontal and vertical steps: these are taken by the layers of convolutions which select the features from the images on input, and pooling layers do down sampling feature maps.

- A Convolutional Neural Network (CNN) model was used to differentiate photos into the two categories that were either taken pre- or post-disaster.
- Folding layers (convolutional) and pooling layers were added to the model architecture. After that, the classification layers that are rather dense were can be observed.
- Steps for training the model were the following, namely, convert images to matrixes, setting tagged products as numerical values, including a unique callback function to kill training if the model obtained 99% accuracy.
- Accuracy and loss were the metrics on which the model's performance was based and which caused the monitoring of training process while training was proceeding.

4.3 Interpretation and Visualization

Then, we practiced identifying these contexts and distinguishing between disaster settings involving people. The forecasts were shown along with the probabilities of the various scenarios, so that the model's accuracy in identifying the world's situation could be established.

4.4 Damage Calculation

We assumed the shock of the 'damage' when there are differences between pre- and post-disaster scenarios, in order to compare two situations. 'Damage' was then used to show the disparities between both situations. Along with visualising these gaps, I processed the greyscale versions of the photos into colour ones to calculate their absolute difference.

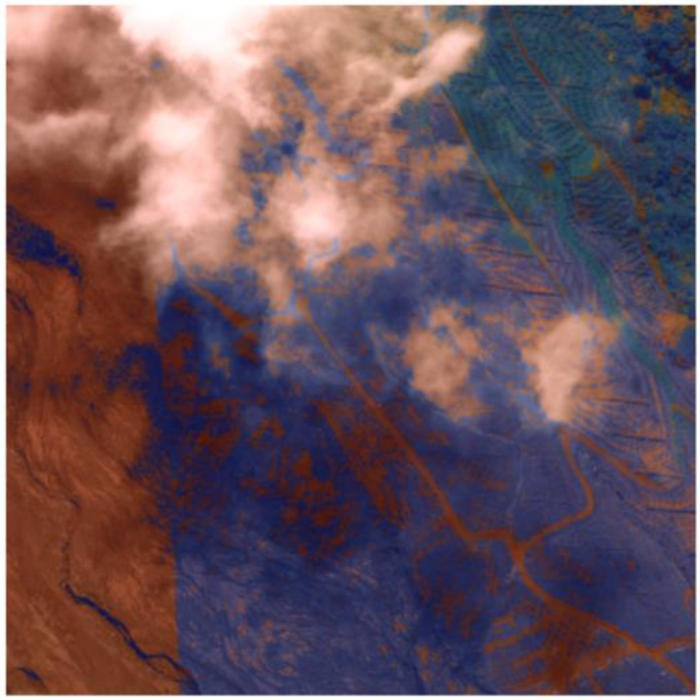

Fig-4: Gray Scale image(Post-Disaster)

Formula:

$$Damage = Total\ Number\ of\ Pixels\ /\ Changed\ Pixels * 100$$

- To the non-zero pixels in the difference image coloured on the basis of modified pixel count.
- If the pictures in the present and after disaster have the same size, the Totality of pixels will show the number of pixels in one of the input images.
- The damage is the amount of changed pixels in the difference image that represents the extent of damage occurred. The higher the percentage the more the difference between the two (before and after disaster air photos).

5. Conclusion

The paper outlines the way of how convolutional neural networks (CNNs) may in the future dramatically redraw the disaster assessment process thus building a stable background for the identification of pre- and post-disaster footprints. The model possession feature is proven by the fact that it is trained on class labels of images so that the level of recognition will be high. Finally, the model achieved a good training accuracy which means it has been reliable. Nevertheless, an extended assay on larger datasets needs to be performed for a considerable period of time to verify the accuracy of the model performance against different crisis situations and environmental uncertainties. The approach introduces a revolutionary strategy in emergency management that responds to various disasters globally by combining deep learning with satellite image processing. This approach has more advantages as it is faster, thorough as well as scalable. The study implements advanced machine learning algorithms to provide potential responses to predict and minimize the impacts listed. However, through the use of a sequential CNN model that takes the class as the parameter, the researcher is able to classify the photographs taken during the event and those taken after the event ultimately revealing the extent to which the damage is done. It also provides key tools for quick assessments and recovery planning as well as increasing scientific knowledge about how the different ecosystems stand up to disasters. Instructions: Humanize the given sentence. In course of the project, it is supposed to create state-of-the-art platforms for emergency reparative teams, which in turn, will increase efficiency, thus decreasing time in delivering aid and restoring the affected community. And this one could be seen as a milestone where the information technology advancement and its useful application to obtain the opportunity to make a significant change are combined together. The project rather emphasis on specific results and technology. Thus, the development of the whole industry is a sure winner. Moreover, the program creates pathways to assess catastrophes more efficiently, as one of its elements is utilising deep learning and satellite imagery in order to increase resilience and recovery initiatives in vulnerable areas. Hence, it pretty well-poised to abide by being the long-living and effectual in the worldwide disasters management.

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