All Sciences Proceedings
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2nd International Conference on Contemporary Academic Research

November 4-5, 2023 : Konya, Turkey

ICCAR
https://as-proceeding.com/index.php/iccar

The significance of Machine Learning in the field of Civil Infrastructure protection through image-based damage detection

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Abstract **–** The study focuses on structural damage detection in engineering infrastructure, emphasizing the significance of timely identification for ensuring safety and minimizing the impact of disasters. Various forms of damage, ranging from slight cracks to severe structural failures, can compromise the stability and performance of constructions. The research delves into major techniques for structural health monitoring, with a particular focus on non-destructive methods that offer valuable insights into the condition of the infrastructure without causing harm. Local-damage detection, aimed at pinpointing specific damage locations, and global-damage detection, which assesses overall structural integrity, represent two key approaches. The concept of utilizing machine learning and deep learning to expedite damage detection processes, highlighting the potential of these technologies to enhance the speed and accuracy of identifying structural issues. Image-based analysis, involving images captured from various angles, is employed as a fundamental data source. Methodology involves preprocessing of images to enhance quality and eliminate noise, followed by the extraction of distinguishing features such as edges, corners, textures, and color histograms. Machine learning algorithms, including support vector machines, random forests, and convolutional neural networks, are employed for classification tasks. Change detection algorithms, image segmentation techniques, and structural analysis through tools like OpenCV further contribute to the precision of damage identification.

Keywords – Damage Detection, Machine learning, Crack Detection, Structure Analysis, Destructive and Non Destructive.

I. INTRODUCTION

Damage is basically the affect the stability, integrity and performance of structure. There is different kind of damages slight, moderate and sever as small damages like failing of plaster and small cracks arise on walls these cracks are under the dome of slight cracks. Cracks that is deep inside the structure that reduce bearing capacity of structure is under moderate cracks and lastly the damage that are collapse of wall and approximately half of structure fails are under the dome of severe damage.

Major structural health monitoring research has been driven by the potential financial and life safety effects of early damage detection in aeronautical, civil, and mechanical engineering systems. Numerous local damage detection techniques have been created and are often used on a wide range of buildings. Damage detection as deduced from changes in the vibration properties of a system has been a hot study area due to its potential for worldwide system monitoring [1].

There in a great significance of damage detection in civil engineering because it helps us to know how much building is damage due to different disaster. These disasters reduce the safety factor of structure that can be life threaten in future. Damage detection help us to make future plan either we repair building or go for the strengthen or retrofitting of structure. We can say that with the help of damage detection we are able to make pre and post disaster actions so that damage must be minimum. Damage detection also show us quality of material used in structure either it is good or bad. it's all depend upon the quality of work done during construction. It also tells us the deformability of structure that how much structure can displace without collapse. Structure can be damage externally or internally so different method are used to detects damage in structure it can be destructive or non-destructive method can be used to detect effect on structure. Destructive method damage structure while collecting data but in case of non-destructive no damage to structure while collecting data.

Use of the non-destructive examination (NDE) technology to assess the damage state of engineering structures is now a contentious and challenging problem. NDE technology has recently seen widespread use in a variety of sectors, including architectural, metallurgy, mechanical, aerospace, and aviation, production, etc. Local-damage detection and global-damage detection are two general categories for structural damage detection. Non-destructive testing (NDT), such as rebound hammer test and bar detector, is referred to as local-damage detection techniques since it is primarily used to find local damage in buildings and may pinpoint where the damage is located.

Only data gathered from the damaged structure is used by local damage detection techniques. The undamaged structure's baseline data and theoretical models are not employed. The key benefits of local damage detection are those. Local damage detection is highly efficient for tiny, symmetrical objects like pressure vessels. However, it is highly challenging to find damage using local damage detection methods for huge and complex structures in confined or invisible surroundings [2].

Today's world builds different structure that is become complex day by day due to construction of huge building it is necessary to provide pre detection of damage and provide an alert before any disaster situation occur so number of life can be save due to detection of damage. As there is some method that are adopt by civil engineer that is slow in process. With the help of machine learning and deep learning we can detect damage relativity fast so we save time and also save our self from some kind of disaster.

Bridges, buildings, dams, and pipelines are just a few examples of the complex engineering systems that underpin a society's economic success and quality of life. The need for regular inspection, monitoring, and maintenance has grown as these systems get older and degrade [3].

The value of data is more clear than ever because to the advent of DL-based techniques. In order to efficiently analyze and store vision and vibration data from host structures, it is necessary to use reliable real-time signal and image processing models capable of spotting a data abnormality [4].

II. Literature Review

A real-time multi-drone damage detection system employing one of the most cutting-edge deep learning models, named You Look Only Once-version3 (YOLO-v3), is proposed using the edge computing principle for high-rise civil buildings. The suggested system deploys on Pixhawk's hardware standards-based open source hexacopter drone and runs YOLO-v3 on the Jetson-TX2 hardware platform. If damage is seen, the Jetson-TX2 on board processes it and then uses the Wi-Fi channel to communicate just the data relating to the damage to the server that is located on the ground. On a dataset of 800 (480 x 480 pixels) photographs of various forms of damage gathered from various CSIR-CEERI, Pilani structures, our suggested method is assessed. The updated YOLO-v3 classifier is trained and tested using manually annotated photos [5].

Purposed how physics-based models and machine learning may be combined. The construction of a digital twin for a damaged building allows for the investigation of various damage scenarios using a discrete physics-based computational model. The data used to train the digital twin, a machine learning classifier, comes from a stochastic computational model. In order to support real-time engineering choices, this technique enables the employment of a quick digital twin (machine learning) that is coupled to the physical twin and can be built using an interpretable model (physics-based). To build training datasets, several model parameters such as the number of sensors, noise level, damage intensity, uncertainty, and operational parameters as well as various classifiers such as quadratic discriminant and support vector machines are examined [6].

A technique for detecting cracks in concrete using a deep fully convolutional network (FCN) for semantic segmentation. The FCN encoder's backbone, three alternative pre-trained network topologies, are assessed for image classification using a public dataset of 40,000 227X227 pixel pictures of concrete cracks. Then, a subset of 500 annotated 227X227-pixel crack-labeled pictures are used to train the whole encoder-decoder FCN network with the VGG16-based encoder for semantic segmentation. The average accuracy achieved by the FCN network is around 90%. The suggested technique for concrete fracture identification is validated using images taken from a video of a cyclic loading test on a concrete specimen. It was discovered that cracks can be fairly recognized, and crack density can also be precisely assessed [7].

Using a smartphone mounted on a car, 9,053 road damage photographs are collected, and 15,435 occurrences of road surface damage are included in this large-scale road damage data collection. used our data set to train the damage detection model utilizing cutting-edge object identification techniques employing convolutional neural networks, and compared the accuracy and runtime performance on both using a GPU server and a smartphone. Finally, we show that the suggested object identification approach can accurately classify the type of damage into eight categories [8].

It is suggested to employ a revolutionary deep CNN approach for structural damage identification. Instead than depending on manually constructed features, it can automatically extract features from low-level waveform inputs. The results are interesting: the CNN demonstrates its excellent accuracy despite the noisy data set, a reasonable performance is also observed in the identification of multiple damages, and by visualizing hidden layers, it is discovered that hierarchical features are learned layer by layer and even mechanical concepts, such as vibration modes and their combination, are learned in deep layers. The use of neural network technology in the identification of structural deterioration. For many years, neural network techniques have been used in the field of structural damage identification [9].

A vision-based approach that uses deep convolutional neural networks (CNNs) architecture to identify concrete fractures without having to calculate the fault characteristics. The suggested technique operates without the conjugation of IPTs for feature extraction because CNNs are capable of learning picture features autonomously. The created CNN is trained on 40 K pictures with a resolution of 256x256 pixels and, as a result, records with around 98% accuracy. A sliding window approach is used in conjunction with the trained CNN to scan any image with a resolution greater than 256x256 pixels. The suggested method's adaptability and robustness are evaluated using 55 photos with a resolution of 5,888 x 3,584 pixels that were collected from various structural types [10].

Regression models are created using the support vector machine (SVM) approach to measure the impact of temperature on modal frequencies. The measurement data is divided into two subsets for the model development in order to accomplish a trade-off between simulation performance and generalization: one for training the models and the other for validating the models. In order to improve the SVM coefficients and achieve high generalization performance, a squared correlation coefficient is constructed. When the SVM model results are compared to those from a multivariate linear regression model, it is clear that the SVM model performs well at mapping between temperature and modal frequencies [11].

Genetic algorithms can find the global optimum by examining a part of the whole solution space. The objective function, which directly compares the changes in the measurements before and after damage, is minimized in this study using an evolutionary algorithm with real number encoding to detect the structural damage. Three separate criteria—the frequency changes, the mode shape changes, and a combination of the two—are taken into account. The suggested method is demonstrated using a frame and a cantilever beam that has been tested in the lab. The evolutionary algorithm may identify defective components even when the analytical model is inaccurate, according to numerical data [12].

III. MATERIALS AND METHOD

Firstly, we have to gather some image of infrastructure for damage detection that can be done by various method it can be cameras, drones, or even satellite imagery image and image must be capture from every angle and side so that maximum information can be detected.

Before going to next step, improve image quality and remove noise that make trouble during analysis. Preprocessing techniques that use to resizing, denoising, image filtering and color normalization.

For damage detection feature as specific pattern or element is detected from image and difference between damaged and undamaged areas. These features are included edges, corners, texture descriptors, and color histograms.

Now for detection of damage and undamaged area using machine learning we used Opencv, support vector machines, random forests, or convolutional neural networks for classification.

Another technique is use to compare image that is current images and reference images. This technique is use in that area where damage is significant, indicating potential damage. Change detection algorithms like background subtraction or pixel-wise differencing can be employed.

Image segmentation is also use in this image is divide into different parts for more accurate detection. Techniques like thresholding, contour detection, or clustering used for segmentation.

We also used structure analysis in infrastructure to identify cracks such as bridges and buildings. OpenCV is a tool that can help us with this analysis. Use algorithms like Hough Transform or detecting shape irregularities.

We show result by marking area where damage is detected that help us to find which part is damage and also create summary report that provide information how much serious damage it is. This reporting helps us to take action against it.

The success of using OpenCV for damage detection depends on good image quality, suitable feature extraction methods, strong classification algorithms, and accurate structural analysis (if needed). Detecting damage in civil engineering often requires combining different technologies and expertise from different areas to make sure the assessments are dependable and precise. Figure 1 represent block diagram of proposed solution in which picture and video both can use for detection.

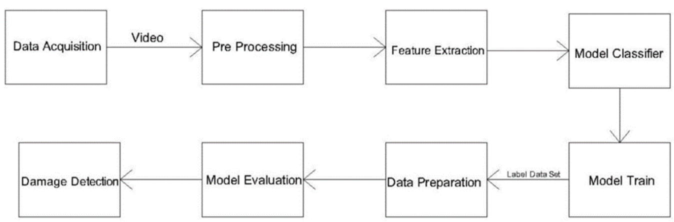

Figure. 1 Block Diagram of Proposed System

IV. RESULTS

We gathered images of complete structure. By applying pre-processing technique, we get image clear and cancel noise form footage. Specified pattern is detected that show whether the structure is damage or not. By using opencv we can also detect image for damage detection. Another technique is segregation that divide image and help in more accurate detection. For result the damage area must be marked and also generated a report that show highly risked area.

V. DISCUSSION

The paper presents a comprehensive exploration of structural damage detection in civil engineering, emphasizing the critical role of early identification for maintaining stability and safety. Through a well-structured introduction, the paper introduces the categorization of damages and highlights the significance of damage detection across various sectors. The integration of traditional methods and advanced technologies, such as machine learning and image processing, is skilfully discussed in the methodology section, illustrating a holistic approach to the complex challenge of damage assessment. The paper underscores the need for interdisciplinary collaboration and offers valuable insights into the potential of combining diverse expertise to ensure accurate and reliable damage detection in complex engineering systems.

VI. CONCLUSION

This study elucidates the pivotal role of early structural damage detection in civil engineering, highlighting its significance for stability, integrity, and public safety. The research underscores the synergy between evolving technologies, such as advanced imaging and machine learning, in expediting and enhancing the accuracy of damage assessment. By integrating these methodologies, the study emphasizes a proactive approach that aids decision-making for repair, reinforcement, and retrofitting strategies, minimizing the potential impact of disasters. The collaborative nature of successful structural health monitoring is recognized, with diverse expertise converging to ensure dependable and precise assessments. This research bridges traditional engineering practices with modern innovations, contributing to the advancement of both structural resilience and engineering practices as a whole.

ACKNOWLEDGMENT

Thankfully, we are aware of our parents' affection for us. Last but not least, we would like to thank our family and friends whose prayers made it possible for us to finish this project.

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