# Fault Prediction Using Fuzzy Convolution Neural Network on IOT Environment with Heterogeneous Sensing Data Fusion

S. Gokul, G.E. Madhorubagan and M. Sasipriya

***Abstract---*** *Because of the developing worldwide familiarity with natural issues, the expansion of sun-based power plants has turned into an unmistakable element of the energy scene. Nonetheless, keeping up with these sunlight's-based offices, especially with regards to recognizing breaking down photovoltaic (PV) cells inside huge scope or far off establishments, presents critical difficulties. The focal goal of our exploration project is to resolve this issue by empowering the convenient identification of flaws in PV cells, consequently possibly saving significant time, exertion, and upkeep costs, especially as for the pivoting gear ordinarily utilized in sun-based power plants.*

*I have developed a non-contact vibration pickup system that makes it possible to collect vibration data from PV cells operating at various speeds and loads without having to physically connect them to machine tools. In addition, I rank and select the most relevant features for accurate fault detection using the Sequential Floating Forward Selection (SFFS) method and Principal Component Analysis (PCA) to reduce the extracted features' dimensionality. This thorough methodology offers a promising answer for improve the effectiveness and dependability of sun-oriented power plant upkeep while adding to the more extensive objectives of supportable energy creation and natural safeguarding.*

***Keywords---*** *Photovoltaic (PV) Cells, Sequential Floating Forward Selection, Machine Learning, Faults Bearings.*

## I. INTRODUCTION

The proliferation of solar power plants has emerged as an essential response to the urgent need for sustainable energy sources in an era marked by an increasing global awareness of environmental issues. Be that as it may, the productive and solid activity of these sun based establishments relies on the early discovery of issues in photovoltaic (PV) cells, especially on account of broad or somewhat found power plants. Developing a non-contact vibration pickup system that eliminates the need for physical connections to machine tools and enables the acquisition of vibration data from PV cells under a variety of operating conditions is the primary goal of this research initiative.

### *1.1. Photovoltaic (PV) Cells*

Photovoltaic (PV) cells, frequently alluded to as sun powered cells, are semiconductor gadgets that convert daylight into power. These cells are an essential component of solar panels and are crucial in harnessing solar energy for a variety of uses, including power generation for residential, commercial, and industrial purposes. PV cells use the photovoltaic effect, in which sunlight photons cause electrons in the semiconductor material to be released, to produce an electric current when placed in direct sunlight. This environmentally friendly power innovation has acquired colossal significance with regards to perfect and reasonable energy creation, offering a promising answer for diminish reliance on petroleum derivatives and moderate natural effects related with traditional energy sources.

### *1.2. Sequential Floating Forward Selection*

Successive Drifting Forward Determination (SFFS) is an element choice procedure utilized in information examination and AI. It methodically fabricates a list of capabilities by beginning with an unfilled set and iteratively adding the most important elements to improve model execution. What separates SFFS is its "drifting" system, which adds highlights as well as checks if eliminating any of the recently chosen elements could additionally work on the model.

### *1.3. Machine Learning*

A recent development in artificial intelligence is machine learning, which gives computers the ability to learn from data and make judgments or predictions without explicit programming. It centres on the creation of algorithms and models with pattern recognition, inference capabilities, and experience-based performance enhancement. Applications for machine learning can be found in many different fields, such as recommendation systems, autonomous cars, and picture and speech recognition. Its ability to automate difficult operations and extract useful information from enormous databases has transformed businesses and spurred innovation, making it a vital tool for resolving practical issues in today's data-driven world. The capability of machine learning to handle vast datasets and make sense of complex, unstructured information has not only enhanced our understanding of the world but also opened doors to new possibilities.

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### *1.4. Faults Bearings*

In many different industrial applications, bearings are essential mechanical parts that support and facilitate the rotation of rotating machinery. Their main purpose is to lessen friction and support shafts or axles so that they can revolve effectively and smoothly. However, bearings are prone to wear and damage with time, even with regular care and maintenance. This can result in a number of problems that can affect the functionality and dependability of machinery. Bearing problems are the most prevalent of these problems and can result in expensive downtime, decreased efficiency, and, in certain situations, safety risks. We will discuss bearing defects, their types, and the value of prompt maintenance and identification in the context of industry in this introduction. Numerous symptoms, including high vibrations, strange noises, and increased friction, can indicate a bearing failure and shorten the life of the machine. In order to minimize operating disruptions and avoid catastrophic failures, it is imperative to identify and diagnose these defects. In the talk that follows, we'll explore the different kinds of bearing failures and their causes, as well as the techniques and tools used to track, identify, and address these problems in real time and support industries in maintaining the dependability and effectiveness of their machines. Professionals in maintenance, reliability engineering, and manufacturing need to understand the nuances of bearing problems in order to make well-informed decisions that can protect equipment, guarantee seamless operations, and reduce production losses.

## II. Literature Survey

### *2.1. A Survey on Image Data Augmentation for Deep Learning*

CONNOR Abbreviate et.al., [1] has proposed in this framework Profound convolutional brain networks have performed astoundingly well on numerous PC Vision assignments. To avoid overfitting, these networks, on the other hand, heavily rely on big data. Overfitting alludes to the peculiarity when an organization learns a capability with extremely high difference, for example, to show the preparation information impeccably. Sadly, big data is unavailable to many application domains, including medical image analysis. Data Augmentation, a data-space solution to the issue of limited data, is the focus of this survey. Information Increase incorporates a set-up of methods that improve the size and nature of preparing datasets to such an extent that better Profound Learning models can be constructed utilizing them. The picture expansion calculations talked about in this review incorporate mathematical changes, variety space increases, portion filters, blending pictures, irregular deleting, highlight space expansion, ill-disposed preparing, generative antagonistic organizations, brain style move, and meta-learning.

### *2.2. A Systematic Study of the Class Imbalance Problem in Convolutional Neural Networks*

Mateusz Budaet.al.,[2] has proposed in this system in this study, we systematically investigate the impact of class imbalance on classification performance of convolutional neural networks (CNNs) and compare frequently used methods to address the issue. Class imbalance is a common problem that has been comprehensively studied in classical machine learning, yet very limited systematic research is available in the context of deep learning. In our study, we use three benchmark datasets of increasing complexity, MNIST, CIFAR-10 and ImageNet, to investigate the effects of imbalance on classification and perform an extensive comparison of several methods to address the issue: oversampling, If not, these verification methods will produce a counterexample. In many real-world situations, an answer with certain error tolerance limitations may be sufficient if a deterministic solution is difficult to attain. Although DNN verification methods show promise, their scalability is limited by the vast size and high computational complexity of DNNs. Thus far, DNN verification strategies are limited to either small-scale DNNs orthat ensure convergence on the bounds. DNN testing methods emerge as an addition to DNN verification methods approximate approaches.

### *2.3. Better Open-air Thermography and Handling of Infrared Pictures for Deformity Recognition in PV Modules*

M. WAQAR AKRAM et.al.[3] has proposed in this framework Imperfection recognition in photovoltaic (PV) modules and their effect evaluation means quite a bit to upgrade the PV framework execution and dependability. To recognize and break down the deformities, a superior open-air infrared (IR) thermography plot is introduced in this review. PV modules that are in good working order and those that are defective are used in both the indoor (dark) and outdoor (illuminated) IR experiments. Normal operating modules have comparable measurements for the indoor and outdoor environments. Notwithstanding, the estimations for blemished modules show distinction for example the open-air pictures show less or not the slightest bit abandons in contrast with indoor pictures.

### *2.4. Deep Learning Based Module Defect Analysis for Large-Scale Photovoltaic Farms*

XIAOXIA LI and others, [4] has proposed in this system that novel inspection methods and analysis tools are required for efficient condition monitoring and precise module defect detection in large-scale photovoltaic (PV) farms. This paper presents a profound learning-based answer for deformity design acknowledgment by the utilization of flying pictures got from automated elevated vehicles (UAVs). The convolutional brain organization (CNN) is utilized in the AI cycle to order different types of module deserts. Such managed educational experience can remove a scope of profound highlights of working PV modules. It essentially works on the proficiency and precision of resource review and wellbeing evaluation for huge scope. Deep learning-based object recognition is becoming a crucial component of many different robotic systems, and in order to guarantee the system's overall safety and dependability during the deployment phase, it is imperative to be able to continuously evaluate and monitor the system's performance. In this paper, we suggested a customized performance monitoring network that can forecast the object detector's map quality, which can be utilized to communicate the expected reliability of object detection to downstream robotic system components.

### *2.5. Deep Convolutional Neural Network for Automatic Detection of Damaged Photovoltaic Cells*

R. Pierdiccaet.al. [5] has proposed in this system that there are now a significantly larger number of distributed photovoltaic (PV) plants that produce electricity. As a result, the problem of monitoring and maintaining a PV plant has become a major concern and presents numerous difficulties in terms of efficiency, dependability, safety, and stability. This paper presents the clever way to deal with gauge the PV cells debasements with DCNNs. This is, to the best of our knowledge, the first use of data obtained with a thermal infrared-equipped drone, despite the fact that numerous studies have classified images. The experiments on the "Photovoltaic images Dataset," a dataset that was collected, are shown to demonstrate the degradation issue and provide a comprehensive evaluation of the method that is presented in this study. The proposed method's efficacy and suitability are demonstrated. In order to do this, we introduced an introspective method for tracking the effectiveness of deep learning-based object detection. By sounding an alert when per-frame mean average precision is found to fall below a crucial value, we demonstrated how our method might increase safety. Additionally, we demonstrated how the detector's inherent properties could be utilized to forecast when a per-frame map will deteriorate. Our findings provided quantitative evidence of our method's capacity to lower risk by balancing the risk of making an error in detection with the risk of sounding the alert and failing to detect.

## III. EXISTING SYSTEM

Research on the classification and prediction of mechanical failures using fuzzy convolutional neural networks and multi-source sensing data based on the Internet of things and fusion has become increasingly relevant. In order to identify and diagnose the defect signs, this study uses the bearing dataset from Case Western Reserve University (CWRU) and fuzzy convolutional neural networks. Additionally, a model based on a direct convolution neural network is used to assess the efficacy of the suggested model. When the Fuzzification approach was used on a fully linked layer for classification, the outcomes were better. Using the fuzzy layer, the suggested method yields an average classification accuracy of 99.87% when applied to the bearing dataset. The suggested approach is assessed in comparison to alternative deep learning and machine learning-based approaches. In every imagined working scenario, the accuracy attained with the suggested method is better than that attained with the existing approaches. The suggested method can be utilized to identify mechanical motor issues and offer pre-emptive advice.

## IV. PROPOSED SYSTEM

By introducing a non-contact vibration pickup system for monitoring the health of photovoltaic (PV) cells, the proposed system aims to improve the efficiency and dependability of solar power plants' maintenance. The collection of vibration data from PV cells operating at varying speeds and loads is made possible by this novel approach, which eliminates the need for physical connections to machine tools. A Hilbert transform is used to denoize signals for fault diagnosis. Principal Component Analysis (PCA) is used to reduce dimensionality, and the Sequential Floating Forward Selection (SFFS) method is used to select features. Finally, these selected features have been passed to Support Vector Machines (SVM) and Artificial Neural Networks (ANN) for identifying and further classifying the various bearing defects.

### *4.1. Data Loading*

The investigation initiates with the gathering and uploading of unprocessed bearing data, which is commonly obtained via sensors or monitoring apparatus. This data serves as the foundation for subsequent scrutiny.

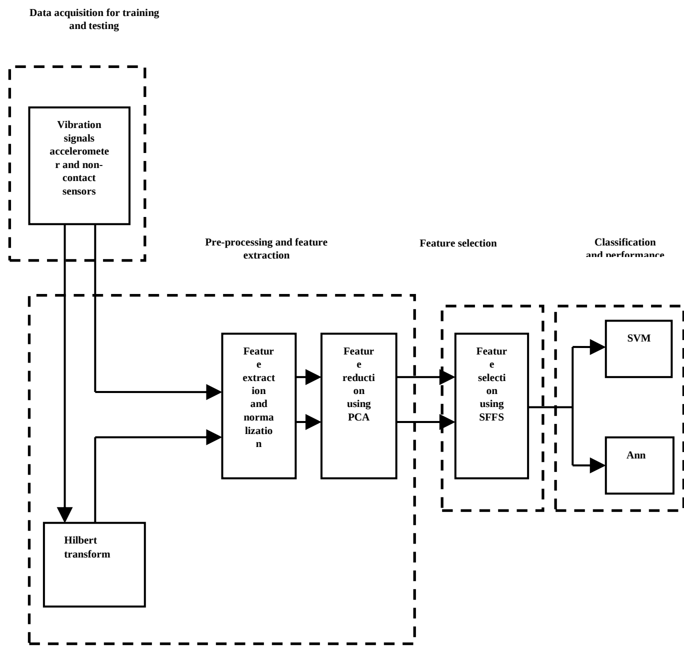



Figure 1: Block Diagram

### *4.2. Training and Testing*

The vibration characteristics derived from unprocessed and processed signals, acquired through both contact and non-contact sensors, were subjected to training and testing in order to classify bearing faults. Support Vector Machines (SVM) and Artificial Neural Networks (ANN) were employed for this purpose. The study encompassed a total of 11 instances and features for the raw signal, and 13 instances and features for the envelope signal. Statistical parameters were incorporated for each bearing condition, rotor speed, and the number of loads applied.

### *4.3. Feature Extraction and Dimensionality Reduction*

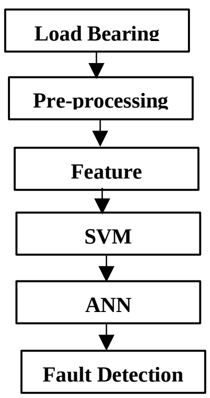
Feature extraction is defined as the process of estimating certain measures that provide information contained within a signal. In the context of machine health monitoring, the diagnostic task involves pattern characterization and recognition, with feature extraction being a critical step

### *4.4. Fault Detection Using SVM Classification with SFFS*

A hybrid approach combining filter and wrapper feature selection methods is employed, leveraging a modified version of the sequential forward floating search (SFFS) algorithm. The filtering approach assesses the predictive capability of features and their complementarity with other features. The resulting candidate subset, generated through the filtering approach, is then utilized in cross-validation of a support vector machine (SVM) with user-defined classification. Both raw and envelope signals are utilized to extract and select features, which are subsequently employed in the classification of bearing faults using an SVM classifier.

### *4.5. Fault Detection Using ANN*

In this study, a hidden layer consisting of four computation nodes (specifically, 5, 10, 15, and 20) has been utilized. The parameters of the applied Back Propagation Neural Network (BPNN) have been provided for the purpose of training. The training process would terminate upon encountering any of the specified conditions. The program randomly initialized the network weights and biases. The relevant feature matrix, derived from 316 raw data, was divided into three categories: 70% for training data, 10% for validation data, and 20% for testing data. This division was performed randomly, resulting in five repetitions to calculate the mean value of the output matrix and evaluate the performance of the neural network classifier.




Flow Diagram

*Algorithm Details: (SVM) and (ANN)*

SVM: Encouragement Strong supervised learning algorithms that perform well in classification tasks are called vector machines. SVMs function by determining the best hyperplane to divide data points into distinct classes while maintaining the largest possible margin. SVMs can be trained on vibration data gathered from the non-contact pickup mechanism in the context of PV cell defect detection. SVMs can categorize PV cells into distinct groups and help identify possible flaws by learning patterns linked to both normal and defective operation.

ANN: Artificial Neural Networks, on the other hand, are skilled at discovering intricate relationships within data since they are modelled after the structure of the human brain. ANNs are made up of layers of networked nodes, or neurons. An ANN can capture complex patterns and dependencies that may be difficult for conventional approaches by being trained on the vibration data. The neural network can discover subtle flaws in PV cells under a variety of operating situations because of its capacity to adapt and generalize from the training data.

The feature selection and dimensionality reduction strategies described in the abstract, such as Principal Component Analysis (PCA) and Sequential Floating Forward Selection (SFFS) method, can help both SVM and ANN algorithms. By concentrating on the most important features, these techniques increase the efficiency of the algorithms and increase the accuracy of defect identification.

## V. Result Analysis

Table 1: Comparison Table

| **Algorithm** | **Accuracy** | **Precision** | **Recall** | **F-measure** |
|---|---|---|---|---|
| **SVM** | **0.84** | **0.79** | **0.75** | **0.84** |
| **ANN** | **0.88** | **0.9** | **0.87** | **0.98** |

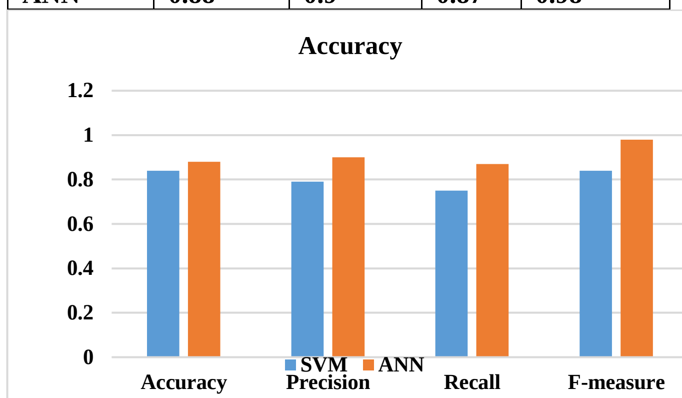



Figure 2: Comparison Graph

Research on the classification and prediction of mechanical failures using fuzzy convolutional neural networks and multi-source sensing data based on the Internet of things and fusion has become increasingly relevant. In order to identify and diagnose the defect signs, this study uses the bearing dataset from Case Western Reserve University (CWRU) and fuzzy convolutional neural networks. Additionally, a model based on a direct convolution neural network is used to assess the efficacy of the suggested model. When the Fuzzification approach was used on a fully linked layer for classification, the outcomes were better. Using the fuzzy layer, the suggested method yields an average classification accuracy of 99.87% when applied to the bearing dataset. The suggested approach is assessed in comparison to alternative deep learning and machine learning-based approaches. In every imagined working scenario, the accuracy attained with the suggested method is better than that attained with the existing approaches. The suggested method can be utilized to identify mechanical motor issues and offer pre-emptive advice.

## VI. Conclusion

The identification of bearing defects is a crucial undertaking in numerous industries, as it has the potential to prevent unscheduled downtime and expensive repairs. Machine learning presents a promising avenue for bearing defect identification, as it can effectively learn intricate patterns from vibration data. A prevalent method for bearing defect identification through machine learning involves the initial extraction of features from the vibration signal. These features may include statistical, time-domain, or frequency-domain features. Subsequently, dimensionality reduction is employed to decrease the number of features to a more manageable level. This is a critical step as it can enhance the performance of the machine learning model and mitigate the risk of over fitting.

## VII. Future Work

Subsequent research in this field may concentrate on several directions for more enhancement. To improve the model's robustness, the study could first benefit from enlarging the dataset to include a greater variety of bearing problems and operating situations. In order to treat problems before they worsen and prevent unanticipated breakdowns, it might also be investigated to integrate real-time monitoring with predictive maintenance capabilities. In order to find latent patterns in the vibration data, research may also focus on optimizing the feature selection procedure and integrating more sophisticated methods like deep learning and auto encoders.

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