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Fault Detection in Wireless Sensor Network Based on Deep Learning Algorithms

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Abstract

This paper is about Fault detection over a wireless sensor network in a fully distributed manner. First, we proposed the Convex hull algorithm to calculate a set of extreme points with the neighbouring nodes and the duration of the message remains restricted as the number of nodes increases. Second, we proposed a Naïve Bayes classifier and convolution neural network (CNN) to improve the convergence performance and find the node faults. Finally, we analyze convex hull, Naïve bayes and CNN algorithms using real-world datasets to identify and organize the faults. Simulation and experimental outcomes retain feasibility and efficiency and show that the CNN algorithm has better-identified faults than the convex hull algorithm based on performance metrics.

Keywords: Wireless sensor network, Fault detection, Convolution neural network, convex hull, Naive-Bayes, performance metrics and energy efficiency.

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1. Introduction

Due to recent advances in wireless communication and embedded computing, wireless sensor networks can deliver various applications identified. Wireless sensor networks have been widely used to support various monitoring and control applications, such as environmental surveillance, industrial sensing, or traffic checking. WSNs include enormous quantities of small, low power, wireless devices, for example, monitoring the environment, industrial sensing, or traffic. WSNs include huge quantities of wireless devices, small, low power, regularly sent at remote and badly arranged locales. Various mobile and unavoidable applications are always gathering and handling data from the physical world and giving data about the detected condition or occasions at a high level of detail. Specifically, SVM is a classification algorithm with the advantages of broad applicability, sparsity of information, and optimal worldwide. Preparing an SVM requires a quadratic dimensionality optimization issue based on the preparation set's cardinality. A subset of the preparation set, known as support vectors, communicates the subsequent discriminating guideline [12]. In new studies, distributed SVM preparation was investigated due to tight energy, data transfer capacity, and various imperatives on wireless sensor systems' communication capabilities. One methodology is a parallel structure of centralized SVM [16], [10]. When the information collection of training is enormous, partial SVMs are obtained using small subsets of training and joined in a combination focus. This methodology can handle huge information sizes but can be applied only if a central processor is accessible to join the incomplete, partial support vectors [17-24]. The arbitrary partitioning of the data set is not constantly guaranteed to the concentrated SVM [7]. Then again, there are completely appropriate methodologies for the whole SVM utilizing conveyed enhancement strategies [25-32].

Since SVM is a quadratic advancement issue, an existing convex optimization method can be utilized. A distributed SVM was introduced in [4] that receive the multiplier exchange direction technique [3].

This methodology relies on neighbourhood message trading and is proven to be linked to centralized SVM. As the gradient-based iteration should maintain the connection between nodes until combination, it may result in enormous intercommunication costs. Also, the traded message duration may turn out to be incredibly long in a nonlinear situation [33-37]. These problems make wireless sensor network applications inappropriate. Another distributed SVM class, which did not rely on the gradient method, relies on the distributed support vectors obtained from neighbouring information collections [2], [1]. These gossips based distributed SVM methodologies ensure intermingling when the marked classes are linearly divisible. When they are not directly distinguishable, these methodologies can be rough, even though not guaranteed, intermingling with the SVM arrangement. The concept of gossip-based gradual SVM with a geometric depiction is used in this article. The geometric understanding of SVM relies on the concept of the convex hull and the nearest geometric point calculations [11], [8]. Not at all like the incremental support vectors based on gossip [14]. At that point, we recognize the fault in the system we proposed and analyzed methods, such as convex hull, Naïve Bayes and CNN [15]. The Convolution Neural Network gives better fault detection when compared to the other methods. This paper's structure is as follows. Section 2 emphasizes the suggested framework model in this work; section 3 clarifies the findings of the experiments, and chapter 4 concludes the paper [38-43].

2. Methodology

We are using algorithms such as the convex hull, Naïve Bayes, and CNN algorithm in this proposed work. In the convex hull algorithm, the message is exchanged only with adjacent nodes [44-51]. The network link's topology is fundamentally decided with one-hop communication where the proportion of traded information can be controlled, even in the most pessimistic scenario. The naïve Bayes classifier and CNN algorithms identify the system faults in a wireless sensor network to improve the power and convergence performance [5]. The CNN technique achieves better performance when compared to other techniques [13]. Generally, a fault can happen to a physical layer device, as shown up underneath Figure 1. Deficiency is a deviation of, on any occasion, one trademark property or parameter of the system from conventional activity [52-59]. For example, insufficiencies can occur in light of the way that a network node is broken due to low battery, correspondence impedance, physical damage, and environmental deterrent [60-61].

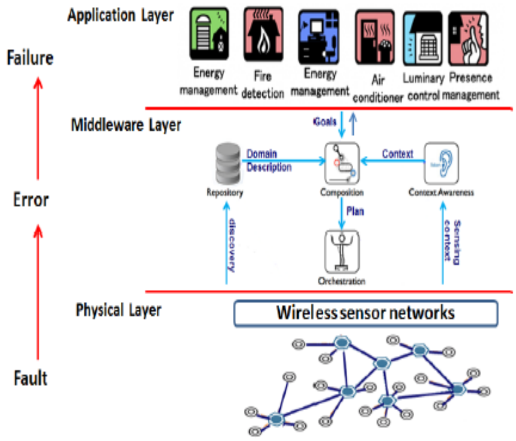

Figure 1. Architecture of Sensor Network Application

Error is an incorrect distinguishing of a state or occasion in the given space at the middleware layer due to a deficiency. An error is an effect whose reason is some lack. This considers a logically outrageous issue with the devices since they are alive anyway, identifying inaccurately. Therefore, services fail at the application level either due to middleware erroror the physical layer [6]. Therefore, failures in such dynamic and interactive systems can result in user displeasure. For instance, various sensors are used to identify a user in a smart home. When a user comes home, the system settings are configured according to user preferences. Failure to correctly identify the user can result in an unexpected system configuration. Faults in any device can lead to the inappropriate control and usage of devices in the physical environment [9]. For example, incorrect sensing of temperature sensor readings can cause over-cooling or overheating in the room or physical space.

2.1. Convex Hull Algorithm

Convex hull for a set Scan likewise be characterized as the arrangement of focuses that can be communicated as arched mixes of the points in that set S. Convex hull have their image processing applications, design acknowledgement, etc. medicinal recreations. A convex hull is diverse for various items since it depends on the feature point of each object. The convex hull can be characterized for the object of any sort with any number of measurements. The convex hull's complexity and extreme points are focused on the feature space's dimensionality.

In Feature Space, Convex Hull Algorithm

Input: set No = {c1} and N=∅, arbitrarily picked c1 ∈ C
Initialize: C* = C − No
Until C* is empty,
Get c ∈ C*, update C* = C* − {c}

If Checkpoint (c, No) = False, N = No {c}
Until No is empty,
Get k ∈ No, update No = No − {y}
If Checkpoint (k, N− {k}) = True, N = N− {y}
No = N
Output: the extreme point set of C, E(C) = No

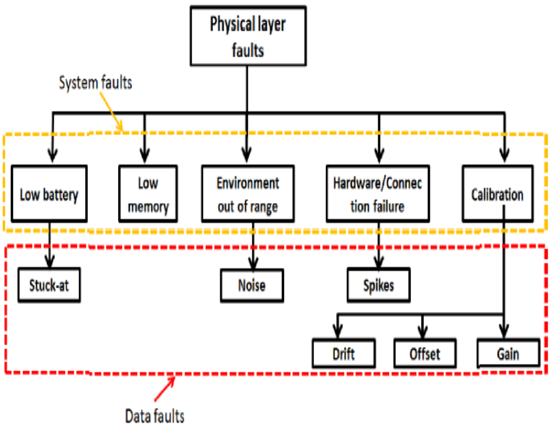

Figure 2. Faults in Wireless Sensor Network

The performance of machine learning techniques to detect faulty sensor readings and classify data and system fault types in WSNs is shown in Figure 2. Classifying the type of data and system faults is necessary to confirm the accuracy of a WSN. Differentiating data faults from system faults is essential to identify the causes of failure and to offer precise recovery action. In the first step, we collect data from multiple sensors at the base station. We operate under the assumption that at the time that we collect this data from these sensors, faults have not yet conceded into the sensors. At the second step, to apply machine learning techniques, the fault detection problem is formulated into a binary classification problem where the fault types are learned from the given dataset and used as reference models to classify new runtime observations and concludes whether the sensor reading is faulty or not. Our goal is to identify and classify the type of fault and take actions to recover from faults.

2.2 Naïve Bayes

Naive Bayes is one of the most effective and effective learning algorithms for inductive learning. Naive Bayesian classifier is a simple classification scheme that estimates the class-conditional probability by assuming that the attributes are conditionally independent given the class label c. The conditional hypothesis of independence can be indicated officially as follows

$$P(C|A) = c = \prod_{i=1}^{n} P(A_i \backslash C = c$$

Where each attribute set A={ A1, A2... An} is made up of the values of n attributes. Instead of calculating the class conditional probability for each grouping of A, only estimate the conditional probability of each Ai given C with the conditional independence assumption. The latter strategy is more practical because it does not require a very big training set to get a decent assessment of the probability.

$$P(C|A) = \frac{P(C)\prod_{i=1}^{n} P(A_i \backslash C)}{P(A)}$$

Since P (A) is set for each A, choosing the class that maximizes the numerator word is adequate.

$$P(C)\prod_{i=1}^{n} P(A_i \backslash C)$$

There are several benefits to the naive Bayesian classifier. It's simple to use, and unlike other approaches to classification, you only need to scan the training data once. The naïve Bayesian classifier can manage missing attribute values readily by merely omitting the likelihood of membership in each class. The algorithm of the SVM naïve Bayers classifier is described as follows.
Algorithms

- Read information
- Create a cvpartition purpose that defines folds
- Create a guidance set
- Create an analysis set
- compute the class likelihood
- normal training set distribution percentage

Parameters

- test set probability
- kernel supply
- test set estimate likelihood
- re-structure
- get an anticipated test set output
- compare expected output with the actual set

Naive Bayes requires better fault detection as it is necessary to calculate the probabilistic models from a continuous distribution. This means the training phase is pretty fast. The computing time, the best algorithm for classification error, appears to be the Naïve Bayes algorithm. The Naïve Bayes algorithm is better than the convex hull algorithm.

2.3 Convolution Neural Network

A convolutional neural network (CNN) is a specific type of artificial neural network that uses perceptron, a machine learning unit algorithm, for supervised learning to analyze data. CNN's apply to image processing, natural language processing and other kinds of cognitive tasks. A convolutional neural network is also known as a ConvNet

Algorithm

Step 1: Convolution Operation

The first building block in our plan of attack is convolution operation

Step 1b: ReLU Layer

The second part of this step will involve the Rectified Linear Unit or ReLU

Step 2: Pooling

In this part, we'll cover pooling and will get to understand exactly how it generally works.

Step 3: Flattening

This will be a brief breakdown of the flattening process and how we move from pooled to flattened layers when working with Convolutional Neural Networks.

Step 4: Full Connection

In this part, everything that we covered throughout the section will be merged. By learning this, you'll get to envision a fuller picture of how Convolutional Neural Networks.

3. Experimental Results

The experimental outcomes of the proposed research are defined as follows, which will be implemented in the MATLAB 2018a software platform

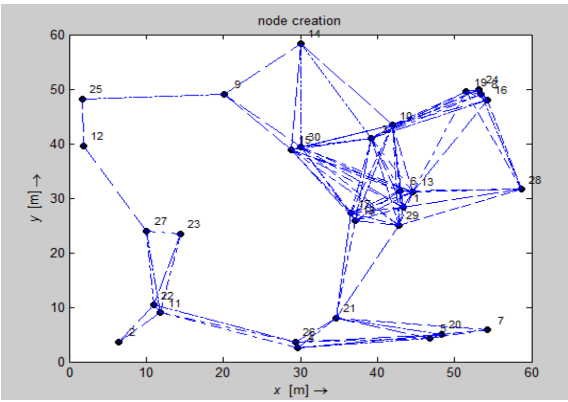

Figure 3. Node Creation

Figure 3 demonstrates a node creation representing the information in a single data structure. These nodes may contain exchanged information, condition, or data from another node.

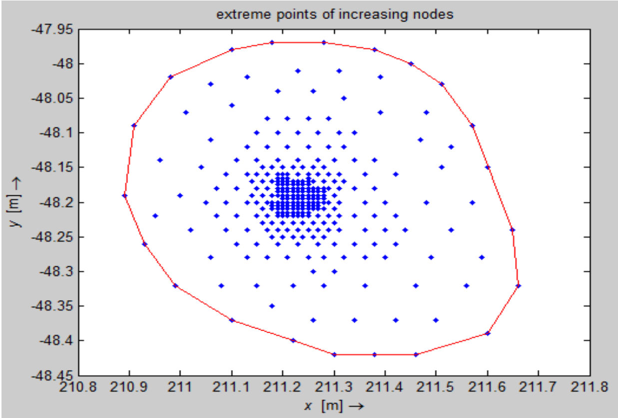

Figure 4. Computation of Extreme Points

Figure 4 demonstrates extreme points of growing nodes using a convex hull algorithm that includes all information points in the extreme point set. The message length remains bounded as the number of nodes increases.

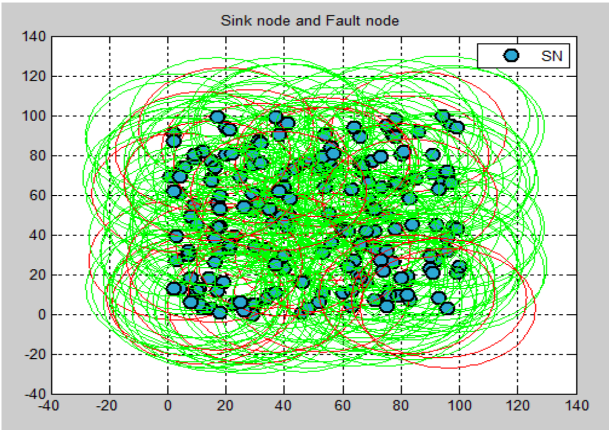

Figure 5. Sink node and Fault node

Figure 5 represents the fault and the sink node. All the communication in the wireless sensor network is taken place between source and destination. The destination is called a base station or sink node.

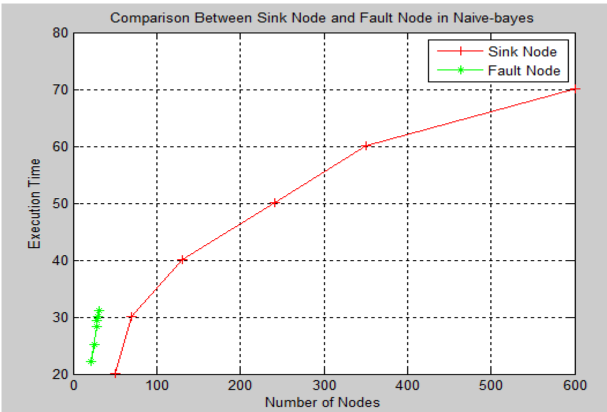

Figure 6. Comparison between Sink node and the Fault node

Figure 6 demonstrates the comparison between sink and fault node by using naïve Bayes classifier

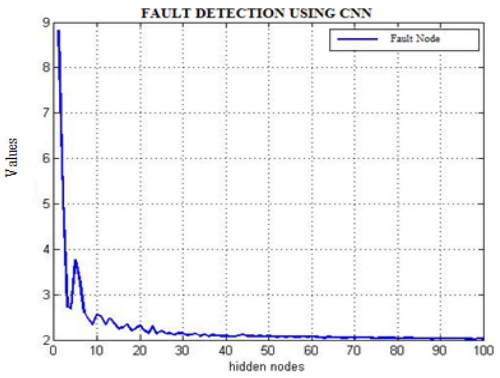

Figure 7. Fault Detection Using CNN

Figure 7 shows that the performance of Node faults detection by using a convolution neural network. The CNN technique detects fault easily from all the hidden nodes.

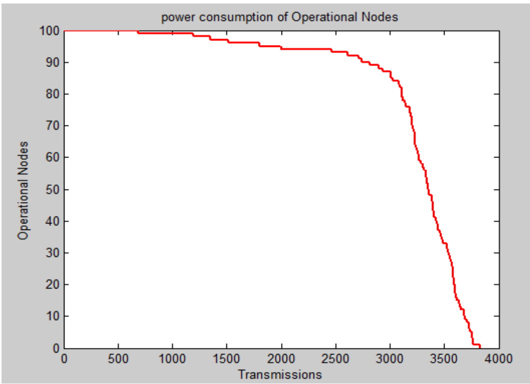

Figure 8. Power Consumption Analysis

Figure 8 shows a region where both the average length of the path and the estimated power consumption is small. In this region, with only a negligible rise in energy consumption, we can significantly enhance our suggested CNN algorithm's efficiency in terms of convergence velocity.

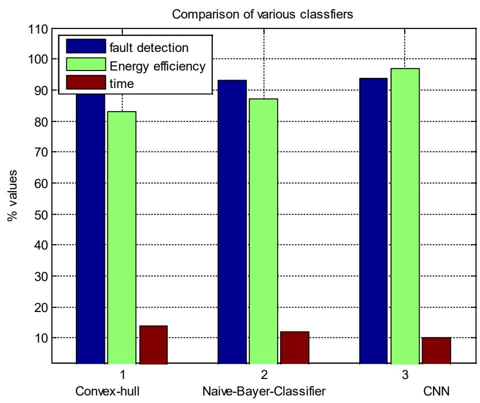

Figure 9. Performance Analysis

Figure 9 shows the performance analysis of convex hull, Naïve Bayes and CNN techniques. The deep learning method provides better results than the Naïve-Bayes algorithm and the convex hull. This proposed work easily detects the faults and gives better energy efficiency, and Here, the time consumption is very low compared to both techniques.

4. Conclusion

This paper proposed fault detection in wireless sensor network using different algorithms such as Convex hull, Naïve Bayes and convolution neural network. The convex hull algorithm relies on incremental nodes where the nodes acquired at the extreme points of their local convex hulls' duration of the message, and the number of nodes increases. The naïve Bayes and CNN improves energy efficiency and identifies the system faults in a wireless sensor network. Next, we analyzed these three algorithms' comparative study to recognize wireless sensor network information and system faults. Our findings show that CNN is doing better than other algorithms to detect faults. Simulation and experimental outcomes promote feasibility and efficiency. We will study how to use RL techniques to coordinate multiple MCs to complete the charging task in future work jointly. And the implementation of our proposed charging scheme will be performed and investigated in a practical environment.

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