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AIR QUALITY MONITORING AND AIR POLLUTANT LEVEL PREDICTION SYSTEM USING MACHINE LEARNING APPROACH

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Abstract:

Air pollution (AP) impacts not only the environment, but also the respiratory system and body organs. Therefore, in addition to the early method, scientific air quality (AQ) monitoring is needed to estimate the level of AP and also to accurately foresee the concentrations of pollutants. With the deployment of the sensor focused on the Internet of Things, the AQ prediction has significantly improved (IoT). All current AP prediction techniques are expensive and have low accuracy in most cases. Therefore, by using the IoT-centered Deep Learning Modified Neural Network (DLMNN), a monitoring and prediction technique is proposed here.As for IoT devices, sensor values (SV) are considered as inputs. After that, using the Gaussian Kernel Membership function (GMF) centred Adaptive Neuro-Fuzzy Inference System (ANFIS) referred to as (GMF-ANFIS), an attack detection mechanism is performed on the received sensor data to check whether the data is an attacked one or not. In order to envisage the AP level, the system conducts training. Information from the Air Quality Index (AQI)-UCI dataset is used for training. Around '3' operations are performed in training. Data is preprocessed initially. Secondly, the relevant characteristics are chosen from the preprocessed data using the Modified Dragonfly Optimization Algorithm (MDOA). Thirdly, by using DLMNN, the chosen features are classified into '6' sorts of data. Testing is done on the non-attacked SV after training. Finally, the testing outcomes are visualised. To analyse the proposed method's performance, the experiment is implemented. The results showed that DLMNN performed better when weighed against other existing AQ prediction algorithms.

Keywords: Air pollution, Deep Learning Modified Neural Network (DLMNN), Gaussian Kernel Membership function (GMF.

1. INTRODUCTION

AP is one such primary cause that is detrimental to the welfare of a person. The health of 'seven billion' people as stated by the 'World Health Organization' is jeopardised because of AP (WHO). For several health problems such as asthma, skin infections, heart problems, throat and eye disorders, bronchitis, lung cancer, and respiratory system diseases, it is the predominance and root cause [1, 2, and 3]. Typically, pollutants such as sulphur dioxide (SO2), nitrogen dioxide (NO2), particulate matter (PM10 and PM2.5), lead (Pb), ozone (O3) and carbon monoxide (CO)[4, 5] are caused by the aforementioned problem.

It also affects the environment in addition to the terrible impact of human health and causes disasters such as acid rain, smog, deterioration of the ozone layer, along with global warming. Superintendence and control over AP [6] must therefore be ensured. AP and the lack of control to track and examine AQ demonstrate the constraints of the environment and technology[7, 8]. To overcome this effect, industries emphasise the discovery of a dexterous product and allow AQ to be further improved on network sites, providing reference values where customary monitors flop to perform[9]. Customary air automatic monitors have comparatively intricate equipment technology, wobbly functioning, and economically high. Wobbly efficiency and higher costs make it impractical for an extensive installation and can only be located in the main monitoring areas of the key enterprise that generate the absence of system data to anticipate the overall pollution[10]. The (IoT) Internet of Things is used in specific environments to inspect and track live AQ[11]. Myriad devices are possessed by IoT over-assisted interlinked nodal devices for mutual communication. Sensor-embedded gadgets use the internet to collect and transmit data via wired/wireless gadgets, where data analysis is performed to implement the required operations[12]. Because of its many applications across industries and smart cities, the progress of IoT is increasing every day and becoming renowned[13].IoT sensor data may be hacked by intruders. Therefore, the protection of information and the prevention of such attacks is a prerequisite. Devices used for attack prevention must have characteristics such as detection, confidentiality, internality, and undeniability.

Consolidating such devices into existence provides enormous data that is periodically annotated. The concept of Deep Learning (DL)[14] has resulted in prediction and the treatment of such data. The machine learning techniques that are widely used to predict AQ are linear regression, support vector machines, artificial neural networks (ANN),[15] random forest. However, few methods prioritise focusing on specific pollutant predictions, such as Ozone or PM2.5. Numerical models are central to AP control.Mainstream AQ numerical models such as WRF-Chem[16], Community Multi-scale AQ Model (CMAQ), CAMx, and NAQPMS are employed by the government authorities and the Environmental Research Institute with a view to predicting AQ. In order to foresee the prospective values, the temporal data obtained from the monitored fumes is previously analysed. Supposing that the system has increased accuracy and that the envisaged attacks are null in the forecast, it is indicated as the best system.

2. LITERATURE REVIEW

Xiang Li *et al* [18] presented the Spatio-Temporal Deep Learning (STDL) by to forecast the AQ that examined the interrelationships among spatial with temporal features intrinsically. A stacked auto-encoders model was employed for extracting intrinsic AQ features, in addition, trained on a greedy layer-wise mode.

When contrasted with customary time-sequential paradigms, the implied paradigm effectively forecasted the AQ of every location concurrently and depicted the temporal permanence inentire seasons. Furthermore, when the paradigm was compared with other models, it evinced splendid execution.

Zhongshan and Jian [19] developed a system, which monitored the AQ and gave prior portent. In the monitoring of AQ, the primary contaminants were scientifically ascertained and examined by a fuzzy extensive analysis. A hybridization paradigm was merged with several techniquesto enhance the monitoring of six primary components in AP. The results evinced that the principal pollutants in Xi'an and Jinan were PM10 as well as PM2.5 accordingly. The AQ of Xi'an was found enhanced to AQ of Jinan. The outcome evinced that the hybrid prototype was superior on grounds of greater stability and accuracy.

Dixian Zhu *et al.* [20] Predicated on the compiled metrological data acquired for previous days, developed a model that computed the hourly AP concentration. A beneficial standardization was done by enforcement of the prediction paradigms of sequential hours be nearer and various conventional regularizationssuchlike standard Frobenius norm regularization, nuclear norm regularization, and $l_{2,1}$-norm regularization were contrasted with it. The formulationsthat diminish the parametersand sequential-hour-paradigms were superior in performance contrasted to the contemporarytypicalretrogression models and available methodologies.

Jiangshe and Weifu [21] calculated the intensity of pollutants in AP by utilizing a qualified intense learning machine that requisite the data from 2 monitoring locations from eight AQ parameters comprising Sham Shui Po along with Tap Mun. The results evinced that the paradigm's performance was found enhanced in quantity together with quality. The technology generated superior prediction outcomes with augmented R 2 and diminished error of root means square.

Xiaozheng Lai *et al.* [22] developed an instantaneous forecasting system premised onIoT together with edge computing that diminished IoT reliance on cloud computing.This algorithm utilizes the Kalman Filter (KF) that enhanced the sensors by twenty-seven percentage, was effectual in forecasting the denseness of AP. Centered upon the KF algorithm; the system attained an instant prediction of the AP concentration like SO2, NO2, and PM2.5 by joining the observations with errors. The optimal outcome was exhibited by the result with a reduced error of root means square further, depicted on the utilization of the algorithm in agriculture

Sandro*et al.* [23] devised a context-aware AP monitoring algorithm that preemptively cautioned the people through mobile when a highly polluted environment is approached. The system consistently discovered the AQ all through the given environment and transmitted the data to the people's mobile which were in turn accountable for frequently comparing a citizen's position in opposition to the regions of poor AQ.

Miles *et al.* [24] identified a decision support system (DSS) that scrutinized various abatement techniques to diminish AP. Initially, the DSS perceived critical AP and retaliated through the execution of full roads termination. It substantiated the feasibility of DSS to lessen AP as of attaining dangerous levels and enlisted the level at which abatement techniques should be implemented.

3. PROPOSED METHODOLOGY

Air pollution (AP) is a major global warming factor. The AP level has been increasing every day because of the increase in population, countless vehicles, industrialization, along with urbanisation. This affects all individuals who are all vulnerable to pollution. Thus, using DLMN, this paper proposed an IoT-centered AP monitoring and prediction system. This technology can detect road pollutants, measure multiple types of APs, and report the status of APs in smart cities. Initially, the SV is given as the input for the IoT devices. The GMF-ANFIS classifier is then used as the method of attack detection to check whether the attacked or non-attacked sensor data.If attacked data is retrieved, that data is stored in a log-file and stored on a cloud server for future data analysis purposes. And, to find the AP level in the smart cities, the non-attacked data is additionally processed. This system of AP monitoring undergoes training and testing. The data values from the AQI dataset are used in the training phase to analyse the AP level. During training, three different operations are performed: I) preprocessing, ii) selection of features, iii) categorization. There are 3 stages of pre-processing: i) removal of redundant data, ii) imputation of missing values and iii) normalisation of data. Then, by using MDOA, the significant features are chosen from the pre-processed data. For the classification of data values into '6' classes of pollutant data, these selected characteristics are added to the DLMNN as good, moderate, unhealthy for sensitive groups, very unhealthy, unhealthy, and dangerous.

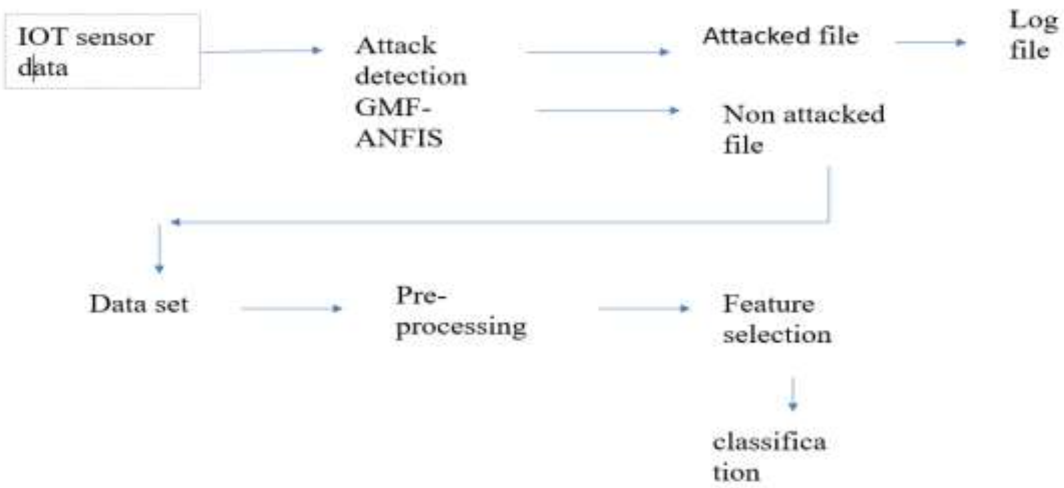

Figure 1:Architecture of the proposed method

The level of pollutants is predicted by the DLMNN. The non-attacked data is tested following the training process by performing the same '3' operations as training. By comparing the training outcomes, the method tests the non-attacked SV and gives the pollutant level. It then visualises the results of the testing classification. In figure 1, the proposed method's architecture is shown.

3.1 IoT Sensor Values

Initially, as of numerous nodes, the SV of different IoT sensor devices is collected, which are present in different places. The sensor will collect a number of surrounding data that is indirectly or directly linked to IoT networks. The concentration of pollutants such as carbon monoxide, harmful gases, dust level, and meteorological parameters such as temperature and location of GPS are collected by these sensors. Then, the collected values are sent out to the cloud server to monitor the AP level. But there is a likelihood that such data will be attacked and that data will be sent to the cloud. It is therefore essential to know whether or not the sensor data that is received from the IoT is attacked. This leads to the GMF-ANFIS, which is explained below, an attack detection technique.

3.2 Attack Detection using GMF-ANFIS

The Black Hole (BH) attack detection stage is performed using GMF-ANFIS after attaining the SV. The most dangerous attack is considered to be BH. Malicious nodes are called the sensor nodes that were affected via a BH attack. The bad nodes promote the incorrect path to the network during a BH attack, like disparate advertising along with a short route to the destination. The only intention of these bad nodes is to create more traffic and drop the caught-up packets instead of forwarding them. The attack by BH is essentially a DOS attack, which deteriorates the performance of the network. Thus, for the detection of BH attacks, GMF-ANFIS is used. The elucidation of GMF-ANFIS is provided as follows:

ANFIS comes under ANN and it is formed on the basis of the fuzzy inference system of Takagi-Sugeno. ANFIS incorporates neural networks with the principles of fuzzy logic, thus encompassing the potential of both. Its inference system is similar to a set of fuzzy IF-THEN rules that include the ability to learn how to approximate nonlinear functions.

The ANFISis made of ‘5’ layers. They are

- The initial layer that determines membership functions (MF) for the input values is the fuzzification layer.
- The rule-layer is the second one responsible for the entire rules for creating the Firing Strengths (FS).
- The calculated FS is normalised by the third layer. For the total FS, this is done by splitting every value.
- The standardised values and the resulting parameter are entered on the 4th layer, which returns the output defuzzification values.
- The result of the 4th layer is entered into the last layer, which provides the last output.

The suggested work in the initial layer uses GMF in place of the bell-MF to improve the performance of the rule generation process. Therefore, ANFIS is referred to as ANFIS based on GMF (GMF-ANFIS).

3.3 Monitoring and Prediction System of Air Pollution

The attacked data is stored in a log file that is retained for future use in a cloud server after the attacked and non-attacked data is discovered, and the non-attacked data goes through additional processes via the AP monitoring system. The system uses the training and testing phase to find the AP level. The data values from the AQI dataset are used in training. The three processes, such as a) preprocessing b) selection of features c) classification, are carried out under training. The short explanation of these '3' procedures is given in the section below.

3.3.1 Pre-processing

The pre-processing step is inserted into the AQI database. The pre-processing includes steps'3 I redundant data removal, ii) missing values imputation, and iii) data normalisation. The redundant attributes (irrelevant ones) are eradicated in the initial step to decrease the size of the data. In the second step, the missing value of a specific parameter is exchanged for other parameters (CO(GT), PT08.S1(CO), NMHC(GT), etc.) if the other parameter corresponds to most of its value from any date and time. Finally, the data is scaled in the third step for it to come under a specific gamut and Min-Max Normalization is used.

3.3.2 Feature Selection using MDOA

Within the AQI dataset, there are numerous parameters present and it will take loads of time to process each parameter when entering all these parameters into the classifier. Thus, in order to decide on the relevant features for the AQ level forecast, the feature selection stage is included here. To select the features of pre-processed data, the modified dragonfly optimization algorithm is used here. The primary goal encompassed by the dragonfly swarms is their survival, which they work out by only following food sources and deflecting from all enemies. Mathematically, such behaviours are designed. Here, the chief rules of '3' are followed by each other (nature of swarms)

- Separation () - The dragonflies avoid each other in order to circumvent a collision in a neighborhood-like position.
- Alignment ()-each dragonfly's speed coordinates with another one in the neighbourhood.
- Cohesion () - The dragonflies soar towards the midpoint of the neighbourhood cluster.

3.3.3 DLMNN Classifier

Here, the selected features are supplied as a DLMNN input. It takes more time to train the data as there is only '1' hidden layer (HL) in the current ANN. This suggested method uses more than three HLs to solve this problem and generates an optimised weight value between the HLs and the input layer and the HLs and output layers using the DLMNN Gravitational Search Optimization Algorithm (GSOA).

3.3.3.1 GSOA

GSOA is used to optimise weight values, stimulated by Newton's law of gravity and movement. The solutions are called agents in the GSOA population and these agents inter-communicate via the gravitational force (GF). The agents are regarded as objects, and their respective masses measure their performance. All objects on account of the GF travel in the direction of other objects with heavy masses. This step means the object's global movement, while the agent with a heavy mass that travels slowly guarantees the algorithm's exploitation step.

3. 4 Testing and Visualization

After the above training, the non-attacked sensor information is tested using the same training processes. Subsequently, the results of the testing classification are visualised, which is explained in the following section. The classified data is displayed on the network in several formats, for example, in the Google map, the base of severity in the equivalent locations is offered using disparate colours as listed below.

i. Good (AQI 50): if the classification result is good, the "Outdoor air is safe to breathe" visualisation is marked with green colour.

ii. Moderate (AQI: 51-100): If the outcome is moderate, the visualisation "unusually sensitive people may avert long or heavy outdoor exertion" is marked with yellow colour.

iii. Unhealthy for sensitive groups (AQI: 101-150): The "Sensitive individuals (e.g., children, elderly people, outdoor workers, and patients with lung disease, such as asthma) need to reduce long or heavy outdoor exertion" visualisation is marked with orange here.

iv. Unhealthy (AQI: 151-200): Here, the "Sensitive people" visualisation should prevent long or heavy outdoor exertion. Everyone else is marked with red to reduce long or heavy outdoor exertion.

v. Very unhealthy (AQI: 201-300): Here, the visualisation is "Each outdoor effort should be prevented by sensitive people." Everyone else in purple has to reduce outdoor exertion.

vi. Hazardous (AQI 301): Here, in maroon colour, the visualisation is "Everyone should avoid all outdoor exertion.

5. CONCLUSION

The IoT-based AQ monitoring and prediction system utilising DLMNN is proposed in this work. On the received sensor values, the attack detection phase is executed. The non-attacked sensor values are subsequently tested and the air pollutant level is predicted. Six kinds of pollutant levels are found and visualised in total. By contrasting their performance with the existing techniques, the results of the proposed method are assessed. In contrast to the existing ANFIS, the proposed GMF-ANFIS achieves the lowest and highest of 100 to 500 records. Furthermore, the performance shown for AQ prediction by the proposed DLMNN is contrasted with the existing LaSVM.

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