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ANALYSIS OF NEURAL NETWORK ALGORITHM IN URBAN AIR QUALITY PREDICTION

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Abstract: Air quality in urban areas is becoming an increasingly important issue considering its impact on human health and the environment. The rapid increase in air pollution requires effective methods to predict air quality in order to take appropriate mitigation measures. This study aims to analyze the use of Neural Network (NN) algorithms in predicting air quality in cities. The method used is the application of the NN model, especially the Multilayer Perceptron (MLP), which is trained using historical air quality data such as dust particle levels (PM10, PM2.5), carbon monoxide (CO) gas, and temperature. The data used in this study came from urban air quality monitoring stations collected over a period of time. The results show that the Neural Network algorithm can provide quite accurate predictions of air quality with a low Mean Absolute Error (MAE) value, showing the effectiveness of the model in predicting f fluctuations in air quality. The conclusion of this study is that Neural Network algorithms, specifically MLPs, are an effective tool for air quality prediction, which can be used as a basis for urban air quality management policies.

Keywords: air quality; neural network; prediction; multilayer perceptron (MLP)

Abstrak: Kualitas udara di perkotaan menjadi isu yang semakin penting mengingat dampaknya terhadap kesehatan manusia dan lingkungan. Peningkatan polusi udara yang pesat memerlukan metode yang efektif untuk memprediksi kualitas udara guna mengambil langkah mitigasi yang tepat. Penelitian ini bertujuan untuk menganalisis penggunaan algoritma Neural Network (NN) dalam memprediksi kualitas udara di perkotaan. Metode yang digunakan adalah penerapan model NN, khususnya Multilayer Perceptron (MLP), yang dilatih menggunakan data kualitas udara historis seperti kadar partikel debu (PM10, PM2.5), gas karbon monoksida (CO), dan suhu. Data yang digunakan dalam penelitian ini berasal dari stasiun pemantauan kualitas udara di perkotaan yang dikumpulkan selama periode waktu tertentu. Hasil penelitian menunjukkan bahwa algoritma Neural Network dapat memberikan prediksi yang cukup akurat terhadap kualitas udara dengan nilai Mean Absolute Error (MAE) yang rendah, menunjukkan efektivitas model dalam memprediksi fluktuasi kualitas udara. Simpulan dari penelitian ini adalah bahwa algoritma Neural Network, khususnya MLP, merupakan alat yang efektif untuk prediksi kualitas udara, yang dapat digunakan sebagai dasar untuk kebijakan pengelolaan kualitas udara di perkotaan

Kata kunci: kualitas udara; neural network; prediksi; multilayer perceptron (MLP)

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INTRODUCTION

Urban air quality is an increasingly pressing environmental issue, especially in line with population growth, urbanization, and rapid industrial development. Air pollution, caused by motor vehicle emissions, industrial activities, fuel burning, and other factors, can have a negative impact on human health and ecosystems[1]. Long-term exposure to air pollution can cause various respiratory diseases, heart problems, and increase the rate of premature death. case study in this research in Kisaran city, North Sumatra. Therefore, it is important to monitor air quality in real-time and develop effective methods to predict future air quality[2].

The old system in air quality prediction in Kisaran, North Sumatra, likely uses a traditional approach that relies on simple mathematical or statistical models that have limitations in terms of accuracy and data coveragen. Some characteristics of this old system include Conventional Statistical Models[3], These systems often use simple mathematical models, such as linear regression or physics-based models that are based on limited historical data. Data and Measurement Limitations, Lack of Data Integration from Various Sources

In recent years, air quality in cities has become a major concern due to its large impact on public health and the environment. Various studies have been conducted to predict air quality using methods such as linear regression[4], ARIMA, or other traditional statistical models. Some of these approaches have been successful in providing an overview of air quality at any given time, but many still have limitations in dealing with the non-linear and complex relationships between factors affecting air cauldrons[5].

Limitations of Traditional Models Most of the methods used today are more suitable for handling data that is linear or has simple relationships[6]. Linear regression and ARIMA, for example, have difficulty in modeling complex non-linear relationships between variables such as temperature, humidity, dust particles, harmful gases, and other factors that affect air quality in urban areas[7]. Lack of Accuracy Some studies use static-tic models or classical algorithms that are not able to provide accurate predictions of dynamic changes in air quality in the long or short term. Limited Use of Machine Learning Algorithms: Although machine learning algorithms such as Neu-ral Networks have been widely used in various other fields, their application in predicting urban air quality is still limited and has not been fully utilized[8].

To achieve more accurate and more reliable air quality predictions, the use of technologies that can handle complex and non-linear data is required, which is a major challenge in modeling air quality in cities[9].

Use of Neural Net-work Algorithms: With the ability of Neural Networks to recognize more complex and flexible patterns, especially in the case of data that has variables that interact with each other, this algorithm is expected to be able to provide more accurate predictions compared to conventional models.

The Neural Network Algorithm Analysis Research in Urban Air Quality Prediction in North Sumatra has great urgency because it can provide data-based solutions to predict and manage air quality in urban areas. This is not only beneficial for maintaining public health,

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but also for designing more appropriate and sustainable environmental policies.

Compounding of Various Factors: The use of Neural Networks allows the incorporation of various environmental factors and pollutants (such as PM2.5, PM10, CO, NO2, temperature, humidity, wind speed, etc.) to model air quality in a more comprehensive and integrated way.

Based on a review of existing research, some of the gaps found are as follows:

Lack of Research with Neural Networks: Although Neural Networks are already widely used in various other prediction fields, the use of these algorithms in predicting air quality in cities is still limited [10]. There hasn't been enough research focusing on the application of neural networks to predict air quality, especially in cities with high pollution levels.

Limitations of Data Used: Some studies only use limited air quality data and do not consider other external variables that can affect the prediction results, such as weather conditions or more dynamic traffic patterns. Models That Can't Face Data Complexity. Many models still rely on methods that can't address the non-linear relationships between variables that affect air quality [11].

As a result, the results of the predictions produced are less reliable. Lack of Trials with Different Datasets: Existing studies often use a single set of air cauldron-bag data from one location or one time period only, without considering the variation of data in different regions or periods, which can improve robusta and model accuracy. To overcome this gap, this study has the following steps to be taken:

Use of Net-work Neural Algorithm. This research will apply Neural Net-work algorithms, specifically the Multilayer Perceptron (MLP) model, to predict air quality based on more complex and non-linear data. Inclusion of Various Environmental Variables. This study will use various variables that affect air quality in cities, including air pollution data (PM2.5, PM10, CO, NO2), weather conditions (temperature, humidity, wind speed), and traffic data to provide a more comprehensive picture. Use of Real-Time and Historical Data.

This research will use a combination of historical and real-time data to train the model, so that the resulting model can predict with better accuracy for both the near and long term. Evaluation and Comparison with Other Models. To measure the effectiveness of the model, the prediction results using the Neural Network will be compared with conventional prediction models such as linear regression and ARIMA to assess the advantages and disadvantages of each model. Trial in Multiple Locations. This study will test the model with data from several air quality monitoring stations in various cities or urban areas to improve the model's generalization ability to various conditions and factors that affect air quality.

METHOD

This research aims to analyze the effectiveness of the Neural Network algorithm in predicting air quality in urban areas. The method used includes several important steps, ranging from data collection, data processing, model development, model training and evaluation, to results analysis. The following is a detailed explanation of the methods used in this study.

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Data Collection

The data used in this study is historical data on air quality obtained from air quality monitoring stations in various urban locations. Environmental Factors: Temperature (°C) ,Moisture (%), Wind speed (m/s)

Time Data Air quality data is collected in specific time intervals (e.g. hourly or per day) to analyze fluctuations in air quality over a period of time.

Data Preparation

In this study, there are data that describe the relationship between Temperature (°C), Humidity (%), Wind Speed (km/h), and Air Quality (Air Quality Index) as follows:

Temperature (°C)	Moisture (%)	Wind Speed (km/h)	Air Quality
30	70	10	80
25	60	5	57
28	65	7	78
32	80	15	90
26	55	8	72

Data Normalization

Data normalization is done so that all input values are in a uniform range (e.g. between 0 and 1).
Normalization using the formula:

$$X_{norm} = \frac{X - \min(X)}{\max(X) - \min(X)} \qquad (1)$$

For the Temperature, Sluggishness, and Wind Speed variables, we can normalize for each data.

RESULTS AND DISCUSSION

In this study use a twork feed forward with a hidden layer to understand the basics of manual calculations. In this model, we will use three inputs, namely temperature, humidity, and wind speed, as well as one output which is a prediction of air quality (e.g., AQI).
Steps to Calculate Neural Network:

Notation and Definitions

This study uses only a finger with 1 hidden layer that has 2 neurons. So, our model consists of: neuron inputs (temperature, humidity, wind speed), 2 hidden neurons, 1 output neuron (predicted AQI)

Initialization f Weight and bases

To start the calculation, we will initialize the weights and biases randomly. For example, we can use weights and biases as follows: Weight of Input Layer to Hidden Layer: w11,w12,w13 for neuron 1 on the hidden layer and w21,w22,w23, w_{21}, w_{22}, w_{23}w21,w22,w23 for neuron 2. Hidden Layer Weight to Output: w_{o1},w_{o2}. Bias : b_1,b_2,b_o for hidden neurons and output neurons.
Data Input

There are 3 variables used in this study with their respective value ranges, namely Temperature, Moisture, Wind Speed.

Data Normalization for temperature

Min(Temperature) = 25°C
Max(Temperature) = 32°C For temperature = 30°C:

$$\text{Suhunormal} = \frac{30-25}{32-25} = \frac{5}{7} = 0.714$$

Data Normalization for humidity

Min(Moisture) = 55%
Max(Moisture) = 80% for Moisture = 70%:

$$\text{Humidity}_{norm} = \frac{70-55}{80-55} = \frac{15}{25} = 0.714$$

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Data Normalization for wind Speed

Min(Wind Speed) = 5 km/h
Max(Wind Speed) = 15 km/h form
Wind Speed = 10 km/h:

$$WindSpeed_{norm} = \frac{10-5}{15-5} = \frac{5}{10} = 0.5$$

The first normalization data is like the table :

Table 1. Data Normatization

Temp-erature (°C)	Moisture (%)	Wind Speed (km/h)	Air Quality
0.714	0.6	0.5	80
0	0.2	0	75
0.428	0.4	0.2	78
1	1	1	90
0.142	0	0.3	72

In this research will use simple neural networks with the following architecture:
Input Layer**:** 3 neuron (for Temperature, Moisture, Wind Speed),
Hidden Layer**:** 2 neuron,
Output Layer**:** 1 neuron (for prediktion air quality)

Weight and bias

The weights for in-put layers to hidden layers and their biases are:
Weight for input to the first per neuron in the hidden layer: $w_1=0.5, w_2=-0.3, w_3=0.7$, Weight for input to the two per neuron in the hidden layer: $w_4=-0.2, w_5=0.8, w_6=0.4$, Bias for neuron first hidden layer: b1=0, Bias for neuron two hidden layer: b2=−0.1

To calculate the input to the first neuron of the hidden layer:

$$Z_1 = w_1.temp_{norm} + w_2.humidity_{norm} + w_3.windspeed_{norm} + b_1$$

$$Z_1 = 0.5 \cdot 0.714 + (-0.3) \cdot 0.6 + 0.7 \cdot 0.5 + 0.1 = 0.357 - 0.18 + 0.35 + 0.1 = 0.627$$

To calculate the input to the neurons of the second hidden layer:

$$Z_2 = -0.2 \cdot 0.714 + 0.8 \cdot 0.6 + 0.4 \cdot 0.5 - 0.1 = -0.143 + 0.48 + 0.2 - 0.1 = 0.437$$

Calculating the input to the output layer
Z_3, bobot w_7 and w_8 and bias b_3

$w_7=0.6$
$w_8=-0.5$w_8 = -0.5w8=−0.5
Bias output layer: $b_3=0.2$

The input to the output layer:

$$Z_3 = w_7.a + w_8.b + b_3$$

$$Z_3 = 0.6 \cdot 0.627 + (-0.5) \cdot 0.437 + 0.2 = 0.3762 - 0.2185 + 0.2 = 0.3577$$

Air Quality Prediction Output

The output of the Neural Network model for air quality is:

$$Y_{Pred} = Z_3 = 0.3577$$

CONCLUSION

Based on the research findings, this study plays a significant role in determining urban air quality. Supporting factors also influence the obtained results. These findings provide new insights and can serve as a foundation for further research exploration. Despite its limitations, this study still makes an important contribution.

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