REAL-TIME PREDICTION OF DISSOLVED OXYGEN LEVELS IN AUTOMATED AQUACULTURE FEEDING SYSTEMS USING A COMBINED TIME SERIES DECOMPOSITION

Avalov Akbar
Alfraganus University, Tashkent, Uzbekistan
akbaravalov@gmail.com

Abstract. In the aquaculture industry, improper feeding can significantly decrease dissolved oxygen concentration, posing a high risk of mortality. To mitigate this risk, it is crucial to monitor safety in real time before feeding. This study proposes a novel method to predict dissolved oxygen concentration in real time, even when feeding occurs at arbitrary times. Our approach integrates a time series data decomposition model with a pre-trained deep learning model. The effectiveness of the proposed method was validated by comparing its predictive performance for both regular and irregular feeding schedules against other deep learning models.

Keywords: time series decomposition, TCN, deep learning.

INTRODUCTION. In aquaculture, feed quality is closely linked to the overall water quality in rearing environments. Unconsumed feed rapidly decomposes, leading to a reduction in dissolved oxygen levels, alterations in pH, and an increase in harmful substances such as ammonia, thereby deteriorating the aquaculture conditions [1]. In this study, we combined time series decomposition with Temporal Convolutional Networks (TCN) to develop a model that predicts dissolved oxygen concentration in real time based on the feeding rate. This model is designed to enhance the operation of automatic feed supply systems by providing timely and accurate predictions of water quality metrics.

Method

The method of analyzing time series data by dividing it into trend, seasonal, and residual components is known as time series decomposition. The trend represents the long-term progression of the time series data. The seasonal component refers to

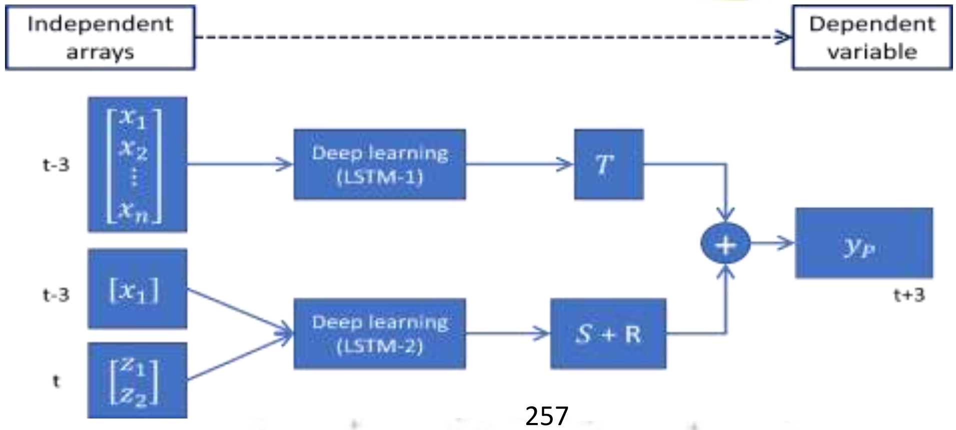

Figure 1. The figure illustrates the Decomposition TCN Model proposed in this study. The model predicts data from t to t+3 using data from t-3 to t as the prediction point. T and S+R are dependent variables representing the trend and the combined seasonal and residual components obtained through time series decomposition of the dissolved oxygen levels (y), which is the target variable.

changes that repeat at regular intervals. The residual component is the data that remains after removing the trend and seasonal components. The time series decomposition equations for trend (T_t), seasonal (S_t), and residual (R_t) are as follows (1).

$$y_t = f(T_t, S_t, R_t).\ y_t = T_t + S_t + R_t$$

The independent variables, [x_1 ⋯ x_n] and [z_1 z_2], consist of sensor data and management data. The sensor data [x_1 ⋯ x_n] includes measurements of dissolved oxygen (DO), temperature (temp), pH, oxidation-reduction potential (ORP), and carbon dioxide (CO2), using data from t-3. The management data [z_1 z_2] includes feed and water records that can be manipulated by the manager, allowing the use of data at time t when making predictions. This approach enables more accurate predictions of dissolved oxygen levels, especially when they change due to feed input at arbitrary times.

The addition of R to S as a dependent variable is crucial because the seasonal component alone only accounts for periodic patterns. By including the residual component, the model can predict variations in dissolved oxygen levels that result from feed supply and other factors, thereby adjusting the overall graph height accordingly.

Result

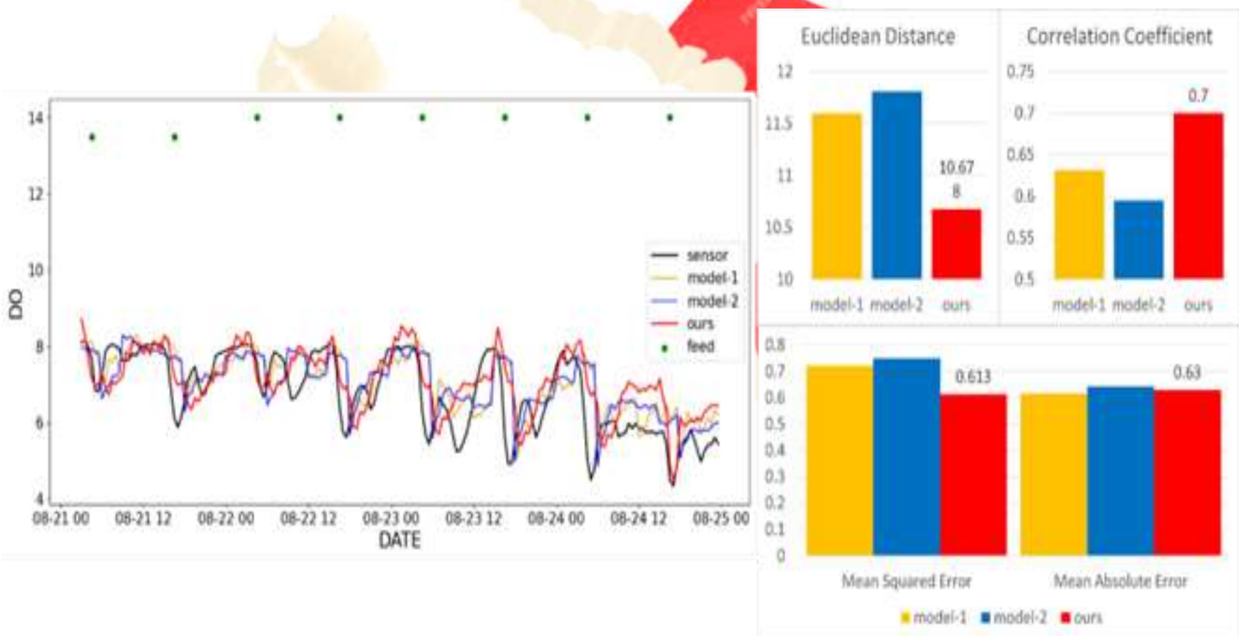

Figure 2. The figure compares the performance of the proposed TCN-based decomposition model in predicting dissolved oxygen concentration. In the left graph, the x-axis represents time, and the y-axis represents the measured dissolved oxygen

concentration, with green dots indicating feeding times. The predictions were made using test data from August 21 to August 25, 2021. The bar graph on the right visualizes the evaluation results for all 5 days of data using four metrics: Euclidean Distance, Correlation Coefficient, Mean Absolute Error, and Mean Squared Error. The x-axis denotes the metric names, and the y-axis represents the error values. Higher error values indicate greater deviation from the actual values.

Table 1. A detailed description of each model used is summarized in a table.

Model	Description
model-1	Only TCN
model-2	Typical Time-Series-Decomposition model
new model	Time-Series-Decomposition model with pretrained TCN

The model utilizes data on dissolved oxygen concentration and the water tank environment measured from 3 hours prior to the prediction point, along with the presence or absence of a feeding event, to predict dissolved oxygen concentration 3 hours ahead. The results indicate that the proposed model, represented by the solid red line, aligns most closely with the overall solid black line.

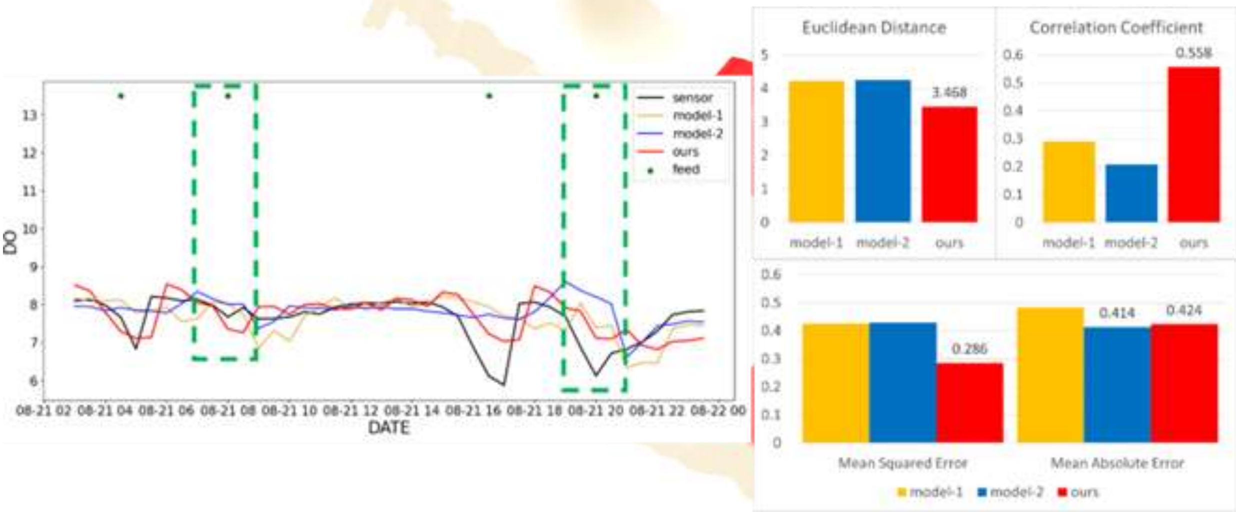

Figure 3. The figure presents the results of comparing the performance of the proposed TCN-based decomposition model for predicting dissolved oxygen concentration. The experiment aimed to determine whether predictions could be made when feed was supplied at random times rather than at regular intervals. Normally, feeding was conducted twice daily at 4:30 and 16:30. For the data on August 21, 2021, a similar feeding environment was artificially created at 8:00 and 20:00, outside the regular feeding times. The green dotted box highlights the periods of randomly supplied feed.

The performance of three different models, including the proposed model, was compared using the entire day's data. The other two models failed to predict changes in dissolved oxygen concentration resulting from randomly timed feedings. However, the proposed model successfully reflected the changes, demonstrating its ability to adapt to feeding events occurring at arbitrary times.

CONCLUSION

In this paper, we propose a new artificial intelligence model capable of predicting changes in dissolved oxygen concentration in real time within an automatic feeding system. The previously utilized single model was effective in predicting changes in dissolved oxygen concentration when feed was supplied regularly. However, it struggled to make accurate predictions when feed was supplied at irregular intervals, which is a realistic scenario in aquaculture environments. To address this issue, we developed a new model that combines a time series decomposition method with a deep learning model. The performance of this proposed model was verified through comparisons with other models, demonstrating its ability to provide accurate predictions even when feed is supplied non-periodically.

REFERENCES:

1. Relationship between changes in marine environment (dissolved oxygen) and survival of aquatic organisms.
https://www.busan.go.kr/comm/getFile?srvcId=BBSTY1&upperNo=151614&fileTy=ATT ACH&fileNo=1
2. O’.I.Begimov, T.M.Bo‘riboyev / Extracting tagging from exocardiographic images via machine learning algorithmics // Analysis of world scientific views International Scientific Journal Vol 2 Issue 1 IF(Impact Factor)8.2 / 2023
3. O’.I.Begimov, T.M.Bo‘riboyev / General Theory About the Traditional Methods and Algorithms of Machine Learning // AMERICAN Journal of Public Diplomacy and International Studies Volume 02, Issue 04, 2024 ISSN (E):2993-2157.