2025 年 04 月 15 日

2024 年度カーボンニュートラル研究助成制度実施報告書

カーボンニュートラル推進特設部会　御中

以下のとおり研究実施報告書を提出します。

<table>
<tr><td rowspan="6">基本情報</td><td>研究課題名：深層学習を利用した排出削減を目的とした汚水処理プロセスの最適化研究</td></tr>
<tr><td>研究代表者　氏名：余 恪平</td></tr>
<tr><td>【在籍者】
研究科・専攻・学年（学生証番号）：
【修了者等】
所属・職種：理工学研究科応用情報工学専攻・准教授</td></tr>
<tr><td>指導教員（所属・職・氏名）：
（※在籍者のみ記入）</td></tr>
<tr><td>共同研究者（所属・職・氏名）：理工学研究科応用情報工学専攻博士後期課程 2 年生在籍・陳錦華(CHEN JINHUA)
（※指導教員と同人の場合は記入不要）</td></tr>
<tr><td>その他　研究分担者：</td></tr>
<tr><td>研究期間：</td><td>研究期間：　　２０２４　年度</td></tr>
<tr><td>年間の研究実施概要</td><td>This project aims to optimize wastewater treatment processes using deep learning to enhance efficiency and reduce greenhouse gas emissions. Below is a summary of the project implementation, detailing the key steps and methods used to complete the project:

<u>1. Needs Analysis and Background Research</u>
<u>1.1 Objective Establishment</u>: Addressing the inefficiencies, high energy consumption, and greenhouse gas emissions caused by reliance on manual experience in traditional wastewater treatment plants, the project set out to optimize dissolved oxygen (DO) control using deep learning for energy saving and emission reduction.
<u>1.2 Literature Review</u>: Analyzed limitations of existing wastewater treatment technologies, including high energy use, instability of manual control, and lack of data-driven decision support. Leveraging recent advancements in 6G-IoT and machine learning, the research direction was clarified.

<u>2. Data Collection and Preparation</u>
<u>2.1 Data Source</u>: Collected 8,760 hours of continuous monitoring data from a wastewater treatment plant with a daily capacity of 300,000 tons, covering key indicators such as chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), and DO concentrations at the inlet and outlet.
<u>2.2 Data Preprocessing</u>: 2.2.1 Removed unstable or erroneous data points to ensure data quality. 2.2.2 Normalized input variables to maintain consistency. 2.2.3 Constructed input-output pairs, such as predicting DO concentrations using COD and NH_3-N ratios at the inlet and outlet, preparing the data for model training.</td></tr>
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年間の研究実施概要

3. Methodology Design and Modeling

3.1 Technical Framework: Proposed an intelligent sensing framework supported by industrial 6G-IoT and machine learning to optimize DO control strategies in wastewater treatment through data-driven approaches.

3.2 Model Selection: Adopted Support Vector Regression (SVR) with a Radial Basis Function (RBF) kernel for nonlinear modeling to predict DO concentrations. RBF-SVR was chosen for its superior performance in handling complex nonlinear relationships.

3.3 Model Development:

- Defined the SVR optimization objective function, incorporating slack variables to balance model complexity and prediction error.
- Designed a DO prediction model based on the RBF kernel, using Lagrangian multipliers for accurate predictions.
- Model outputs were used to guide intelligent aeration control, optimizing energy consumption.

4. Experiments and Validation

- **Experimental Design**: Conducted experiments using datasets from six different zones (Y1 to Y6) of the wastewater treatment plant to evaluate model performance across various scenarios.
- **Comparative Analysis**: Compared RBF-SVR with baseline models (Linear SVR, Multi-Layer Perceptron [MLP], Random Forest Regression [RFR]) using metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE).
- **Result Analysis**:
  - **RBF-SVR achieved the best performance on the Y1 dataset, with an MAE of 0.5047, RMSE of 0.7733, and MAPE of 21.44%.**
  - **Overall, RBF-SVR outperformed all baseline models across datasets, with an average MAE improvement of approximately 0.2, validating the model's effectiveness.**

5. Achievements and Optimization

- **Technical Outcomes**: Successfully developed an RBF-SVR-based DO prediction model, enabling precise aeration control and significantly reducing energy consumption and methane emissions. Experiments showed a prediction deviation below 0.6, with a performance improvement of approximately 5% compared to traditional methods.
- **Academic Output**: **The project results were published in the *IEEE Internet of Things Journal* (2024), titled "Industrial 6G-IoT and Machine-Learning-Supported Intelligent Sensing Framework for Indicator Control Strategy in Sewage Treatment Process."**
- **Continuous Improvement**: Identified data inconsistencies affecting performance on the Y2 dataset, providing insights for future model optimization.

6. Future Plans

- Plan to expand the intelligent sensing framework to include more wastewater treatment indicators, enhancing model adaptability.
- Further refine the RBF-SVR model to reduce prediction deviation and improve control efficiency.
- Apply the proposed framework to other industrial IoT scenarios, such as smart manufacturing and environmental monitoring.

研究業績

成果発表（学会・論文・研究会等）

学会・論文・研究会等の別	タイトル	発行または発表年月
IEEE Internet of Things Journal	Industrial 6G-IoT and Machine-Learning-Supported Intelligent Sensing Framework for Indicator Control Strategy in Sewage Treatment Process	September, 2024

その他（アピールすることがあればご記入ください。）

支出報告

費目	計画時金額	実績額	備考
設備備品費	300,000	303,800	
消耗品費	50,000	91,959	
旅費	100,000	59,659	
謝金等	50,000	44,548	
その他			
合計	500,000	499,966	