Forecasting the Color and Ammonia Concentration in the Reclaimed Water using Deep Learning

by

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This is to certify that I have examined the above MPhil thesis
and have found that it is complete and satisfactory in all respects,
and that any and all revisions required by
the thesis examination committee have been made.

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Abstract

Water scarcity is a global challenge. One of the promising ways to mitigate the water resource crisis is via wastewater reclamation. Chlorine is commonly used for reclaimed water disinfection and requires precise dosing to satisfy endorsed quality standards. Ammoniacal nitrogen (NH_3N) and colour exist in the reclaimed water at concentrations between 0.23 – 5.44 mg N/L and 80 – 150 Hazen units, respectively, and can affect the chlorine demand. Forecasting the reclaimed water quality enables a feedback control system over the disinfection process by predicting the exact chlorine dose required which secures sufficient time to respond to sudden surges in color and ammonia levels. This study developed time-variant models based on machine learning to predict the NH_3N concentration and colour three hours into the future in the reclaimed water. The NH_3N data was collected by an online analyzer, and colour data was collected by a customized auto-sampling spectrophotometer, both are installed in the reclaimed water treatment plant in Hong Kong. Long Short-Term Memory (LSTM) was found to be the most effective architecture for training NH_3N and colour forecasting models. In the training processes, we applied data pre-processing methods and feature engineering, a technique to select or create relevant variables in raw data to enhance predictive model performance. From feature engineering, we discovered that the daily fluctuation in NH_3N and colour has correlations with the urban water consumption patterns. This finding further enhanced the NH_3N and colour forecasting model performance by 4.9% and 5.4% compared to baseline models. This research work offers novel methods and feature engineering pro-

cesses for NH_3N concentration and colour forecasting in reclaimed water for treatment optimization.

CHAPTER 1

INTRODUCTION

1.1 Background

Intelligent robots are influencing many aspects of the world nowadays, from collaborative robot arms in factories to L4 autonomous driving technology, from biped household robots to quadruped mobile military agents, and from unmanned surface vehicles to quadrotor swarms. The more deeply we imagine the future, the more indispensable we find robot services.

For mobile robots, navigation is always the kernel function. However, compared with the automation of manipulation, mobile robot navigation is evolving more slowly. In the classical manipulation and manufacturing scenarios, the workspace of robots is usually well defined, and the robots can perform correctly under human-designed programming, without any interaction between uncertain objects and themselves. If we regard *replacing the repetitive workloads* as the first step, we should start to consider *living with the robot* in the next step. For mobile robots, to be incorporated into human's daily life, they must be intelligent in unknown and pedestrian-rich environments for tasks like autonomous driving, cargo delivers and household mobile robots, which is *behaving like a human.*

Human beings can navigate in crowded environments smartly without dependence on pre-defined high-resolution maps. We can also explore unknown environments without taking time to think about the information gain or frontiers. To navigate safely and efficiently like a human being, mobile robots should be able to perceive and predict behaviours of unfamiliar and dynamic agents. Based on the implicit or explicit understanding, an accessible policy considering various constraints is needed to guide the robots.

Deep learning, as a solution for artificial intelligence, is capable of building progressively meaningful feature abstraction of input data. It plays an essential role in various fields of study bringing the state of the art in image classification semantic segmentation , human-level game playing , driving real robotic systems in navigation and manipulation tasks.

We may be witnessing the most rapidly growing trend of deep learning techniques for robotics tasks in recent years. Replacing hand-crafted features with learned hierarchical distributed deep features, and learning control policies directly from high-dimensional sensory inputs, the robotics community is making substantial progress towards building fully autonomous intelligent systems.Bla.[1].

1.2 Objectives

The specific objectives of this thesis work are:
(1) To investigate the daily patterns of Color and Ammonia concentration in SWHEPP.
(2) To build deep learning models for training Color and NH_3N forecasting models.
(3) To develop methods of data pre-processing and feature engineering for training forecasting models.
(4) To elucidate the architecture design of the deep neural networks.

1.3 Organization of the thesis

CHAPTER 2

LITERATURE REVIEW

2.1 Water reclamation in WWTPs

2.1.1 Reclaimed water for urban water crisis

To address urban water crisis, there are four primary solutions which are rainwater harvesting, stormwater runoff, onsite groundwater, and reclaimed water. [2]

2.1.2 Decision-making processes for water quality control

In this study the new control objectives for the reclaimed water system in Shek Wu Hui Effluent Polish Plant have been established: to monitor color and ammonia concentration in the MBR effluent and at the same time provide a predictive model to assist the disinfection control strategy for disinfecting the MBR effluent to meet the endorsed reclaimed water standard.

2.1.3 The use of machine learning in model predictive control

2.2 Introduction to Deep Learning (DL)

2.2.1 Deep Learning in water quality forecasting

2.2.2 Recurrent neural networks (RNNs)

2.3 Environments for developing deep learning models

2.3.1 The use of Python programming languages

2.3.2 Build forecasting models with deep learning frameworks

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