Predicting Soil Moisture Levels with Gated Recurrent Units: A Deep Learning Approach Integrated with Internet of Things Data

Fahmi Rozan Mustafa
Information Technology
School of Computing, Telkom University
Bandung, Indonesia
fhmrzn@student.telkomuniversity.ac.id

Hilal Hudan Nuha
Information Technology
School of Computing, Telkom University
Bandung, Indonesia
hilalnuha@telkomuniversity.ac.id

Aji Gautama Putrada
Information Technology
School of Computing, Telkom University
Bandung, Indonesia
ajigps@telkomuniversity.ac.id

***Abstract*--- This study examines the prediction of soil moisture levels using Gated Recurrent Units (GRU) integrated with Internet of Things (IoT) technology. Recognizing the critical role of soil moisture in plant growth and ecosystem health, the research employs real-time data collected from IoT devices, including soil moisture, temperature, and humidity, to enhance irrigation efficiency in agricultural practices. Various prediction samples (n_samples) were analyzed, specifically focusing on n_samples of 6, 12, 18, and 24. The findings reveal that the GRU model with a prediction sample of n_samples =12 achieved the highest accuracy, bring in an R^2 value of 0.89944 and the lowest Mean Absolute Percentage Error (MAPE) of 0.03201. In contrast, shorter and longer prediction intervals demonstrated decreased accuracy and increased error rates. The study underscores the importance of selecting optimal prediction intervals for reliable soil moisture forecasting and highlights the potential of GRU models in real-time environmental monitoring. By combining deep learning methodologies and IoT technology, this research contributes to more efficient irrigation practices that can enhance water conservation and improve crop yields, ultimately promoting sustainable agricultural management strategies. Future work may focus on further enhancing model performance and expanding its applicability across diverse agricultural contexts.**

Keywords--- soil moisture, Internet of things, prediction, deep learning, gated recurrent units.

I. INTRODUCTION

Plants are living organisms that require water to grow and develop [1]. They utilize soil as their medium for growth, and fertile soil is essential for optimal plant development. Soil moisture is one of the critical factors influencing plant growth. It plays a vital role in enhancing vegetation and ecosystems, as well as facilitating the nitrogen cycle within the soil [2]. Proper utilization of water for growth is important and crucial. [3]. However, there is still a lot of water wasted in the watering process, as indicated by 40% of water wasted in ineffective irrigation systems. [4]. It is necessary to implement sustainable and effective water management practices to achieve optimal plant health status, crop yields, and minimize water consumption and costs. [5]. To achieve sustainable water management, predictions are essential for the rational use and management of water resources [6].

Recently, numerous studies have been performed to accurately determine and forecast soil moisture levels. One notable article [7], titled "Sustainable Irrigation Requirement Prediction Using Internet of Things and Transfer Learning," discusses a sustainable irrigation system. The primary objective of this article is to predict current and future water requirements over various time intervals, such as 3 hours, 8 hours, 12 hours, 24 hours, and 48 hours. This study combines IoT devices, K-Nearest Neighbors (KNN), cloud storage, Long Short-Term Memory (LSTM), and Adaptive Neuro-Fuzzy Inference System (ANFIS) to perform irrigation system predictions. The findings indicate that all plants require less water compared to manual irrigation methods. This article is highly relevant to the current sensors, as data is collected from agricultural locations using soil moisture sensors; furthermore, LSTM and transfer learning techniques are utilized to enhance the R^2 value.

Another journal article [2] discusses soil moisture prediction conducted using a genetic algorithm combined with LSTM and an attention mechanism. This research integrates LSTM layers, attention mechanisms, and fully connected layers (FCL) for soil moisture prediction based on multivariate time series data. Genetic algorithm (GA) is applied to simultaneously determine the hyperparameters of the proposed network, called GA-LSTM-ATT. These hyperparameters include the number of LSTM layers, hidden units in layers, dropout rates, and learning rates. Through model evaluations using metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), R^2, and Root Mean Squared Percentage Error (RMSPE), this research demonstrates GA-LSTM-ATT method provides a notable solution for soil moisture prediction across various areas.

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