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Utilizing a Hybrid CNN-RNN Machine Learning Approach for Forecasting Time-Series Outlet Fluid Temperature Monitoring by Long-Term Operation of BHEs System

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ABSTRACT

The Borehole Heat Exchanger (BHE) significantly enhances heat exchange efficiency in Ground Source Heat Pump (GSHP) systems. Accurate prediction of the BHE's outlet fluid temperature is essential for optimizing GSHP performance, energy storage, and resource conservation. Traditional machine learning methods face challenges with manual feature extraction and complex nonlinear relationships. To overcome these, this research introduces a hybrid Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) model for long-term outlet fluid temperature forecasting. The model uses CNN for temporal feature extraction and RNN for sequential pattern learning. Evaluated against LSTM, CNN, and SimpleRNN models, the proposed model achieved superior performance, with an RMSE of 0.818, MAE of 0.642, AARE of 0.0305, and R^2 of 98.75%, demonstrating significant advancements in BHE system efficiency and sustainability.

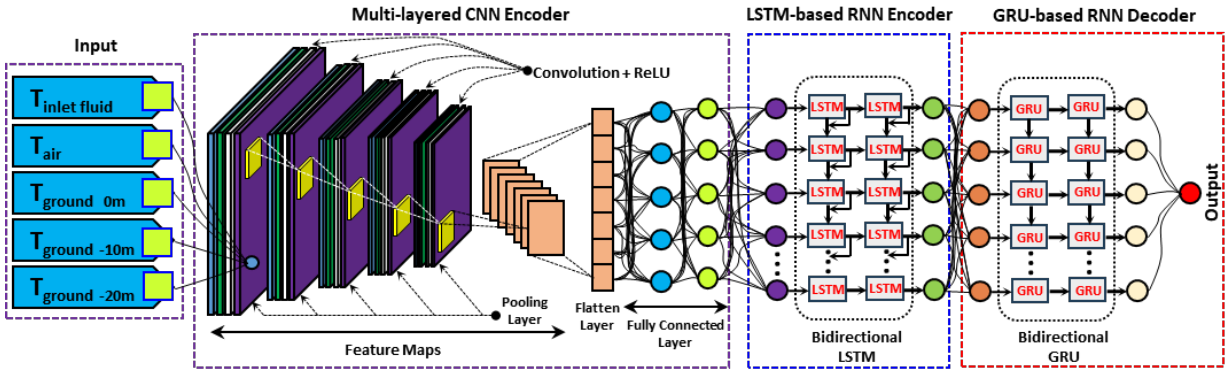

Fig. 1 Architecture of multi-layer CNN encoder, LSTM-based RNN encoder, and GRU-based RNN decoder.

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