ABSTRAK

Pasar saham Indonesia bersifat nonlinier dan nonstasioner, dengan *noise* tinggi serta perubahan harga yang volatil yang sering mematahkan asumsi model klasik. Banyaknya indikator teknikal menimbulkan redundansi fitur dan risiko *overfitting*, sementara validasi berbasis *hold-out* rawan data *leakage* pada runtun waktu. Kondisi ini menuntut rancangan yang sekaligus menapis *noise*, memilih fitur, dan memvalidasi secara selaras dengan struktur temporal. Namun, sebagian besar studi sejenis cenderung mengandalkan satu jalur pemodelan tanpa penapisan *noise* yang sistematik, melakukan pemilihan indikator secara *ad hoc*, dan menilai kinerja pada skema *hold-out* yang rentan bias waktu. Akibatnya, estimasi akurasi sering kali optimistis dan sulit direplikasi pada data BEI yang ber-*noise*.

Penelitian ini mengusulkan *pipeline deep learning* hibrid dua cabang. Rancangan dua cabang dipilih agar pemodelan pola data historis dan indikator teknikal berjalan khusus dan saling melengkapi, sehingga representasi lebih informatif tanpa menambah kompleksitas yang tidak perlu. Jalur historis untuk mengolah harga penutupan diproses dengan *Adaptive Wavelet Thresholding* (AWT) sebagai tapis, jalur teknikal memanfaatkan himpunan indikator konvensional yang diperkaya koefisien DWT (A3, D3) sebagai kandidat fitur yang kemudian diseleksi dengan *minimum Redundancy Maximum Relevance* (mRMR). *Temporal Convolutional Network* (TCN) diidentifikasi sebagai *baseline* tunggal terbaik pada tahap uji model *deep learning* tunggal. Kemudian berdasarkan pengujian model hibrid terpilih model TCN-GRU dan TCN-LSTM. Optimasi hiperparameter dieksplorasi dengan *Bayesian Optimization* (BO) dan dievaluasi menggunakan *walk-forward cross-validation*. *Dataset* mencakup enam saham *blue-chip* BEI dalam periode 2005–2022 dan metrik evaluasi yang digunakan adalah MSE, RMSE, R^2.

Pada *pipeline* lengkap menggunakan mRMR-AWT-BO, TCN-GRU mencapai MSE rata-rata 0,00011 dan median 0,000075, RMSE rata-rata 0,00905 dan median 0,008655, serta R^2 rata-rata 0,980668 dan median 0,982376. TCN-LSTM menghasilkan MSE rata-rata 0,000124 dan median 0,000086, RMSE rata-rata 0,009331 dan median 0,009272, serta R^2 rata-rata 0,979279 dan median 0,984279. *Ablation study* menunjukkan bahwa AWT konsisten menurunkan *error*, mRMR meningkatkan stabilitas dan kinerja melalui reduksi redundansi, sementara BO memberi manfaat yang kontekstual. Secara keseluruhan, kombinasi AWT pada jalur data historis dan seleksi mRMR atas kandidat menghasilkan *pipeline* hibrid yang efektif, stabil, dan dapat direplikasi untuk prediksi harga saham *blue-chip* BEI. Implikasinya bagi kecerdasan buatan untuk ilmu finansial ialah bahwa *pipeline* yang menyatukan penapisan, seleksi, dan optimasi di dalam validasi berorientasi waktu dapat meningkatkan keandalan generalisasi dan kemudahan replikasi pada data pasar yang ber-*noise* tinggi. Rancangan ini juga mudah diadaptasi untuk tugas terkait seperti prediksi multilangkah, penilaian risiko, serta pengambilan keputusan berbasis aturan atau kebijakan.

Kata kunci: Prediksi harga saham, Bursa Efek Indonesia, *hybrid deep learning*, *Temporal Convolutional Network*, GRU, LSTM, *Adaptive Wavelet Thresholding*, mRMR, *Bayesian Optimization*.

ABSTRACT

The Indonesian stock market is nonlinear and nonstationary, with high noise and volatile price movements that often break the assumptions of classical models. The large number of technical indicators introduces feature redundancy and increases the risk of overfitting, while hold-out based validation is prone to data leakage in time series. These conditions call for a design that simultaneously filters noise, selects features, and performs validation in a way that is consistent with the temporal structure. However, most related studies still rely on a single modelling path without systematic noise filtering, perform indicator selection in an ad hoc manner, and assess performance under hold-out schemes that are vulnerable to time bias. As a result, accuracy estimates are often overly optimistic and difficult to replicate on noisy IDX data.

This study proposes a two-branch hybrid deep learning pipeline. The dual-branch design is chosen so that the modelling of historical data patterns and technical indicators can be handled separately yet in a complementary way, producing more informative representations without adding unnecessary complexity. The historical branch, which processes closing prices, is filtered using Adaptive Wavelet Thresholding (AWT), while the technical branch uses a set of conventional indicators enriched with DWT coefficients (A3, D3) as candidate features, which are then selected using Minimum Redundancy Maximum Relevance (mRMR). Temporal Convolutional Network (TCN) is identified as the best single baseline model in the single Deep Learning experiment. Based on subsequent hybrid model experiments, TCN-GRU and TCN-LSTM are selected as the best hybrid candidates. Hyperparameter optimization is explored using Bayesian Optimization (BO) and evaluated with walk-forward cross-validation. The dataset covers six IDX blue-chip stocks over the 2005-2022 period, and the evaluation metrics used are MSE, RMSE, and R^2.

In the full mRMR-AWT-BO pipeline, TCN-GRU achieves an average MSE of 0.00011 with a median of 0.000075, an average RMSE of 0.00905 with a median of 0.008655, and an average R^2 of 0.980668 with a median of 0.982376. TCN-LSTM produces an average MSE of 0.000124 with a median of 0.000086, an average RMSE of 0.009331 with a median of 0.009272, and an average R^2 of 0.979279 with a median of 0.984279. The ablation study shows that AWT consistently reduces error, mRMR improves stability and performance by reducing redundancy, while BO provides context-dependent benefits. Overall, the combination of AWT in the historical branch and mRMR selection over wavelet-technical candidates yields an effective, stable, and replicable hybrid pipeline for predicting IDX blue-chip stock prices. The implication for artificial intelligence in finance is that a layered pipeline which integrates filtering, selection, and optimization within time-oriented validation can improve generalization reliability and ease of replication on market data with high noise. The design is also easily adaptable to related tasks such as multi-step prediction, risk assessment, and rule- or policy-based decision making.

Keywords: stock price prediction, Bursa Efek Indonesia, hybrid deep learning, Temporal Convolutional Network, GRU, LSTM, Adaptive Wavelet Thresholding, mRMR, Bayesian Optimization.