ABSTRAK

ANALISIS PREDIKTIF KONFIGURASI SERI–PARALEL *SMART FLOOR PIEZOELECTRIC* MENGGUNAKAN PENDEKATAN *MACHINE LEARNING*

(2026 : xviii + 118 Halaman + 62 Gambar + 52 Tabel + Daftar Pustaka + Lampiran)

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Kebutuhan energi global mendorong pemanfaatan energi kinetik langkah kaki manusia melalui teknologi *piezoelectric*, namun keluaran dayanya yang kecil dan fluktuatif menjadi tantangan utama yang belum terpecahkan secara prediktif. Penelitian ini membangun model prediktif *Power Output* sistem *Smart Floor Piezoelectric* dengan membandingkan algoritma *Random Forest Regression* (RFR) dan *Extreme Gradient Boosting* (XGBoost) menggunakan tiga variabel input: berat badan (*Weight*), frekuensi langkah (*Rate of Motion*), dan konfigurasi rangkaian seri-paralel (*Circuit Configuration*). Sistem dibangun dari 12 blok modular dengan akuisisi data otomatis berbasis ADC 16-bit ADS1115 dan ESP32-S3 yang terintegrasi dengan IoT, menghasilkan dataset dari 12 responden (480 sesi pengujian). Penelitian menguji dua pendekatan dataset: per-baris (13.250 sampel) yang menghasilkan R^2 rendah akibat variansi internal tinggi (RFR: 0,0294; XGBoost: 0,0677), dan per-sesi menggunakan agregasi nilai puncak daya P_max (480 sampel) yang menghasilkan performa cukup presisi (RFR: R^2=0,8114; XGBoost: R^2=0,8297, MAE=12,14µW, RMSE=16,19µW). Model terbaik XGBoost per-sesi mengidentifikasi konfigurasi rangkaian sebagai fitur paling dominan (43,44%), diikuti frekuensi langkah (33,47%) dan berat badan (23,09%). Analisis prediktif menunjukkan pola optimal yang bersifat *hybrid*: konfigurasi Seri unggul 36,93% pada aktivitas berjalan, sedangkan konfigurasi Paralel unggul 7,65% pada aktivitas berlari. Temuan ini menegaskan bahwa pemilihan konfigurasi optimal harus mempertimbangkan pola aktivitas pejalan kaki secara dinamis.

Kata kunci: *Piezoelectric Energy Harvesting*, *Smart Floor*, *Random Forest Regression*, XGBoost, *Machine Learning*, Analisis Prediktif.

ABSTRACT

PREDICTIVE ANALYSIS OF SERIES–PARALLEL CONFIGURATIONS IN PIEZOELECTRIC SMART FLOORS USING A MACHINE LEARNING APPROACH

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The global demand for clean energy has intensified interest in harvesting kinetic energy from human footsteps using piezoelectric technology; however, the small and highly fluctuating power output remains a critical challenge without a reliable predictive solution. This study develops predictive models for the Power Output of a Piezoelectric Smart Floor system by comparing Random Forest Regression (RFR) and Extreme Gradient Boosting (XGBoost) algorithms using three input variables: body weight, step frequency (Rate of Motion), and series-parallel circuit configuration. The system comprises 12 modular piezoelectric blocks with automatic data acquisition via a 16-bit ADS1115 ADC and ESP32-S3 microcontroller integrated with an IoT platform, yielding a dataset from 12 subjects across 480 test sessions. Two modeling scenarios were evaluated: per-row (13,250 samples), which produced low accuracy due to high internal variance (RFR: R^2=0.0294; XGBoost: R^2=0.0677), and per-session using peak power aggregation (P_max, 480 samples), which achieved fairly precise performance (RFR: R^2=0.8114; XGBoost: R^2=0.8297, MAE=12.14 µW, RMSE=16.19 µW). The best-performing model, XGBoost per-session, identified circuit configuration as the dominant feature (43.44%), followed by step frequency (33.47%) and body weight (23.09%). Predictive analysis revealed a hybrid optimal pattern: the Series configuration outperforms Parallel by 36.93% during walking, while the Parallel configuration outperforms Series by 7.65% during running — demonstrating that dynamic activity-aware circuit selection is essential for maximizing energy harvesting efficiency.

Keywords: *Piezoelectric Energy Harvesting, Smart Floor, Random Forest Regression, XGBoost, Machine Learning, Predictive Analysis*