

Rancang Bangun dan Evaluasi Model Prediksi Remaining Useful Life dan Klasifikasi Health Status pada Mesin Turbofan menggunakan Multitask Learning dengan Arsitektur Multi-Gate Mixture-of-Experts (MMoE) = Design, Development, and Evaluation of a Model for Remaining Useful Life Prediction and Health Status Classification on Turbofan Engines using Multitask Learning with a Multi-Gate Mixture-of-Experts (MMoE) Architecture

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Abstrak

Prediksi Remaining Useful Life (RUL) dan klasifikasi Health Status (HS) pada mesin aero merupakan aspek penting dalam Prognostics and Health Management (PHM). Penelitian ini mengusulkan model Multi-gate Mixture-of-Experts (MMoE) multitask yang domain-aware untuk prediksi RUL dan klasifikasi HS secara simultan pada semua domain C-MAPSS (FD001–FD004). Kinerja model dievaluasi dengan metrik RMSE, MAE, MAPE untuk RUL dan akurasi, F1-score untuk HS, serta dibandingkan dengan baseline CNN–LSTM–Attention per domain. Model MMoE tunggal menurunkan rata-rata RMSE RUL menjadi 9,75 (baseline 12,68), MAE 6,43 (baseline 8,31), dan MAPE 13,61% (baseline 19,99%). Akurasi klasifikasi HS naik dari 85,12% menjadi 90,11%, dan F1-score makro dari 0,815 menjadi 0,875. Efisiensi pengelolaan model juga meningkat karena hanya satu model diperlukan untuk seluruh domain dan kedua tugas. Hasil ini telah diverifikasi melalui eksperimen dan analisis komparatif. Pendekatan multitask dengan arsitektur MMoE domain-aware terbukti lebih efektif dan efisien dibandingkan baseline domain-spesifik.

.....Predicting Remaining Useful Life (RUL) and classifying Health Status (HS) in aero-engines are crucial for Prognostics and Health Management (PHM). This study proposes a domain-aware Multi-gate Mixture-of-Experts (MMoE) multitask model for simultaneous RUL prediction and HS classification across all C-MAPSS domains (FD001–FD004). The model's performance is evaluated using RMSE, MAE, MAPE for RUL and accuracy, F1-score for HS, and compared against per-domain CNN-LSTM-Attention baselines. The single MMoE model reduced average RUL RMSE to 9.75 (baseline 12.68), MAE to 6.43 (baseline 8.31), and MAPE to 13.61% (baseline 19.99%). HS classification accuracy increased from 85.12% to 90.11%, and macro F1-score from 0.815 to 0.875. Model management is also more efficient as only one model is required for all domains and tasks. These results, verified by experiments and comparative analysis, confirm that the multitask MMoE approach is more effective and efficient than domain-specific baselines.