

INTISARI

Pengembangan *Multi-Class Domain Adaptation* untuk Kompensasi *Drift Temporal* dan Variasi Antar Perangkat pada Sistem E-nose Multi Unit

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Sistem *electronic nose* (e-nose) multi-unit menghadapi tantangan berupa drift temporal respons sensor serta variasi karakteristik antar perangkat, yang berdampak pada penurunan konsistensi klasifikasi dan kemampuan generalisasi model. Penelitian ini bertujuan mengembangkan dan mengevaluasi kerangka *Multi-Class Domain Adaptation* (MCDA) untuk mengompensasi kedua sumber pergeseran domain tersebut secara simultan, tanpa memerlukan data berlabel eksplisit dari domain target. MCDA dirancang untuk menyelaraskan distribusi fitur antar domain sekaligus mempertahankan struktur diskriminatif multikelas. Eksperimen dilakukan pada sistem e-nose yang terdiri dari empat unit dengan tiga jenis gas uji, menggunakan delapan fitur statistik yang merepresentasikan respons transien dan *steady-state* sensor. Evaluasi dilakukan melalui dua strategi pemilihan domain sumber, yaitu berbasis urutan waktu pengambilan data dan berbasis performa klasifikasi rata-rata antar unit. Kinerja MCDA selanjutnya diuji pada skema transfer kalibrasi antar unit dan divalidasi menggunakan *Sensor Drift Dataset* dengan rentang waktu 36 bulan. Hasil menunjukkan bahwa MCDA memberikan performa yang konsisten dan stabil pada kedua skema. Pada skema berbasis waktu, MCDA mencapai akurasi rata-rata 94,69% dengan nilai ROC-AUC 0,993, sedangkan pada skema berbasis performa diperoleh akurasi 93,33% dan ROC-AUC 0,995, dengan variasi akurasi antar domain yang rendah ($SD \leq \pm 1,02\%$). Sebanyak 5 dari 6 kombinasi domain menunjukkan nilai $AUC \geq 0,99$. Pada evaluasi dataset *drift* jangka panjang, MCDA mencapai akurasi rata-rata hingga 73,82% dan melampaui metode pembandingan konvensional. Visualisasi PCA dan t-SNE mengonfirmasi penyelarasan distribusi fitur dan pemisahan kelas yang lebih jelas setelah adaptasi. Secara keseluruhan, MCDA terbukti meningkatkan konsistensi dan kemampuan sistem e-nose multi-unit lintas perangkat dan waktu pada kondisi *drift* temporal dan variasi antar perangkat.

Kata kunci: E-nose, *Drift* temporal, *Multi-Class Domain Adaptation* (MCDA), *Transfer* kalibrasi, *Transfer learning*.

ABSTRACT

DEVELOPMENT OF MULTI-CLASS DOMAIN ADAPTATION FOR COMPENSATION OF TEMPORAL DRIFT AND INTER DEVICE VARIATION IN MULTI UNIT E-NOSE SYSTEMS

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Multi-unit electronic nose (e-nose) systems face challenges in the form of temporal drift in sensor responses and variations in characteristics between devices, which impact the consistency of classification and the generalization ability of the model. This study aims to develop and evaluate a Multi-Class Domain Adaptation (MCDA) framework to compensate for both sources of domain shift simultaneously, without requiring explicit labeled data from the target domain. MCDA is designed to align feature distributions across domains while maintaining a multi-class discriminative structure. Experiments were conducted on an e-nose system consisting of four units with three types of test gases, using eight statistical features representing transient and steady-state sensor responses. Evaluation was performed using two source domain selection strategies, namely based on data acquisition time sequence and based on average classification performance across units. The performance of MCDA was further tested on an inter-unit calibration transfer scheme and validated using the Sensor Drift Dataset with a time range of 36 months. The results show that MCDA provides consistent and stable performance in both schemes. In the time-based scheme, MCDA achieved an average accuracy of 94.69% with an ROC-AUC value of 0.993, while in the performance-based scheme, it achieved an accuracy of 93.33% and an ROC-AUC of 0.995, with low accuracy variation between domains ($SD \leq \pm 1.02\%$). Five out of six domain combinations showed an AUC value ≥ 0.99 . In the long-term dataset drift evaluation, MCDA achieved an average accuracy of up to 73.82% and outperformed conventional comparison methods. PCA and t-SNE visualizations confirmed the alignment of feature distributions and clearer class separation after adaptation. Overall, MCDA was proven to improve the consistency and capability of multi-unit e-nose systems across devices and time under conditions of temporal drift and inter-device variation.

Keywords: E-nose, Temporal drift, Multi-Class Domain Adaptation (MCDA), Calibration transfer, Transfer learning.