Implementasi Algoritma Pembelajaran Mesin untuk Klasifikasi Suara Lingkungan Hutan Buatan Berbasis Fitur MFCC

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INTISARI

Tekanan lingkungan di Indonesia akibat deforestasi, urbanisasi, dan aktivitas industri menuntut adanya metode pemantauan ekosistem yang murah, non-invasif, dan mampu beroperasi secara realtime. Pendekatan konvensional yang bersifat visual maupun invasif seringkali memerlukan biaya besar, tenaga intensif, dan tidak efisien untuk pemantauan jangka panjang. Analisis berbasis audio melalui kerangka *soundscape ecology* dan standar ISO 12913 menawarkan solusi alternatif dengan menjadikan komposisi suara lingkungan sebagai indikator kondisi ekosistem. Namun, tantangan utama yang masih dihadapi adalah kebutuhan akan sistem klasifikasi sumber suara lingkungan yang efisien, akurat, dan adaptif agar dapat mendukung implementasi pemantauan akustik secara berkelanjutan.

Data penelitian berupa 804 rekaman berdurasi 5 detik dari Hutan Wanagama, terbagi ke dalam empat kategori: suara manusia, *biophony*, *geophony*, dan suara mesin. Fitur diekstraksi menggunakan 13 koefisien *Mel Frequency Cepstral Coefficients* (MFCC) dengan perhitungan nilai rata-rata dan simpangan baku. Empat algoritma pembelajaran mesin diuji, yaitu *Logistic Regression*, *Support Vector Machine*, *Random Forest*, dan *Multi-Layer Perceptron* (MLP), dengan evaluasi berbasis matrik evaluasi.

Hasil pengujian internal menunjukkan seluruh model memiliki akurasi di atas 95%, dengan MLP tertinggi pada 98,12%. Kinerja model stabil pada sampling rate menengah (~16 kHz). Validasi eksternal menunjukkan Random Forest unggul dalam mendeteksi biophony, sedangkan MLP menjaga kontinuitas prediksi. Sistem ini efektif, adaptif, dan hemat daya, sehingga layak diimplementasikan untuk pemantauan lingkungan akustik berkelanjutan.

Kata kunci: Klasifikasi suara lingkungan, Pemantauan akustik, MFCC, Pembelajaran mesin, Soundscape ekologi, ISO 12913

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Implementation of Machine Learning Algorithms for Environmental Sound Classification in Artificial Forests Based on MFCC Features

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ABSTRACT

Environmental pressures in Indonesia caused by deforestation, urbanization, and industrial activities demand monitoring methods that are cost-effective, non-invasive, and capable of operating in real-time. Conventional approaches, which are often visual or invasive, require high costs, intensive labor, and are inefficient for long-term monitoring. An audio-based analysis through the framework of soundscape ecology and ISO 12913 offers an alternative solution by using the composition of environmental sounds as indicators of ecosystem conditions. However, the main challenge lies in the need for an efficient, accurate, and adaptive environmental sound source classification system to support sustainable acoustic monitoring.

The research data consists of 804 five-second recordings from Wanagama Forest, divided into four categories: human sounds, biophony, geophony, and machine sounds. Features were extracted using 13 Mel Frequency Cepstral Coefficients (MFCC), calculated through mean and standard deviation values. Four machine learning algorithms were tested, namely Logistic Regression, Support Vector Machine, Random Forest, and Multi-Layer Perceptron (MLP), with evaluation based on evaluation metrics.

Internal testing showed that all models achieved accuracy above 95%, with MLP achieving the highest at 98.12%. Model performance remained stable at moderate sampling rates (~16 kHz). External validation indicated that Random Forest excelled in detecting biophony, while MLP maintained prediction continuity. The proposed system is effective, adaptive, and energy-efficient, making it suitable for sustainable environmental acoustic monitoring applications.

Keywords: Environmental sound classification, Acoustic monitoring, MFCC, Machine Learning, Soundscape ecology, iso 12913

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