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A Hybrid Speech Enhancement Technique Based on Discrete Wavelet Transform and Spectral Subtraction
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Abstract
Speech quality and intelligibility are often severely degraded by background noise in communication systems such as hearing aid (HA) and speech recognition technologies, compromising their effective use. In low Signal-to-Noise Ratio (SNR) conditions, various approaches and algorithms are applied to improve speech quality and intelligibility. This study introduces a novel hybrid speech enhancement framework that synergistically integrates Spectral Subtraction (SS) and Discrete Wavelet Transform (DWT) to address limitations of traditional noise reduction techniques. Traditional SS methods generate musical noise artifacts due to static noise estimation, while standard DWT approaches struggle with selective thresholding and static coefficient processing. To overcome these challenges, the proposed SS method incorporates iterative noise estimation, Voice Activity Detection (VAD), minimum statistics for dynamic noise adaptation, Spectral Smoothing and phase-aware spectral reconstruction. Concurrently, in the enhanced DWT method adaptive noise refinement with phase-aware soft thresholding is employed to detail coefficients, and the Spatial and Intensity filter is adapted to the approximation coefficients to improve low-frequency features and retain structural integrity while reducing distortion. The integrated SS-DWT framework significantly improves noise suppression, reduces musical noise artifacts, and enhances signal clarity as it leverages the strengths of both phase-aware spectral reconstruction in improved SS and phase-aware soft thresholding in DWT, particularly in adaptive noise refinement and thresholding. Proposed speech enhancement network evaluated and experimental results show that the hybrid SS-DWT method outperforms existing systems, achieving up to 34.15 dB in SDR, 0.98 in STOI, and 3.84 in PESQ, demonstrating significant improvements in speech quality under various noisy conditions.

Author Keywords
adaptive noise refinement; DWT; music noise; phase-aware construction; spectral subtraction; Speech enhancement

Index Keywords
Background noise, Image coding, Image thinning, Noise abatement, Phase noise, Signal to noise ratio, Speech analysis, Speech enhancement; Adaptive noise, Adaptive noise refinement, Discrete-wavelet-transform, Music noise, Musical noise, Noise artifacts, Phase-aware construction, Spectral subtraction methods, Spectral subtractions, Speech quality; Discrete wavelet transforms

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