Wearable Stethoscope Array for Cardiopulmonary Sound Localization and Interference Suppression Using Beamforming

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Traditional auscultation devices and methods have inherent limitations in spatially localizing body sounds and suppressing interference—restricting their diagnostic potential. This project develops a wearable, multi-channel stethoscope array prototype and proposes novel algorithms to overcome these challenges. Each of the prototype’s chest pieces features a digital MEMS microphone mounted on a flexible PCB with EcoFlex gel padding. Individual chest pieces’ performance is benchmarked against a commercial digital stethoscope, and demonstrates higher power spectral density across a wider frequency range. A novel Costas array chest piece configuration was discovered to align with auscultation site guidelines—optimizing spatial resolution and hardware efficiency—and improved lung sound localization accuracy over alternative array geometries. A novel hybrid method of beamforming-assisted machine learning for localization is developed and offers 34%-84% localization error reduction over the SRP-DAS (Steered Response Power-Delay and Sum) alone and ML alone methods. Applying beamforming with a novel dual-mic end-fire chest piece enables directional auscultation, nulling interference with high spatial precision. The chest piece design’s sub-wavelength mic spacing is crucial for achieving frequency invariant beam patterns, facilitating solutions to medical challenges such as fetal-maternal heart sound confusion. Extensive simulations and experiments validated the hardware, algorithm, and software design, with results demonstrating the system’s potential to enable new diagnostic capabilities and possibilities of auscultation.

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