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.

Awards Won: