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a Multi-Modal Approach to Acoustic Reflector Estimation

Riemens, E.H.J.; Martinez-Nuevo, Pablo; Martinez, Jorge; Møller, Martin Bo; Hendriks, R.C.

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1st Ellen Riemens
Circuits and Systems (CAS) Group
Delft University of Technology
Delft, The Netherlands
E.H.J.riemens@tudelft.nl

2nd Pablo Martínez-Nuevo
Acoustics & Research
Bang & Olufsen
Struer, Denmark
PMN@bang-olufsen.dk

3rd Jorge Martinez
Circuits and Systems (CAS) Group
Delft University of Technology
Delft, The Netherlands
J.A.Martinez@tudelft.nl

4th Martin Møller
Acoustics & Research
Bang & Olufsen
Struer, Denmark
MIM@bang-olufsen.dk

5rd Richard C. Hendriks
Circuits and Systems (CAS) Group
Delft University of Technology
Delft, The Netherlands
R.C.Hendriks@tudelft.nl

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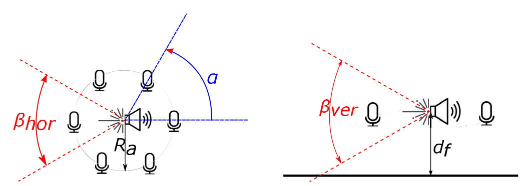
***Abstract*—Loudspeakers are usually placed in an environment unknown to the loudspeaker designers. Having knowledge on the room acoustic properties, e.g., the location of acoustic reflectors, allows to better reproduce the sound field as intended. Current state-of-the-art methods for room boundary detection using microphone measurements typically focus on a two-dimensional setting, causing a model mismatch when employed in real-life scenarios. Detection of arbitrary reflectors in three dimensions encounters practical limitations, e.g., the need for a spherical array and the increased computational complexity. Moreover, loudspeakers may not have an omnidirectional directivity pattern, as usually assumed in the literature, making the detection of acoustic reflectors in some directions more challenging.**

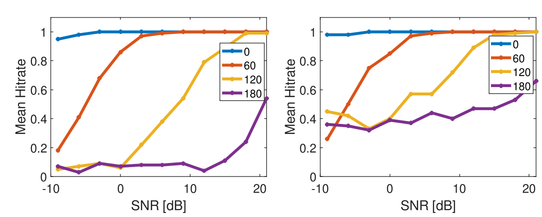
A smart loudspeaker system is considered, where a spherical microphone array is located on the loudspeaker as well as a computation module. It is possible to take advantage of the presence of other sensing modalities like LiDAR to detect walls more accurately. This could be done using point clouds that give direct depth information and can be used to detect planes.

In the proposed method, a LiDAR sensor is added to a smart loudspeaker to improve wall detection accuracy and robustness. This is done in two ways. First, the model mismatch introduced by horizontal reflectors can be resolved by detecting reflectors with the LiDAR sensor to enable elimination of their detrimental influence from the 2D problem in pre-processing. Second, a LiDAR-based method is proposed to compensate for the challenging directions where the directive loudspeaker emits little energy. We show via simulations that this multi-modal approach, i.e., combining microphone and LiDAR sensors, improves the robustness and accuracy of wall detection.



(a) (b)

Fig. 1. The loudspeaker is modelled as a directive point source located at the origin where the front is positioned at $\alpha = 0°$, i.e., in the positive horizontal direction. The LiDAR sensor is also located at the origin, but its front is directed towards the negative horizontal direction. We denote its Field-of-View (FOV) by $\beta_{\text{hor}} \times \beta_{\text{ver}}$. A UCA containing M microphones surrounds the loudspeaker and the LiDAR sensor at distance R_a. (a) Top view; (b) Side view.



(a) (b)

Fig. 2. (a) Acoustic reflector detection performance using acoustic information (Zaccà 2021) over 100 Monte -Carlo runs. For each angle α of the wall normal vector the mean hitrate is shown for several SNR values at fixed distance. (b) Acoustic reflector detection performance using the proposed method. For reflectors coinciding with the LiDAR FOV, i.e., at angles 120° and 180°, the detection rate at low SNR improves.