

Wireless group conversation enhancement with the Tympan open-source hearing aid platform

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Abstract—Hearing aids alone perform poorly in noisy environments. Wireless remote microphones worn by talkers can transmit low-noise, low-reverberation audio directly from the source to the listener’s device. However, current wireless microphones work with only one conversation partner at a time and they do not match the timing, spectrum, or spatial cues of the sound at the ears. This demonstration is a real-time implementation of an immersive multiple-talker wireless microphone system that uses adaptive filtering to align and mix the remote sources with the binaural sound at the hearing device earpieces, thereby preserving spatial awareness. This interactive demo, built on the Tympan open-source hearing-aid research platform, includes app-based controls to adjust the processing applied to each source.

1. APPLICATION AND PROBLEM SCENARIO

People with hearing loss often struggle to communicate in noisy and reverberant environments [1], such as a crowded restaurant [2] or a WASPAA poster session. Group conversations are especially challenging because the listener must divide attention between multiple participants, some of whom may interrupt or talk over one another [3], [4]. Most speech enhancement technologies [5], including beamforming, noise reduction algorithms, and remote microphones, are designed for one-on-one conversations with a single talker of interest. Technologies to enhance group conversations remain comparatively underdeveloped.

This demonstration showcases a wireless remote microphone system suitable for group conversations. Wireless assistive listening devices, such as theatrical broadcast systems attached to a venue’s sound system and personal remote microphones worn by a teacher, can reliably and dramatically improve intelligibility in noisy and reverberant environments by transmitting sound directly from the source to the listener’s hearing device [6], [7]. However, current devices are designed primarily for lecture-style lessons in classroom settings, with a single distant sound source of interest. They are less useful for close-range face-to-face conversations, especially with multiple participants.

The key technical challenge in developing remote microphones for close-range group conversations is to align the timing, spectrum, and spatial cues of each remote talker to the signals at the ear. Conventional remote microphone systems present signals diotically, so that it sounds like talking on a conference call with people sitting across the table. Humans rely on binaural cues like interaural time and level differences to localize and separate sound from different directions. These spatial cues are especially important for divided-attention tasks like a dynamic group conversation. For nearby talkers, it is also critical to temporally align the remote signal with that at the ears to avoid comb-filter distortion or perceptible echoes.

An immersive assistive listening system, illustrated in Figure 1, would combine the low noise and reverberation of remote microphones with the realistic spatial and acoustic cues of on-ear microphones.

2. KEY TECHNOLOGY

The demonstrated algorithm is a refined version of an adaptive binaural filtering algorithm first presented in a paper at WASPAA 2021 [8], which was held virtually and therefore did not provide an opportunity

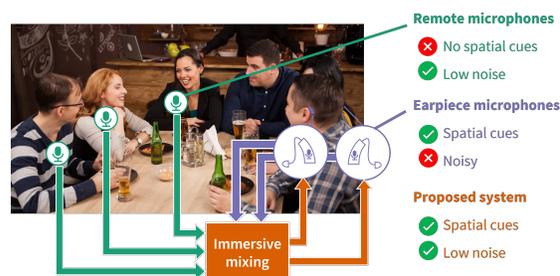


Fig. 1: An immersive assistive listening system combines the low noise and reverberation of remote microphones with the realistic spatial and acoustic cues of on-ear microphones.

for interactive demonstrations. Taking inspiration from the binaural beamforming literature (e.g., [9], [10]), the system uses the on-ear microphones as noisy binaural reference signals. A pair of adaptive filters processes each remote microphone signal to align with the timing and spectrum of the signals captured at the two ears. Essentially, the filters perform system identification to learn the early part of the binaural impulse responses for each source, which include the most important spectral and spatial cues but without harmful late reverberation. This preserves the listener’s spatial immersion, even during talker and listener motion. Notably, unlike in other proposed immersive remote microphone architectures [11], [12], the system does not need to explicitly estimate or track the talkers’ positions or the listener’s head orientation.

This alignment also allows the remote signals to be mixed seamlessly with the unprocessed earpiece signals, providing a tunable tradeoff between intelligibility and situational awareness. A few commercial hearing devices also allow remote microphone signals to be mixed with earpiece signals, but because the signals are not aligned, they create comb-filter distortion and/or echoes when the talker is too close to the listener. The demonstration includes a smartphone app allowing the user to individually adjust the levels of the remote microphones and the earpieces.

3. DEMONSTRATION EXPERIENCE

The WASPAA 2021 paper presented an offline experiment. This live demonstration, shown in Figure 2, has been implemented in real time on the Tympan open-source hearing-aid platform [13]. Developed by Creare as part of the NIH Open Speech Platform initiative, the Tympan allows researchers and hobbyists to quickly prototype and deploy new algorithms and evaluate them in ecologically valid real-world settings. The pocket-sized hardware supports up to four input signals, allowing the demonstration to combine two earpiece microphones and two remote microphones. The system accepts input from two analog wireless lavalier microphones, which were selected for their low transmission delay. Although the Tympan platform includes realistic hearing-aid earpieces, the demonstration uses easy-to-clean earbuds for hygiene purposes.

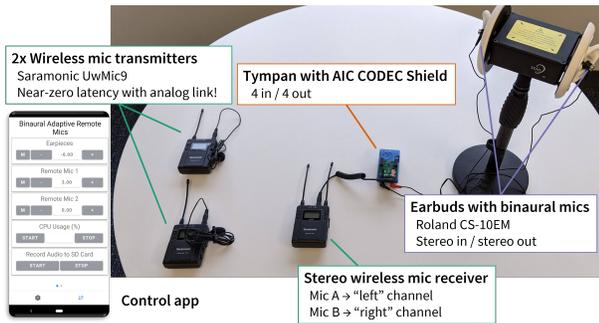


Fig. 2: The real-time demonstration is built around the Tympan open-source hearing research platform.

In the demonstration, one visitor wears binaural earbuds and listen to the device output while two others wear the lavalier microphones and talk. All three can move around to change the spatial cues and listen to the algorithm adapt in real time. The listener can use the smartphone app to adjust the relative levels of different sounds.

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