SHORT-PAPER

# Beyond Sound: The First Workshop on Intelligent Acoustic Sensing on Wearables



**Published:** 12 October 2025

**Citation in BibTeX format**

UbiComp '25:The 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing / ISWC ACM International Symposium on Wearable Computers
*October 12 - 16, 2025*
*Espoo, Finland*

**Conference Sponsors:**
SIGMOBILE
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UbiComp Companion '25: Companion of the 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing (October 2025)
https://doi.org/10.1145/3714394.3750574
ISBN: 9798400714771

# Beyond Sound: The First Workshop on Intelligent Acoustic Sensing on Wearables

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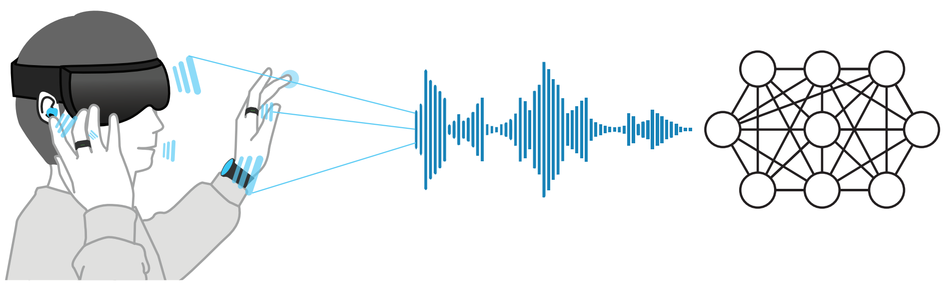

**Figure 1: Intelligent Acoustic Sensing and Interaction For Future Wearables**

## Abstract

Acoustic sensors are now integrated into nearly every wearable device, valued for their affordability, low power consumption, and unobtrusiveness. By design, microphones and speakers are traditionally used for speech interactions and sound playback, respectively. However, recent advancements in artificial intelligence, advanced signal processing, and high-fidelity compact sensors have enabled researchers in Ubiquitous and Wearable Computing and Human-Computer Interaction (HCI) to significantly expand the sensing capabilities of these acoustic components. They are now being repurposed as minimally obtrusive, low-power, and privacy-aware sensing units on wearables to capture high-quality information about users and their surrounding environments. This information can be intelligently interpreted for seamless interaction, contextual awareness, health monitoring, and activity recognition—highlighting the tremendous potential of acoustic sensing for the future of wearable technologies. To fully explore the opportunities and challenges of applying acoustic sensing in real-world applications in the age of AI, this workshop invites researchers and practitioners from academia and industry to share insights, identify key challenges, and discuss emerging developments in intelligent acoustic sensing and interaction technologies for everyday wearable devices. Through collaborative discussion and exploration, participants will address critical issues and propose innovative solutions to advance the field. Topics of interest include, but are not limited to, acoustic sensing system development, open-source tools and datasets, signal processing, AI-driven approaches, privacy concerns, deployment challenges, and novel applications.

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*UbiComp Companion '25, Espoo, Finland*

ACM ISBN 979-8-4007-1477-1/2025/10
https://doi.org/10.1145/3714394.3750574

## CCS Concepts

• **Human-centered computing → Interaction techniques**; *Ubiquitous and mobile devices.*

## Keywords

Acoustic sensing, Wearable devices, UbiComp, HCI

**ACM Reference Format:**
Jiwan Kim, Chi-Jung Lee, Xiaoran Fan, Dong Li, Edison Thomaz, Alanson Sample, Ian Oakley, and Cheng Zhang. 2025. Beyond Sound: The First

Workshop on Intelligent Acoustic Sensing on Wearables. In *Companion of the 2025 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp Companion ’25), October 12–16, 2025, Espoo, Finland.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3714394.3750574

## 1 Background

Sound is a rich and versatile sensing modality that captures speech, surface vibrations, environmental audio, and even inaudible ultrasonic signals, providing expressive insights into human activities and surrounding contexts. Speakers and microphones - the primary components for generating and capturing sound — are already widely integrated into everyday smart devices such as phones, tablets, smartwatches, and head-mounted displays (HMDs). This combination of rich acoustic signals and ubiquitous hardware has powered a growing body of work in Ubiquitous Computing (UbiComp) and Human-Computer Interaction (HCI), enabling a wide range of applications: from novel input systems [4, 5] and sophisticated gesture recognition [7, 12, 13] to accurate activity tracking [6, 11] and reliable health monitoring [3] across mobile, wearable, and Internet of Things (IoT) platforms.

Although the fundamental principles of acoustic sensing are well-established, recent advancements in Artificial Intelligence (AI) and hardware miniaturization have enabled acoustic sensing to support more challenging scenarios, such as health monitoring [3] and eye-tracking [9] on lightweight form factors such as wearable devices (e.g., smartwatches and smart glasses).

In general, acoustic sensing methods can fall into two categories. The first, ***passive acoustic sensing*** has enabled gesture input and context-aware interaction systems by analyzing naturally occurring airborne sounds [6, 10] or the contact sounds generated during user’s interaction with a device-surface [2], or their clothing [1] or body [13]. Since passive acoustic sensing does not involve the controlled emission of acoustic signals, it is often used for monitoring and interpreting natural acoustic events [6] or speech [1, 10] or to detect explicit actions, events, or gestures [13] that inherently generate acoustic signals. For example, Ubicoustics [6] introduced a real-time sound-based activity recognition system that utilizes microphones in consumer devices (e.g., laptops, smartphones). The system classifies 30 everyday activities across diverse environments (e.g., bathroom, kitchen, office, outdoor) by leveraging state-of-the-art sound classification models to enable general-purpose sound recognition.

In contrast, ***active acoustic sensing*** involves the deliberate emission of encoded acoustic signals and the analysis of their reflections or transmissions from surrounding objects. This approach, when paired with advanced signal processing and AI algorithms, has unlocked a broad range of applications on wearables without additional hardware instrumentation, including pose estimation [7, 12], activity tracking [11], input techniques [4, 5], silent speech recognition [14], and even eye gaze tracking [9]. These techniques have been showcased on diverse wearable platforms, such as wrist-wearables [4, 5, 7], glasses [9, 11], rings [12], and headphones [14]. For instance, EchoWrist [7] introduced a low-power wristband that emits inaudible sounds toward the hands and analyzes the reflected signals using deep learning classifiers to continuously estimate 3D hand poses and recognize hand-object interactions. Active acoustic sensing techniques typically leverage inaudible acoustic signals to minimize interference with human speech and environmental sound and, furthermore, address privacy concerns by filtering out low-frequency audible content. Recently, researchers have deployed such systems on the built-in speakers and microphones in commercial wearable devices [4, 5], eliminating the need for additional hardware to implement active acoustic sensing solutions.

Given the broad applications and adaptability of acoustic sensing on wearables, this technology holds significant promise for advancing interaction and understanding human activities in the future of intelligent wearables in real-world applications. As the field continues to evolve, addressing practical considerations will further unlock its potential for robust, efficient, and user-friendly real-world integration. For example, Li et al. [8] identified key factors to optimize for real-life adoption, such as audible sound leakage, negative impact on music listening or voice calls, and impact of device movements on performance. Additionally, privacy concerns, such as unintentional sound capture and the need for privacy-preserving techniques in acoustic data processing, must be carefully addressed. In this context, it is important to discuss the fundamental, practical, and experimental challenges of acoustic sensing, as well as future directions for its real-world applications, with UbiComp and HCI researchers and practitioners.

Building on these opportunities and challenges, this workshop will focus on, but is not limited to, the principles of acoustic sensing, systems, signal processing, AI applications, privacy concerns, and the associated challenges and considerations. The following topics will be featured:

- Acoustic sensing system development, including prototyping or implementing hardware and software to generate or capture acoustic signals for both active and passive sensing for wearable devices.
- Open-source tools and datasets for acoustic sensing, including publicly available datasets, frameworks, and benchmarking resources to facilitate the community to evaluate and develop customized interactive acoustic sensing techniques.
- Signal processing for acoustic signals, covering techniques for generating, filtering, augmenting, and analyzing sound data to support HCI and wearable computing applications.
- Artificial intelligence for sound data, encompassing processing algorithms, feature extraction methods, and model design for deep learning- or machine learning approaches to enable novel acoustic sensing on wearables (e.g., designing foundation model).
- Privacy considerations in acoustic sensing on everyday wearables, addressing challenges related to data security, user consent and perception, unintentional sound capture, and privacy-preserving techniques to ensure ethical and responsible adoption of acoustic sensing in real-world applications.
- Challenges and constraints in acoustic sensing systems, including fundamental hardware and software limitations (e.g., limited memory and battery constraints on small wearables, such as watches and glasses), environmental (e.g., background noise) and mobility constraints (e.g., walking), and practical challenges in a real-world implementation.
- Applications of acoustic sensing systems, covering existing use cases of passive and active acoustic sensing techniques,

as well as emerging opportunities for their integration into novel interactive systems.

# 2 Workshop

## 2.1 Objectives

This workshop provides a platform for researchers from both academia and industry to discuss the development of acoustic sensing systems for wearable devices, with a focus on fundamental, practical, and experimental aspects. The key objectives include: Advancing techniques, addressing key challenges and considerations, fostering collaboration and innovations, and promoting open-source resources for acoustic sensing and wearable interactions.

## 2.2 Pre-Workshop Plans

*2.2.1 Attendees.* We anticipate an interactive workshop with 20 to 30 attendees from both academia and industry. We will ensure broad participation via targeted outreach: mailing lists, social media, and a workshop website. We will also leverage our professional networks to directly engage potential attendees. We extend a warm welcome to all conference attendees to participate in workshop sessions, creating an inclusive and collaborative environment.

*2.2.2 Paper Submission.* To facilitate a robust exchange of insights, we invite participants to submit short papers formatted according to the ACM double-column UbiComp-ISWC 2025 Proceedings. We encourage submissions in one of the three formats: 1. Position papers (up to four pages, excluding references and appendices) presenting perspectives, challenges, or visionary ideas, 2. Research proposals (up to four pages, excluding references and appendices) outlining ongoing or planned research, including preliminary findings or demonstrations, 3. Research Papers (up to six pages, excluding references and appendices) presenting mature research findings or well-developed concepts. Submissions should address key aspects of acoustic sensing on wearable devices, including but not limited to: acoustic sensing system development, open-source tools and datasets, acoustic signal processing, AI for acoustic data, challenges and considerations, and application case studies.

A peer review process will be conducted by a dedicated program committee. Each submission will undergo a single-blind review by two committee members. All submissions will be managed through the Precision Conference System (PCS). Accepted papers will have the option to be published in the ACM Digital Library (DL) and the Adjunct Proceedings, ensuring a broad distribution of the workshop's contributions.

*2.2.3 Outreach Website and Discord Community.* A workshop website [1] will be developed to serve as the primary source of information. This website will be the central hub for all workshop-related details, including the detailed agenda, call for papers, speaker biographies, registration procedures, and contact information.

To foster a sustained connection among all the attendees and the broader community, we will create a dedicated Discord server. All registered participants will be invited to join this server, enabling communication and networking. This will allow participants to introduce themselves, exchange ideas, and begin building relationships. During the workshop, the server will serve as a dynamic space for real-time announcements and discussions.

[1] https://www.beyond-sound.org

## 2.3 Workshop Structure

We propose a full-day workshop, including talks, paper presentations, and discussions to innovate the development of acoustic sensing systems on wearable devices.

*2.3.1 Opening.* The workshop will begin with an opening session led by one of the organizers, Prof. Cheng Zhang, who has a strong record of publishing papers on acoustic sensing systems on wearable devices. This session aims to foster a shared understanding of the field's potential, engaging existing researchers, providing an introduction for those new to the field, and ensuring the workshop's content is both informative and inclusive.

*2.3.2 Keynote.* We will feature one or two exceptional keynote speakers, each with extensive experience in the field. They will share their invaluable insights, aiming to inspire innovative research directions, foster a deeper understanding of the technology's potential, and contribute to the field's growth.

*2.3.3 Paper Presentation.* To highlight the latest contributions to the field, we will feature presentations from authors of selected papers. This session will serve as a crucial platform for promoting recent research findings. Each presentation will be followed by a Q&A session, providing attendees with an opportunity to engage directly with the authors. It is also expected to foster discussion, ultimately driving further innovation.

*2.3.4 Group Discussion.* Group discussions are designed to investigate the diverse aspects of the field. Each group will concentrate on specific thematic areas, allowing for focused problem-solving and idea generation. To begin, we will provide a selection of pre-defined topics, but participants are invited to propose additional areas of interest. We anticipate that these focused discussions will lead to the development of new concepts and collaborative insights.

*2.3.5 Panel Discussion.* The workshop will conclude with an expert panel discussion where panelists will answer audience questions and share insights on the field's current state and future directions. This session offers attendees a valuable opportunity to engage directly with leading professionals and participate in a final discussion summarizing key themes from the day.

## 2.4 Post-Workshop Plans

*2.4.1 Open-Access Paper Materials.* To maximize the impact and reach a broader audience, we will make the selected papers and corresponding presentation videos openly accessible on our website. Furthermore, we strongly encourage the authors to share supplementary materials, such as toolkits, datasets, and demonstration videos, to further enhance the reproducibility and practical application. This will serve as a valuable asset for people in the field.

*2.4.2 Discord Community.* Recognizing the importance of continued collaboration and knowledge exchange, we encourage participants to maintain active engagement on the Discord server. This platform will serve as a persistent community hub, enabling participants to share research updates, seek technical support, and initiate collaborative projects. We aim to strengthen the network of people in the field, facilitating long-term advancement.

*2.4.3 Long-Term Vision.* To ensure the continued impact, we will seek participant feedback to identify areas for improvement and enhance future workshops. Our vision is to make this workshop an annual event, providing a consistent platform for idea sharing and the cultivation of a thriving community dedicated to acoustic sensing on wearable devices. We aim to build a sustainable and influential forum that contributes to the advancement of this field.

## 3 Organizers

**Jiwan Kim** is a Ph.D. student at the School of Electrical Engineering at KAIST. His research focuses on enabling expressive and seamless interaction on wearables using around-device sensing. His recent works are drilling down into how academic acoustic sensing techniques can actually be applied to real-world consumer hardware.

**Chi-Jung Lee** is a Ph.D. student in Information Science at Cornell University. Her research explores wearable sensing technologies that facilitate natural interaction. Her recent work focuses on understanding interaction contexts through acoustic sensing on wearable devices.

**Xiaoran Fan** is a Research Scientist at Google. He is working on building novel health and safety features for the consumer hardware lines at Google (Pixel phone, watch, buds). Xiaoran is an experimentalist and system builder. He is enthusiastic about real-world-experiment-driven research.

**Dong Li** is an assistant professor of the Department of Computer Science and Electrical Engineering at the University of Maryland Baltimore County (UMBC). His research focuses on exploring cost-effective and widely-accessible sensing systems for mobile and IoT devices to revolutionize ambient intelligence in health monitoring and human-computer interaction.

**Edison Thomaz** is an associate professor and William H. Hartwig Fellow in the Chandra Family Department of Electrical and Computer Engineering at The University of Texas at Austin, where he directs the Human Signals lab. His research focuses on human-centered sensing and machine perception using wearable and ubiquitous technologies.

**Alanson Sample** is an Associate Professor in the Electrical Engineering and Computer Science department, where he leads the Interactive Sensing and Computing Lab. His research interests lie broadly in the areas of Human-Computer Interaction, Cyber-Physical Systems, and wireless technology.

**Ian Oakley** is a full professor at the School of Electrical Engineering at KAIST in South Korea, where he directs the Wearable and Interactive Technology Lab. His research focuses on the design, development, and evaluation of wearable, mobile, and interactive technologies.

**Cheng Zhang** is an Assistant Professor in Information Science and Computer Science at Cornell University, where he directs the SciFi Lab. His research focuses on integrating human-centered AI with advanced sensing technologies to empower everyday wearables in comprehending human behavior in real-world environments, with the goal of better-supporting users.

### 3.1 Program Committee Members

The Program Committee (PC) members represent a set of distinguished experts in the area of acoustic sensing and wearable technologies, including, in alphabetical order: Dawei Liang (UT Austin), Hyunchul Lim (Cornell University), Ke Sun (University of Michigan), Rajalakshmi Nandakumar (Cornell University), Riku Arakawa (Carnegie Mellon University), Ruidong Zhang (Cornell University), Shirui Cao (UMass Amherst), Yasha Iravantchi (University of Michigan), Yuki Kubo (NTT Corporation), and Zhanpeng Jin (South China University of Technology).

## Acknowledgments

This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support program(IITP-2025-RS-2024-00436398) supervised by the IITP(Institute for Information & Communications Technology Planning & Evaluation) and the U.S. National Science Foundation under Grant No. 2239569.

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