SonoRo: A Swarm Robotics Platform to Study Acoustically-Driven Collective Behaviour

Alberto Doimo[1,2,3](✉), Heiko Hamann[2,4], Andreagiovanni Reina[2,3,4], and Thejasvi Beleyur[1,2,3]

[1] Active Sensing Collectives Lab, Department of Biology, University of Konstanz, Konstanz, Germany
[2] Centre for the Advanced Study of Collective Behaviour, University of Konstanz, Konstanz, Germany
[3] Department of Collective Behaviour, Max Planck Institute of Animal Behavior, Konstanz, Germany
[4] Department of Computer and Information Science, University of Konstanz, Konstanz, Germany

{alberto.doimo,heiko.hamann,andreagiovanni.reina, thejasvi.beleyur}@uni-konstanz.de

Acoustic signals play a significant role in swarm coordination among animals, enabling individuals to interact and organise collectively. Many acoustically mediated animal collectives (bat swarms, bird flocks, frog and insect choruses) are naturally tolerant, and even robust, to temporal and spectral overlap [2]. In contrast, mobile robotics has mainly relied on specialised hardware such as cameras or radio transceivers that are simultaneously computationally and data intensive.

The SonoRo swarm robotics platform is focussed on developing sound-based coordination without the need for explicit spectral or temporal partitioning and investigates how agents can interpret the complex sounds in groups to show collective behaviour. We designed and implemented SonoRo by combining off-the-shelf, low-cost hardware components and open-source lightweight software, suitable for onboard applications on small, mobile robots. We use the Thymio II robot as a mobile base equipped with a Raspberry Pi 4B, an array of microphones, and a speaker. This setup allows compatibility with Python and enables SonoRo to interact with other agents by alternating the emission of a chirp with a listening phase. During the listening phase, the robot records the incoming audio, which is used to calculate the Direction of Arrival (DoA) using the Delay-And-Sum algorithm. The DoA algorithm returns an egocentric distribution of the sound source directions over the azimuth.

We showcase SonoRo's basic capabilities in environmental awareness, neighbour detection, and spatial target localisation through experiments in four distinct scenarios: collision avoidance with static sound sources, goal finding in a static environment, multirobot aggregation, and multirobot dispersion. Results are discussed in Fig. 1. Videos of all experiments are available at [3]. Our results with three robots demonstrate reliable collective behaviours in aggregation and dispersion tasks, indicating that SonoRo is a promising platform

R. Groß et al. (Eds.): ANTS 2026, LNCS 16515, pp. 496–497, 2026.
https://doi.org/10.1007/978-3-032-26123-6

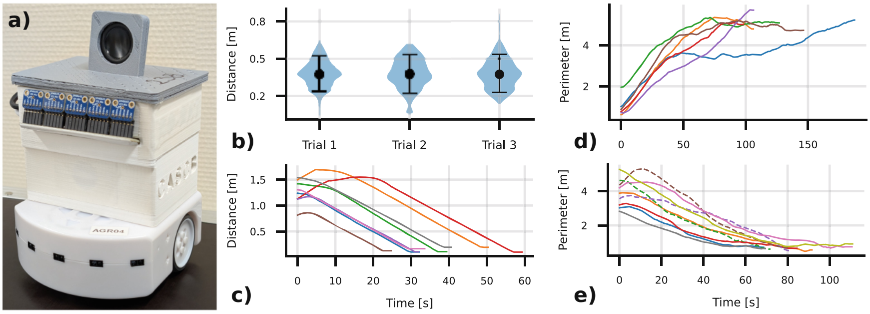

Fig. 1. (a) The SonoRo robot. (b) Results from a single SonoRo performing sound obstacle avoidance. The violin plots quantify performance as the distance to the nearest loudspeaker, showing with the mean value as a black dot and the 10th and 90th percentiles as whiskers. (c) Results from a single SonoRo reaching a loudspeaker goal are shown as the distance between the centre of the robot and the loudspeaker. (d-e) Results from three robots dispersing (panel d) and aggregating (panel e) in space are shown as the perimeter of the convex polygon connecting the three robots.

for swarm robotics research. Unlike other previous sound-based approaches to swarm robotics [1, 4], our novel contribution lies in demonstrating attraction and repulsion using acoustic signals without any form of temporal or spectral partitioning. The robustness to temporal overlap caused by the homogeneous nature of the swarm is a novel feature that allows on-the-fly scaling of group size. Our study indicates that acoustic signalling provides a fast and low-cost coordination modality for robot swarms, particularly useful in challenging conditions such as GPS-denied, low-light, or visually cluttered environments.

Acknowledgments. We acknowledge funding from the Carl-Zeiss-Stiftung, the Deutsche Forschungsgemeinschaft (DFG) under Germany's Excellence Strategy – EXC 2117-422037984, and the DFG's Walter Benjamin program - 502056951.

Disclosure of Interests. The authors have no competing interests to declare.

References

1. Basiri, M., Schill, F., Lima, P., Floreano, D.: On-board relative bearing estimation for teams of drones using sound. IEEE Robot. Autom. Lett. **1**(2), 820–827 (2016)
2. Bee, M.A., Micheyl, C.: The cocktail party problem: what is it? How can it be solved? And why should animal behaviorists study it? J. Comp. Psychol. **122**(3), 235–251 (2008)
3. Doimo, A.: SonoRo: a swarm robotics platform to study acoustically driven collectives behaviour (2025). https://doi.org/10.5281/zenodo.17664282
4. Tsunoda, Y., Nghia, L.T., Sueoka, Y., Osuka, K.: Experimental analysis of shepherding-type robot navigation utilizing sound-obstacle-interaction. J. Robot. Mechatron. **35**(4), 957–968 (2023)