

|  |  |  |
| --- | --- | --- |
| Pilot Projects Final report | | |
| **Call round: 1** | | |
| **Pilot Project Title:** Bioacoustic monitoring using drones | | |
| **PI:** Dr Lin Wang | **Research Organisation:** Queen Mary University of London | |
| **Department:** School of Electronic Engineering and Computer Science | **Start Date:** 1 April 2020 | **Duration:** 10 months |
| **Cost of award (80%):** £46,820 | **Value of co-investment:**  **In kind:**  **Cash:** | |
| **Co-I and associated RO:** Dr Axel Rossberg, Queen Mary University of London | **Acoustic Research themes:** Bioacoustics | |
| **Collaborations & Partnerships involved in project:** Two non-academic partners were involved in the project. They contribute to the project in the form of consultation and discussion. | | |
| **Project Partners:** Ecology Services UK Ltd, Bat Conservation Trust | | |
| **Value and details of in-kind co-investment: £10k**  Ecology Services UK Ltd: in-kind contribution in the form of consultation and discussion, £5k  Bat Conservation Trust: in-kind contribution in the form of consultation and discussion, £5k | **Value and details of cash co-investment: 0** | |
| **Summary:** A summary that can be published on our website (please do consider providing photo/images)  Wildlife population monitoring is a major challenge in the context of global biodiversity loss. With the capability of flying over hard-to-reach terrains, drones promise solutions to such monitoring problems. This project conducts pilot research to investigate the potential of using drones for monitoring acoustically active species, such as birds and bats. A major obstacle to address will be the ego-noise generated by the rotating motors and propellers, which leads to extremely low signal-to-noise ratio at airborne microphones if the drone captures wildlife vocalization from a large distance. The project aims to develop a drone audition prototype system for bioacoustic monitoring and address the challenging ego-noise suppression problem. The project has three objectives. 1) To develop a hardware prototype that captures environmental sound with an audio recorder carried by a quadcopter drone; 2) to collect wildlife vocalization dataset with the developed prototype; and 3) to develop wildlife species detection and identification algorithm in the presence of ego-noise. The project is led by Dr Lin Wang and Dr Axel Rossberg from Queen Mary University of London, and collaborated with Ecology Services Uk Ltd and Bat Conservation Trust. | | |
| **Objectives:**  The project aims to develop a drone audition prototype system for bioacoustic monitoring and address the challenging ego-noise suppression problem. The project has three main objectives. 1) To develop a hardware prototype that captures environmental sound with an audio recorder carried by a quadcopter drone; 2) to collect wildlife vocalization dataset with the developed prototype; and 3) to develop wildlife species detection and identification algorithm in the presence of ego-noise. | | |
| **Outcomes/Impact\*:** Please refer to stated objectives. What impact has this had on the Acoustics Sector? How are the results being applied? Please provide specific examples/evidence to support the provided statements.  The research outcome of the projects consists of five deliverables, which are related to the acoustic sectors of bioacoustics, acoustic sensors, and aeroacoustics.  D1 - Hardware prototype. Two hardware prototypes were developed for bird sound recording from a flying drone platform. The first prototype suspends a microphone underneath the drone with a long rope; the second prototype fix a microphone underneath the drone body. A shotgun microphone pointing downwards is used to collect the bird call from the ground and to reject the ego-noise from the ego-noise from the off-axis.  The two hardwares are both ready for data collection in real environments. The first prototype has better noise suppression capability while the second prototype has better maneuverability.  Fig. 1(a) Prototype 1: a microphone suspended below the drone with a long rope.  Fig. 2(a) Prototype 2: a microphone fixed underneath the drone.    D2/D3 – Dataset collection. A simulated dataset was recording with the first prototype, with the auditory drone hovering at different altitudes, varying at from 5 meter to 30 meter, with an interval of 5 meter. A loudspeaker on the ground emits bird call sound, which is precisely annotated for evaluating bird recognition performance. A 10-minute recording was collected at each hovering location. The total duration of the recording is 60 minutes. The simulated dataset is used to validate the performance of the bird recognition algorithm in presence of ego-noise. Due to the bad weather in the winter and the delay of the hardware production and testing, onsite recording in natural environments will be postponed to April/May 2023.  D4 – The bird recognition algorithm for noisy recordings. A baseline deep-learning algorithm was developed, which from the 5-second clean sound can recognize 80 bird species with an accuracy of 60%, and recognize 20 bird species with accuracy of 75%. A testing signal from the 20 birds was constructed from the correctly recognized audio segments, and used for simulated dataset recording in D2. The baseline algorithm achieves 100% accuracy for the testing signal, and the performance drops significantly in the presence of the ego-noise, e.g. 50% accuracy at a drone hovering altitude of 15 meter. A noise augmentation algorithm was developed that can improve the bird recognition performance remarkably from the noisy recording. The developed algorithm achieves recognition accuracy of 85% at altitude 5 meter, and slightly drops to 75% at altitude 30 meter (Fig. 3). The result is promising, considering in the original proposal we target a detection accuracy that is comparable with clean recordings when the drone is 30 meters away from the ground.  Fig. 2 Bird recognition performance by the baseline model (left) and the noise-augmented model (right) at different drone hovering altitude. | | |
| **\*What activities have you undertaken to engage with research users, special interest groups and the general public to inform them about the research?**  Public engagement activity: The PI and CI participated in the QMUL sustainability week, and introduced to public the use of auditory drones for bird call monitoring in the biodiversity walk event, on 17 and 19 October 2022. (https://www.qmul.ac.uk/about/sustainability/sustainability-week/)    Academic engagement activity: The PI attended the Quiet Drones Seminar in June 2022 (https://www.quietdrones.org/conferences/2-quiet-drones-2022/), introducing the auditory drone techniques to researchers. | **\*Have any new research tools or methods been created or commissioned, if so, provide details: -**  1. New research tools: the hardware prototype for bird call monitoring from the drone.  2. New method: the noise-augmentation algorithm for bird recognition from the noisy recording. The proposed algorithm outperforms the baseline algorithm remarkably in extremely low-SNR scenarios.  3. New method: the ego-noise prediction algorithm from the flight behaviour of the drone. The algorithm is initially prototyped and will be validated in the future. | |
| **\*What activities have you undertaken to engage with research users, special interest groups and the general public to inform them about the research?**  NA | **\*Have any new research datasets, databases and models making, or potential to make, significant difference to your research (or that of others), been created, if so, provide details: -**  1. A simulated dataset recording. The bird call is emitted from the ground loudspeaker and recorded with the hardware prototype at a varying altitude of up to 30 meters. The dataset will be released with the publication.  2. Onsite recording. The recording is planned to be completed in April/May. We plan to organize a dataset challenge before making it open-access. | |
| **Conclusion:** What is the primary outcome of this research?  The project combines hardware and software solutions for drone-based bioacoustic monitoring and address the challenging ego-noise suppression problem. The hardware prototype consists of a shotgun microphone suspending below the drone, and can suppress the ego-noise to certain degree. A proposed noise-augmentation algorithm can further improve the bird recognition accuracy in the presence of the ego-noise. Simulated recording with the hardware prototype achieves comparable results between the clean sound and the recording distance of 30 meters. This demonstrates the feasibility of the using drones for monitoring bird call bioacoustically without disturbing the wildlife species too much. | | |
| **Plans for follow-on activities/grants:** How are these results being used to further the area of research or its application in an industrial setting?  1. We submitted an outline bid (Sustainable Biodiversity Research Institute, £7.5M) to “Expanding Excellence in England (E3) fund” in February 2023 (https://www.ukri.org/opportunity/expanding-excellence-in-england-e3-fund-round-2/), using the UKAN+ project as an important use case. A full proposal will be developed upon the success in the outline stage, which will be informed in May 2023.  2. Based on the research outcome, we plan to prepare a full proposal to be submitted to NERC. The proposal will be about autonomous biodiversity data collection and analysis by combining new acoustic sensor technology and artificial intelligence. | | |
| **Weblink:** (to the outcome of the project, the Open Access repository for the data[[1]](#footnote-1), or press releases):  The dataset produced by the project will be made open access together with the publication. | | |
| **List of publications:** in peer reviewed or non-peer reviewed literature. If no publications are available, what are the plans to publish? Please follow UKRI guidelines for Open Access [**https://www.ukri.org/manage-your-award/publishing-your-research-findings/**](https://www.ukri.org/manage-your-award/publishing-your-research-findings/)  Two research articles are currently under preparation and will be submitted soon.  1. Title:  Content: describing software design of the system  Target venue: Methods in Ecology and Evolution, Scientific Reports  2. Title: A sound acquisition system for UAV bird call monitoring  Content: describing hardware design of the system  Target venue: Remote Sensing in Ecology and Conservation,  Future publication plan  3. Ego-noise prediction algorithm.  4. A paper on on-site dataset collection. | | |

1. As a UKRI award holder you must follow their research data policies- <https://www.ukri.org/manage-your-award/publishing-your-research-findings/making-your-research-data-open> [↑](#footnote-ref-1)