DOI: 10.61782/fa.2023.0402

forum acusticum 2023

Region-wide Environmental Noise Monitoring in Flanders through Citizen Science: Protocol to Integrate Surveys and Measurements

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ABSTRACT

Within the Program for Innovation Procurement, the Flemish government is investing in innovative methods to answer numerous societal challenges. With support of this program the Department of Environment will develop a region-wide noise monitoring protocol in a two year project, started in April 2023. To achieve this, Ghent University partnered up with Scivil, the knowledge center for Citizen Science in Flanders. The noise monitoring question fits in an environmental noise indicator evaluation designed by the Ghent University in 2019-2020. This manuscript gives an overview of the project outline. We discuss the goals, the methodology, the technical implementation and the dataflow. We explain the strategy to include citizens to achieve both the societal and the scientific goals. Since this is a government funded project, the societal aspects have priority. The first component is the technology: hardware, quality, calibration, noise surveys, event classification, privacy and data storage. The second component is the citizen engagement: how to achieve the data collection at a reasonable cost? The third component is the sampling strategy: how to reach an unbiased dataset for multiple variables: spatial characteristics, sources and population? The last component deals with applications: trends in population exposure and perception. This protocol will provide matched exposure and perception data at an unprecedented scale.

Keywords: *noise monitoring, citizen science, population based sampling, noise sources*

1. INTRODUCTION

Traditionally, environmental noise evaluations in Flanders are performed within the overall environmental reporting MIRA, organized by a government organization managing water quality and air pollution. In 2019-2020, an extensive evaluation of the noise indicators in this environmental report was performed [1], and a trajectory was presented to improve the quality and sustainability of these long-term noise indicators. The implementation path is found in a program of the Flemish government aiming at investigating innovative methods to answer societal challenges (see www.innovatieveoverheidsopdrachten.be/en/projects/ambient-noise-flanders, referred to as PIO).
This renewed momentum for noise exposure evaluation in Flanders resulted in an innovative PIO project called "Ambient noise in Flanders". The program started with a market consultation within the noise field and a preparatory stage listing potential projects, applications and general conditions for quality control. Two PIO projects were

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defined: (1) a sleep study protocol including indoor and outdoor measurements with on-body motility and (2) a population based noise exposure protocol based on citizen science approaches. The sleep study project ends in July 2023 and a preliminary version of the protocol is presented at ICBEN 2023 (no reference available at paper submission). The population based project started on April 1st 2023 and ends on March 31th 2025. This publication will shortly introduce the aims and approach of the second project.

Ghent University is responsible for the technical component and the noise reporting. They have extended experience in this field [2]. Scivil is the Flemish knowledge center for citizen science. They will test the methods to engage the public to participate in the data collection. The Flemish government is closely involved as funder and as technological partner. They provide the IoT infrastructure to collect, store and report the data. The main aim is to collect data on a regular basis to provide time series of population based noise exposure. The schedule of the repeated measurements and a full roll-out is not determined yet and will depend on its cost effectiveness.

2. MATERIAL AND METHODS

2.1 Noise monitoring hardware

The goal of the noise monitoring is to collect outdoor sound pressure levels. The noise monitoring unit is based on an open source development performed by Makerspace-Antwerpen with the project 'Klankentappers' by Imec[1]. The hardware components are a raspberry pi 3 and a MEMS (Infineon IM6D130). The software is available on github [2].

In the design process of the sleep study protocol, the raspberry pi 3 and 4 proved to be incapable for the task ahead. A different hardware platform namely Asus Tinkerboard S R2.0 – compatible with the Raspberry pi - was selected to improve functionality [3]. The Tinkerboard has native I^2S and is available with internal storage with higher read/write speeds and longer lifetime compared to the SD cards used in the Raspberry pi configuration. The development of the sensor for the sleep study will be adjusted to a single microphone setup for outdoor measurements. The setup will be extended with a GNNS module to provide accurate position data.

2.2 Noise surveys

Next to the physical exposure measurements, the citizens will be asked to fill in a general noise survey. This survey is aligned with the repeated questionnaires performed every five years by the Flemish Government over the whole region. This survey is also a fundamental component in the historical and revised noise indicator framework mentioned in the introduction [1]. The government has a tool available to organize the survey though a mobile interface.

2.3 Data platform and workflow

The Flemish Government is currently activating a general purpose IoT data platform. One of the requirements of the project is to implement the data collection through the platform. The chosen technology is Thingsboard and the collected data is transferred to an underlying database for further reporting and analysis. The noise monitor is equipped with network connectivity, thus providing online results.

2.4 Measurement equipment and instructions manual

The volunteers of the project will receive a box with the measurement equipment and an instruction manual. This approach has been successfully tested in the sleep study protocol with teenagers. The positioning of the noise monitor will be more flexible compared to the sleep study protocol. Measurement locations will not be limited to front façade or bedroom windows. The data collection aims at general exposure assessments and therefor monitoring will take place not only at facades but also in backyards, parks, public areas etc. This will require a good meta-dataset on the actual positioning of the monitoring equipment. Citizens will provide distances to road side, height, distance to façades etc. This data will be highly relevant for the reporting in various applications.

2.5 Dashboards and reports

Both data users and citizens will require data visualizations. The data users will build and evaluate the applications. The dashboards for the individual measurement locations will be a major incentive for the citizens to collaborate. A significant effort will be required to provide meaningful information for single measurement points and collective exposure information. Regular campaign-wide reports will be used as support for future policy.

[1] https://www.imec.be/nl/articles/hackable-city-things-brengt-stadsgeluiden-kaart

[2] https://github.com/Makerspace-Antwerpen/klankentappers

[3] https://tinker-board.asus.com/product/tinker-board-s.html

3. DATA COLLECTION THOUGH CITIZEN SCIENCE

3.1 Activate the equipment

The main challenge in large monitoring campaigns is the reduction of the cost to deploy the equipment. Citizen science is a potentially interesting way to realize this. Once an easy-to-use protocol is developed, the equipment has to find its way to the public. The measurement points also have to fit the main goals of the intended applications. The application requirements will be considered while selecting users and volunteers.
A preliminary list of potential actors and methods for recruiting citizens is listed below:

- Open call through social media
- Citizen initiatives
- Schools
- Libraries
- Local governments
- Regional government
- Road agency

3.2 Piloting through sub-projects

Within this project, a set of distribution principles and methods will be tested in so-called 'sub-projects'. Each sub-project will test a typical distribution model. The approach can be 'hub-like', with a central point of access or 'chain-like'.

3.3 Stakeholders

A large set of potential stakeholders will be included in the project. Some will be asked to support a sub-project, others will be included in the communication of intermediate results. In this way, a support base is established to facilitate an efficient roll-out at the end of the protocol building (as of 2025). Special attention will be given to motivations for citizens to engage in the project to ensure a wide interest in the project [9].

4. APPLICATIONS

4.1 Population based exposure

The main application of this protocol is – as mentioned – a population-wide noise assessment, part of the noise indicator set of the Flemish government [1]. To achieve this, the potential measurement points will be evaluated across several variables. The initial selection criterion is noise-source based. We will collect data for all relevant combinations of noise sources and acoustic settings: distances to highways and main roads, land-use, built-up areas, railway, aircraft, public transport, industry etc. At the noise monitoring points, survey data will be available which will result in a unique combined dataset. Spatial evaluations will enable land-use regression models to predict and extrapolate real-life noise exposure, noise annoyance and sleep disturbance for the entire population. Examples of these techniques are available in literature [3-6].. In addition, the data collection will aim at including all socio-economic classes. Social injustice in environmental exposure is currently a topic of high relevance [7]. The citizen science component will be used to address and include minorities which might be difficult to activate with the standard communication channels.

4.2 Local initiatives and intervention studies

The sub-projects the possibilities to deploy the equipment is tested in more specific contexts. Local stakeholder groups working on noise exposure could use this equipment to assess local noise issues. Local governments can use the equipment to evaluate interventions and include citizen support in their projects.

5. CONCLUSION

In this paper, a project is introduced preparing the deployment of a measurement campaign to assess environmental noise exposure and noise annoyance in Flanders. The protocol will allow repeated measurement campaigns to study population based exposure trends in Flanders, as part of the renewed noise indicators framework. The measurements go beyond the current state-of-the-art by including noise surveys at each measurement location. For the latter, dedicated low-cost but still accurate equipment will be developed, allowing for an easy installation by the citizens themselves. To achieve large-scale and cost-effective deployment, citizen science techniques will be used to select and encourage citizens to participate. A significant effort is made to collect unbiased data for noise sources, population density and socio-economic status. The minimized operational cost for the government will enable large scale deployment. The technical setup will be available for any future noise monitoring project in a governmental context.

6. ACKNOWLEDGMENTS

We want to thank the Flemish government for funding this project (OMG_VPO_2022_019).

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