DOI: 10.61782/fa.2025.0938

FORUM ACUSTICUM
EURONOISE 2025

UNLOCKING THE POTENTIAL OF OPEN RESEARCH SOFTWARE IN ACOUSTICS: LESSONS LEARNED FROM THE NANTES WORKSHOP

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ABSTRACT

In acoustics, there is a growing collection of research tools that are shared as open source software, that is, free to use, modify, and redistribute according to the respective license of the project. Such software is valuable because it can accelerate science through availability, comparison, and development, foster collaboration in science, and attract industry interest. Despite its potential, open source research software is not yet widely recognized as an essential research output within the acoustic community. During the 2024 workshop in Nantes, participants exchanged information and ideas on this topic and examples of four open source software were presented. The motivations, expectations, experiences, and practices of the participants regarding open source software were captured in a live questionnaire, and the discussions of the workshop were recorded in a collaborative online document. This work presents the results of this workshop. The shared view is that to further develop open source software in the acoustics community, several aspects are important and need attention, of which collaboration and time commitment are prominent.

Keywords: *research software, open science, community*

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1. INTRODUCTION

Research software can be highly valuable. It can increase the quality of science, increase the transparency in science, enhance research reproducibility, leverage the usage of software and collaboration, and accelerate industrial uptake. In short, research software may have an impact on science as well as society. In the acoustics community, open source software, that is, freely shared research software that can be modified and redistributed [1], is still in its infancy. This results in untapped impact potential and limited use, collaboration, and spin-offs from existing software. Three primary barriers that contribute to this situation can be observed [2]:

- Lack of incentives and recognition for research software;
- A long-standing culture of not sharing software;
- Insufficient training on best practices for sharing research software.

Fortunately, there are an increasing number of developments to overcome these barriers. For example, it has become relatively easy to share, curate, and collaborate on research software in version-controlled forms, such as GitHub [2], and journal articles can be written about software, for example, in the Journal of Open Source Software [3]. The latter means that the recognition of open source research software is gaining shape. With regard to training, national research software insti-

[1] Open source is one of the six principles of the open science movement [1]
[2] https://github.com
[3] https://joss.theoj.org

tutes, such as the Software Sustainability Institute [4], the Nordic e-Infrastructure Collaboration [5], and the Netherlands eScience Center [6] provide all the training needed to become an active researcher for sharing and collaborating on research software.
As the domain of acoustics is currently not self-organized around open research software, two workshops have been organized on research software in acoustics, with the intention of driving a culture change to consider research software as an integrable part of scientific output and to accelerate open scholarly communication.
The workshops were developed for two international target audiences:

- Researchers at all levels, at a workshop connected to an international conference, with an emphasis on fostering the culture change;
- Young researchers, during a PhD school, with an emphasis on the transformation of the way researchers publish.

The first workshop was organized in conjunction with the InterNoise 2024 congress in Nantes, France. The lunch-to-lunch workshop consisted of a program that should help drive a culture change and help accelerate scholarly communication. This included a talk on the state-of-the-art in sharing research software practices, the value of communities around software and platforms, the opportunities for training, the existing incentives, and influential examples within the field, a presentation of best-practice examples on sharing research software from own work, which is based on open research software on GitHub/Zenodo, and a presentation on instructions and guidelines for acceleration of sharing research software, following best practices: sharing, licensing, software citations, repositories, and software review. The workshop also contained an online questionnaire to obtain information from participants on the topic.
The other part of the workshop involved invited researchers: presentations by representatives of successful open research software in acoustics, and a panel discussion.
The second workshop was organized in November 2024 as part of the computational acoustics school of the Autumn School Series in Acoustics (ASSA) [7]. The first half of this workshop was similar to the one in Nantes. Instead of the invited speakers section, participants went through the CodeCheck procedure [3] to independently execute the computations underlying the research articles using the code of other participants on GitHub.
This work contains the outcomes of the first workshop in Nantes, on the questionnaire as well as on the workshop log as a whole, and concludes with the lessons learned.

[4] https://www.software.ac.uk
[5] https://www.nordforsk.org/research-areas/nordic-e-infrastructure-collaboration-neic
[6] https://www.esciencecenter.nl
[7] https://assaeindhoven.org

2. METHOD

The organized workshop was called 'Unlocking the Potential of Open Research Software in Acoustics'. It was announced on the social media channels of the organized research group (building acoustics TU/e) and via the InterNoise 2024 congress website, as a satellite event. The workshop consisted of the afternoon of August 29 and the morning of August 30. Registration for the free event was possible through an online registration system and both on-site and online attendance was possible. In total, 50 participants were present on-site and 30 attended the workshop online.
The approval of the Ethics Review Board (ERB) of Eindhoven University of Technology was obtained (reference ERB2024BE52), to be able to use the spoken and written input of the participants as the content of research. Participants were asked to complete the online consent form for participation before the workshop and also received the link to the consent form during the workshop.
In addition to the results as reported in this paper, the data is shared and can be found online [8]. The full program of the workshop can also be found there.
The workshop started with a visionary presentation by Maarten Hornikx (TU/e) on the future of acoustics with open research software, after which Huiqing Wang (TU/e) presented best-practice examples on sharing research software based on his work [4]. The afternoon was completed by two presentations on successful open source software, in particular around the motivation and learning points from sharing software. Eric Bezzam spoke on Pyroomacoustics [5], and Pierre Aumond and Valentin Le Bescond on NoiseModelling [6]. The second day started again with Maarten Hornikx, talking about instructions and guidelines for sharing research software, and again

[8] https://github.com/Building-acoustics-TU-Eindhoven/OSS_Workshops

covered two talks on successful open source software: Lukas Aspöck (RWTH) on Virtual Acoustics [7] and Raven [8], and Andrew Mitchell on Soundscapy [9]. The workshop closed with a panel discussion featuring the invited presenters.

A questionnaire was developed to obtain information on the motivation for participation of the delegates, their current practices, and their views on open research software. Questions were asked right at the beginning of the workshop, after the first presentation was started and the program of the days was shown. The questionnaire was taken collectively via the Mentimeter platform and the presenter (Maarten Hornikx) determined the pace of the questions. In data analysis, Microsoft Copilot has been used to structure the results of the questionnaire data and the workshop log document, supporting the drafting of the key results as presented in this work.

3. RESULTS

3.1 Motivation, experience and opinions

The first source of information obtained from the workshop was the online questionnaire offered to the on-site and online participants. The results of the questions were immediately shown on the (shared) screen. The results of the questionnaire are structured into three components, as mentioned in Section 2. First, the background of the participants was asked for: 22 participants were Ph.D. students, 23 were postdoctoral students, and 13 participants came from a non-academic sector. The most notable domain backgrounds were building acoustics, room acoustics, computational acoustics, environmental acoustics, and soundscaping.

3.1.1 Motivation

Two motivation questions were asked. The first relates to the motivation to sign up for the workshop. The reasons can be summarized as follows.

- Curiosity and interest in open source software;
- Collaboration and sharing research outcomes;
- Learning new tools and best practices;
- Participation and co-organization.

In addition, participants were asked about their willingness to participate in an open source community, which they rated on average with an 8.2 on a scale of 0 to 10.

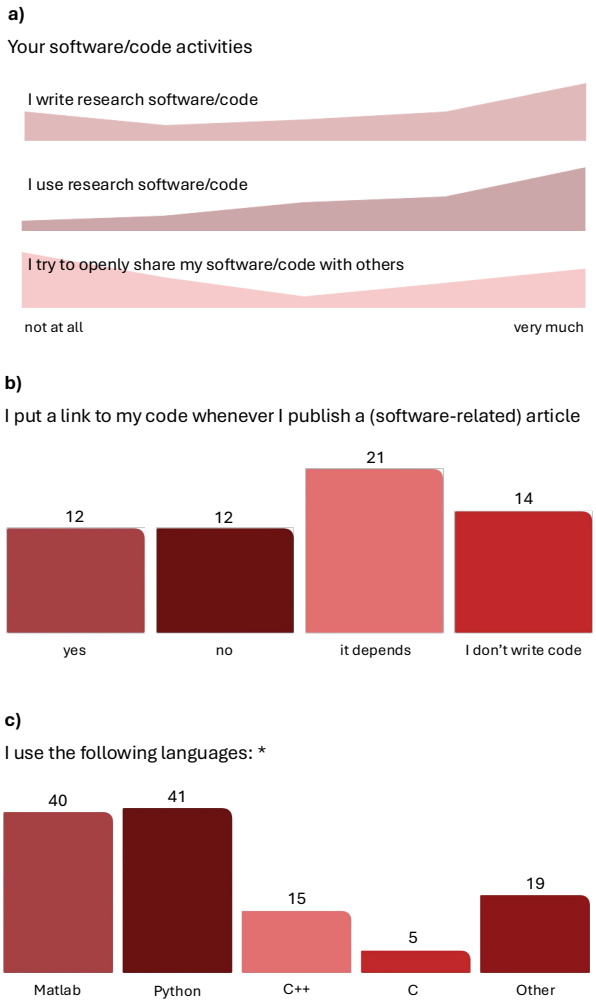

Figure 1. Results from the workshop questionnaire on open research software practices. a) Relative distribution of software/code activities (5 point scale per item), b) practices on sharing software, c) use of software programming languages. *multiple answers possible.

3.1.2 Current practices

The current activities and participation in open source software of the participants were also asked. Fig. 1(a) shows the level of activity of the participants in terms of using, writing, and sharing research software. The results show a wide range of activity patterns, with partici-

pants scoring in the whole range from no activity to very much in all categories. This means that the workshop was attended by complete newcomers in the field and active open research software contributors.
As a follow-up question, we were interested in the connection of code to papers, asking if participants shared code behind their papers. Fig. 1(b) indicates that the practices are mixed, with participants sharing code behind a document, while also participants do not share or not always.
In addition, the usage of common programming languages was asked. The majority of the participants use MATLAB or Python, a lower number uses C++ and C, and some are also using other software (we did not ask what software).
Finally, the delegates answered the question about the platforms on which they share research software. By far, the most used platform is GitHub (37 times), followed by Gitlab (6), supplementary materials (3), and Zenodo (2).

3.1.3 Views on open research software

With regards to the future and value of open-source software, the views of the participants are important. Hence, a couple of questions have been asked. The answers to the question "to me open source software means" can be summarized as follows:

- Free to use, modify, and distribute;
- Collaboration and sharing;
- Transparency and accessibility;
- Democratization and community-driven development.

Furthermore, the views on the current state of open source software in acoustics were questioned in a multiple choice style. Fig. 2(a) shows that the audience, on average, recognizes that we are making progress but that there is room for improvement.
The third question asked the participants what they observed as the limiting factors in developing and maintaining open source software. We see that three needs appear: funding, collaboration, and expertise.
The final two questions were open questions on the advantages and disadvantages of open research software. The main advantages are as follows.

- Collaboration and scientific exchange;
- Transparency and reproducibility;
- Flexibility and customization;
- Free access and avoiding duplication of effort.

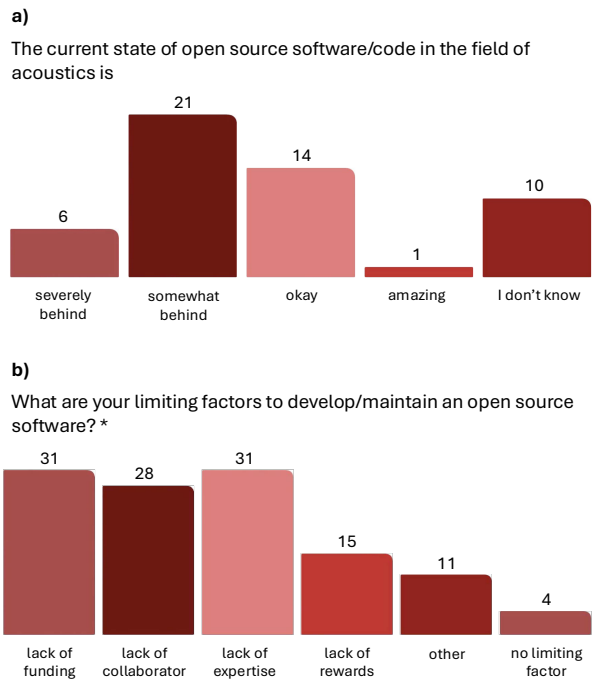

Figure 2. Results from the workshop questionnaire on open research software views. a) Views on the state of open source software in the field of acoustics, b) views on the limiting factors on open source software. *multiple answers possible.

The main disadvantages that were mentioned can be summarized as follows.

- Lack of maintenance and support;
- Possible bugs and instability;
- Documentation issues;
- Competition and quality assurance concerns.

3.2 Discussion points

The second source of information from the workshop comes from the collaborative log collected with HackMD, an interactive online Markdown editor. A HackMD log was prepared for the workshop, including the program and areas where all participants were invited to ask or answer questions related to the workshop program topics. This also allowed online participants to be involved in the

discussions. Remarks posed verbally by the on-site audience were written down instantaneously by two of the co-authors. All questions, answers, and remarks were preceded by the initials of the speaker. The complete log can be found online [9] .

The contents of all discussions are categorized in terms of open research software practices and challenges, needs, and observations in the realm of open research software in acoustics. It is relevant to note that the comments expressed here are remarks from individual attendees, which do not necessarily imply that these are shared by a wider group of experts. At the same time, all participants have a particular interest in the area of the workshop, which is predominantly an intrinsic interest.

3.2.1 Open research software practices

While the workshop focused on research, the use of open research software in education was also mentioned. It was noted that students are trained with closed-source software, so they do not have the opportunity to work with open-source software. Furthermore, collaboration on open source software by students could be very valuable for them. Some discussions revolved around practices regarding digital object identifiers (doi) and licensing. For the latter, the relation to industry was touched upon.
”Regarding licensing, the issue arises when a product with 100,000 lines of code includes open-source code that is only a small part of the code. If this open-source license is GNU General Public License (GPL), a less permissive open license, it imposes restrictions on the rest of the code, which is why companies stay away from this.”
GPL was also mentioned to scare users away, but it was argued that GPL should not be feared. GPL is indeed a less permissive open license, but that means more protection for public code.
There were views on a commercial programming platform (MATLAB) in terms of its use in open science practices. The notion that an open-source research tool in MATLAB is not a full open research software was questioned. It was stated that if the code is available, it can often be adapted to other platforms anyway. However, this view was not supported by others, as it was noted that the MATLAB code cannot be run directly using another free environment. There are good open alternatives now, and new MATLAB code projects are seen as a problem today: ”MATLAB is pay-to-play and definitely not open source.”

[9] https://github.com/Building-acoustics-TU-Eindhoven/OSS_Workshops

A notable remark on standardization was made. It was suggested that if standards emerge on how to read and use data, many people will benefit. Another delegate responded that there is a big challenge in organizing this when combining different fields that have different requirements (as e.g. scattering/absorption/impedance).

3.2.2 Challenges

Various challenges related to the topic appeared during the discussions. The researchers behind acoustic software are typically not trained as software engineers, which could be an issue with respect to the skills needed to develop (sustainable) research software. The ease with which students in acoustics could collaborate was questioned, given that some software is implemented in C++. Another identified challenge was the application of advanced software practices. Individual academics are up against large teams that have the people to do this. Collaboration was seen as important in the evolution of open research software; however, it is harder to get contributions from other researchers because what they are academically rewarded for are papers.
Software sustainability is also a challenge, as witnessed by multiple comments and questions. Questions were raised about whether open-source software needs a project manager, and concerns were expressed that one person is not enough, as they could leave. Open-source code was felt to work when there is a group of software engineers. For popular packages, it was suggested that permanent software engineers should always work and maintain the package forever. It was questioned whether having a lot of institutions working on the same project without one centralized person would bring problems. Another delegate responded that this is really a value of it being open source because if it is closed, such collaboration would not be possible.
Finally, the precious time needed to work on open research software is also seen as a challenge. Challenges were seen to make it more attractive and rewarding for young researchers (PhDs).

3.2.3 Needs

The topic of funding is unavoidable. The conditions for funding were mentioned, noting that there needs to be strong support in political terms and maybe also collaboration with the acoustical societies. At the same time, the opportunity to receive funding from services around open-source software was also discussed. It was suggested that open-source developers can charge a consulting fee. To

further develop open research software in the field and use its full potential, the need for a community is seen, and this is also found important in relation to (a lack of) funding. An open source community could centralize the funding and support, and create pathways to funded projects. Enforcing open source and pushing as many labs as possible would also benefit developers of extensive packages indirectly because it is easier to find people that know about the software.
In addition, a call for support was made from senior acoustics staff. They should be on the open source side. Another participant responded that senior staff should be convinced of the benefits of open science. It was argued that, while papers might not be produced, if others do a better job, it is for the greater good. It was emphasized that people need to know why open science is good for them and their research, as it has many benefits. It was also noted that universities need to support professors in this field. Finally, the importance of a culture change was addressed as a major concern for individual researchers.

3.2.4 Observations

The main observation that the participants shared during the workshop is related to the different types of open research software projects related to different objectives. It was noted that one type is reproducibility and the other is open collaboration projects. These project types were described on a sliding scale, where some situations do not require any open research software practices, but if the objective is to put out a large project intended to live a longer life and require contributions, some practices need to be implemented. Inexperienced software developers might feel overwhelmed at first, but as the project grows, they need to grow along with it. On the same line, it was added that the more professional a project becomes, the more important it becomes to write good code. This makes it harder to find good people who can keep up with this level, indicating a shift or threshold somewhere. Another delegate framed the observation that there are different types of community, some authoritarian, and others collaborative. These extremes are somehow in line with the two types of project. Finally, the wish to welcome more contributors to open research software was addressed. It was suggested that the threshold for people to share should be lowered and that they should not be scared to share. Most of the attendees were felt to know a bit about open research software practices, but the larger crowd should not be scared away by the good practices discussed during the workshop.

4. CONCLUSIONS

The workshop "Unlocking the Potential of Open Research Software in Acoustics" held in Nantes (2024) was a significant event, attracting 80 participants both on-site and online. This high turnout underscores the growing interest in and recognition of open research software within the acoustics community.

From the motivations, experiences, and opinions gathered through the online questionnaire, it is evident that there is a strong curiosity and intrinsic interest in open source software. Participants, with a mix of experience on open research software, are motivated by the potential for collaboration, sharing research, learning new tools and best practices, and actively participating in an open-source community. The most common programming languages are MATLAB and Python. Participants recognize the potential to improve the state of open research software in acoustics and point to funding, collaboration, and expertise as currently limiting factors.

The discussions highlighted some main points that can be considered as lessons for the future.

- **Community and collaboration** Building a strong community is essential for the development and maintenance of open research software and may help as a pathway to funded projects. Collaboration is crucial but challenging, as researchers often prioritize paper publication over software contributions. The sustainability of open-source software may require dedicated project management and permanent software engineers, and a collaborative community may be important then.
- **Support** Open research software activities need time efforts, and support from senior scientific staff members to allow early-career researchers to spend time on open source software development is crucial.
- **From simple code to collaborative projects** Different types of open research software projects cater to various objectives, from reproducibility by software connected to a paper to sustainable software that need collaborative efforts and good software practices to keep them alive and successful. Lowering the barrier to participation and sharing can encourage greater participation of acousticians.

Finally, increasing visibility through conferences and special sessions and promoting accessible tools and methods can significantly enhance the impact and recognition of open research software in acoustics.

5. ACKNOWLEDGMENTS

This work is funded by the Dutch Research Council (NWO) under grant No. OSF23.1.057.

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