2023-10-10

Application-Based Learning Of Signal Analysis Methods With The Help Of A Graphical Open-Source Software

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Recommended Citation

Hetkämper, T., Koch, K., Webersen, M., & Claes, L. (2023). Application-Based Learning Of Signal Analysis Methods With The Help Of A Graphical Open-Source Software. European Society for Engineering Education (SEFI). DOI: 10.21427/159K-G445

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Conference Key Areas: Innovative Teaching and Learning Methods

Keywords: application-based learning, signal analysis, open-source software

ABSTRACT

In almost all engineering disciplines, engineers need to evaluate and extract information from time-dependent quantities, making signal processing and analysis a central topic in engineering education. The theoretical foundation is anchored in many courses, however, often only few application-based learning opportunities are offered. To provide these opportunities without the need for expensive hardware, a graphical open-source software is developed. This workshop offers a first opportunity to explore how a graphical software can be used to learn signal processing and analysis methods.

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1 MOTIVATION

Time-dependent signals occur in nearly every engineering discipline, e.g. electrical engineers measure voltage signals, mechanical engineers and civil engineers deal with mechanical oscillations and audio engineers with audio signals. As engineers need the ability to process and extract information from these signals, signal processing and analysis is a central component in engineering education. While the theoretical foundation is taught in detail in many courses like e.g. signal theory, the curricula often offer only few application-based learning opportunities. This is understandable given that the processing of physical signals requires specialised and often expensive experimental equipment. Alternatively, students can experiment with digital signal processing, but this often requires specific programming skills. This lack of application-based learning in this specific field means that the students often only have the theoretical knowledge of signal analysis and processing methods. This becomes evident when students are confronted with real-world problems. They often possess the necessary knowledge and they can explain specific methods, but do not know what to apply to a given problem.

2 A GRAPHICAL SOFTWARE TO LEARN SIGNAL ANALYSIS METHODS

To overcome the issues mentioned above, graphical software can be used to enrich teaching. For example, research performed by Balakrishnan and Woods (2013) has shown that physical experiments can be complemented by simulations. However, commercial software is often used, requiring the students to either buy licences or work at computers in the university. An example for an open source solution for the teaching of signal processing methods is presented by Barrio et al. (2023), however the focus here is on software defined radios.

To provide a more general, easy-to-use signal processing software, the ‘Multi Channel Analyser’ (MCA), is developed (Measurement Engineering Group 2023). It provides experimental learning opportunities with a focus on problem-solving to students at the undergraduate level. The MCA, which is developed as an open-source project, enables virtual signal processing by connecting processing blocks graphically, thus requiring no programming skills. Available inputs to the processing blocks range from virtual signal generators, audio files and input from the computer’s microphone to oscilloscopes. The output signals of the processing blocks can be displayed as plots, but also written to audio files or played via the computer’s speaker or headphones. Examples for processing block functions are low-pass filters, convolution, multipliers, and the fast Fourier transform. Alongside the numerical values of the signal, the appropriate physical unit of the signal is also stored and processed. Thus, if for example a voltage with unit V is multiplied with a current with unit A, the result is a power with unit W. It is possible to save and to load the current state of blocks, thus allowing for teachers to prepare tasks the students have to complete and for students to submit their solutions.

The MCA can be used in different courses that include signal analysis and processing, such as courses about measurement, instrumentation, and signal analysis, or in laboratory courses. For example, the function of circuits to be designed in a laboratory course can be examined virtually on a block-level to aid in choosing a fitting circuit implementation. Application in adjacent fields is also possible e.g. to demonstrate the effects of a low-pass filter—be it applied to electrical, mechanical or audio signals. As the software does not require specific hardware or expensive licences required by commercially available software, students can use it at home to deepen understanding or in a remote teaching scenario. The MCA is written in Python and also provides an easy-to-use, well-documented API to implement new signal processing blocks and may thus be expanded further by the engineering education community.

3 WORKSHOP DESIGN

In this workshop, the attendees work with the MCA and evaluate and discuss usage of such software. Attendees are asked to bring their own laptop and, if available, headphones, to be able to test the MCA in their preferred operating system (Windows, Linux or macOS). Besides basic understanding of signal analysis methods, no prior knowledge is required. At first, a short introduction is given and the attendees are prompted to install the software. An example on how an application-oriented task can be designed using the MCA will be presented. Afterwards, the attendees take the role of the student and try to solve an exemplary task themselves while the authors will assist and answer questions that arise. A subsequent discussion of the experiences in the practical part will include the following matters:

- Do the attendees already use any similar software/methods in their daily teaching? If not, could they imagine using such a software? Why/Why not?
- How was the user experience in solving the given task and were there problems in using the MCA?
- Is it considered useful to have a physical unit carried along with each signal?
- Are there suggestions for improvement?

The authors will also elaborate on first experiences in teaching with the MCA. However, as the software development is still ongoing, broad usage in lectures still has to be established and the influence on the students' learning outcome has to be examined. In the future, it should also be investigated to what extent an automated evaluation of the user interaction with the MCA is possible.

4 RESULTS

By participating in the workshop, the attendees got to know a new tool for application-oriented teaching of methods of signal processing and analysis. They had the opportunity to evaluate if the proposed software can be used in their own courses and had a first impression of the advantages and possible disadvantages.

The attendees were able to solve the given tasks without any issues. The user experience was generally graded positive, which due to the very short introduction given in the workshop confirms the easiness of use. Most attendees considered it useful to have a physical unit carried along with the signals. The discussion revealed that most teachers already use some kind of graphical software for teaching. A software which was brought up is LTSpice, which is an electronic circuit simulator. It allows to graphically build electronic circuits at a component level and to analyse them afterwards. However, it was mentioned that having to build a working circuit first poses a challenge for some students. Also, the software is limited to electrical signals and not applicable to signal processing in general. Another software mentioned in the discussion is LabVIEW, but it requires licences. Concerning licences, it became apparent that some universities provide every student with a licence from the beginning of their study program, so licensing is not seen as an issue for teachers at those universities. A software previously unknown to the authors is called DADiSP, which allows for easy signal processing and plotting of data. Like the MCA, it carries along the physical unit with each signal. The software has several plot windows and allows assigning data and processing functions to those plots via graphical menus. However, compared to the MCA, the signal processing methods are not available as blocks, but connections have to be created in dropdown menus. Thus, the signal processing chain is not directly visible.

It was seen as an advantage that the MCA is an open-source software, as students interested in learning how to programme digital signal processing functions can look up the implementation. As the workshop was conducted by the developers of the software, the attendees also had questions about some features. It was asked if real-time processing and a direct connection to MATLAB is possible. This is currently not possible, but signals can be exported from MATLAB as files and then get imported in the MCA. Another question was, if the transfer function of processing blocks can be displayed. This is deliberately not implemented, as there is a signal generator block creating an impulse, such that students can visualize the impulse response themselves.

5 CONCLUSION

The discussion showed that using graphical software is considered a useful tool for teaching and learning signal analysis methods. With the MCA we presented a software which can be used in such contexts. The MCA was considered appropriate for this task by the attendees. The authors are still looking forward to getting in contact with people who are willing to participate in the future development of an open-source software that is driven by the engineering education community.

REFERENCES

Balakrishnan, B., and P. C. Woods. 2013. “A comparative study on real lab and simulation lab in communication engineering from students’ perspectives.” *European Journal of Engineering Education* 38 (2): 159–171.

Barrio, Alberto A Del, José P Manzano, Víctor M Maroto, Álvaro Villarín, Josué Pagán, Marina Zapater, José Ayala, and Román Hermida. 2023. “HackRF + GNU Radio: A software-defined radio to teach communication theory.” *International Journal of Electrical Engineering & Education* 60 (1): 23–40.

Measurement Engineering Group. 2023. Multi Channel Analyser (MCA). `https://github.com/emtpb/mca`.