CORTEX

Research and Innovation Action (RIA)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754316.

Start date : 2017-09-01 Duration : 48 Months
http://cortex-h2020.eu

Series of workshops

Authors : Pr. Christophe DEMAZIERE (Chalmers), Dr. Mathieu Hursin (EPFL), Dr. Cartsen Lange (TUD), Dr Alexander Knospe (TUD)

CORTEX - Contract Number: 754316

Project officer: Marco Carbini

Document title	Series of workshops
Author(s)	Pr. Christophe DEMAZIERE, Dr. Mathieu Hursin (EPFL), Dr. Cartsen Lange (TUD), Dr Alexander Knospe (TUD)
Number of pages	14
Document type	Deliverable
Work Package	WP05
Document number	D5.3
Issued by	Chalmers
Date of completion	2021-07-21 08:35:12
Dissemination level	Public

Summary

This report gives an overview of the three workshops organized as part of the subtasks 5.2.1 and 5.2.2 of the CORTEX project. Two workshops on the experiments carried out in the research reactors and on the validation of the neutronic models were offered as part of subtask 5.1.1. One workshop on the demonstration of the methods for reactor noise analysis against plant data was given as part of subtask 5.1.2.

Approval

Date	By
2021-07-21 08:35:52	Pr. Christophe DEMAZIERE (Chalmers)
2021-07-21 08:36:24	Pr. Christophe DEMAZIERE (Chalmers)

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This project has received funding from the Euratom research and training programme 2014-2018 under the grant agreement no.754316. The content in this report reflects only the views of the authors. The European Commission is not responsible for any use that may be made of the information it contains.

Abbreviations

DAQ	Data Acquisition
QOI	Quantity Of Interest
WP	Work Package

Summary

This report gives an overview of the three workshops organized as part of the subtasks 5.2.1 and 5.2.2 of the CORTEX project. Two workshops on the experiments carried out in the research reactors and on the validation of the neutronic models were offered as part of subtask 5.1.1. One workshop on the demonstration of the methods for reactor noise analysis against plant data was given as part of subtask 5.1.2.

1 Introduction

As part of the CORTEX project, three workshops were organized to disseminate the knowledge developed throughout the project both within the consortium and outside the consortium. Two workshops on the experiments carried out in the research reactors and on the validation of the neutronic models were offered as part of subtask 5.1.1. The first one was organized on March 12-13, 2020 by EPFL and the second one on March 23-24, 2021 by TUD. The first workshop was only offered to the consortium members, in order to discuss the validation efforts and remaining issues. The second workshop was offered to a wide audience and was aimed at presenting the main results and outcomes of the validation efforts. Likewise, a final workshop on the demonstration of the methods for reactor noise analysis against plant data was given on June 21-22, 2021 by Chalmers and GRS as part of subtask 5.1.2. This workshop was aimed at presenting the main results of the entire CORTEX project, with a special focus area on the applicability of the methods at commercial nuclear reactors. Because of the Covid-19 outbreak, all three workshops were given online. This report presents the set-up of those workshops and the lessons learnt. Links to the presentations given at the workshops are also available in this report.

2 EPFL workshop on the neutron noise experiments at the research reactors and the validation of the neutronic tools

2.1 Introduction

The first CORTEX validation workshop was organized by EPFL on March 12th and 13th 2020. Initially, it was planned to organize the workshop in Garching, Germany to allow participation of recently retired personnel from ISTec. Due to the outbreak of Covid-19, the workshop was finally held online, using Skype Business.

The workshop was restricted to the Consortium members. As it was designed to facilitate technical discussions between experimentalists and modelers, a detailed knowledge in the field of either simulation or measurement was expected. The workshop was attended by 15 people, 2 postdocs, 2 PhD students, 11 scientists and as such allowed detailed technical discussions.

2.2 Workshop objectives

The goal of the workshop was to foster technical discussions between experimentalists and modelers for the specific purpose of progressing in the validation exercises of Work Package (WP) 2. The workshop was organized such as to mix theoretical discussions with practical, hands-on exercises.

The overall objective was to have each participant leaving the workshop with a global if not detailed understanding of both fields. Specifically, the pre and post processing of the data, both computational and experimental, involved in the validation exercises.

The detailed goals of the meeting were to develop an understanding for the observed discrepancies in the validation exercise. Specifically have a common understanding of the determination of experimental quantities of interest and their associated uncertainties so as to allow at the same time an independent assessment of experimental results as well as decrease the number of basic questions addressed to experimental teams. The goals were similar for the modeling side, e.g., understand the determination of computational quantities of interest and their associated uncertainties; how were the detector responses modeled; how is the raw code output converted in the quantity of interest; and how is the noise source modeled.

2.3 Workshop format

As the workshop took place online, it was not possible to carry out the envisioned practical hands on exercises, even though the material was prepared. However, vigorous discussions took place during and after the presentations made by the various participants.

2.4 Workshop contents

The workshop covered the following topics: 1) background information about noise theory in power reactors, 2) general information about validation, 3) description of the experiments carried out at the reactors, 4) methods employed for data analyses and 5) discussion of the obtained results.

The agenda of the workshop is given in Table 1 below. Due to its online nature, the practical exercises (*b) did not take place; they were replaced by technical discussions based on the presentation's material.

Table 1: Agenda of the EPFL workshop

March 12th, 2020

8:30-8:35 Welcome remarks

8:35-8:45 Approval/modification of agenda

8:45-9:00 I - Power reactor noise (C. Demazière)
- Some theoretical remarks on power reactor noise
- Overview of the various approaches for modelling neutron noise
- Importance of the noise source modelling

9:00-9:15 II - Introduction and Motivations (M. Hursin / P. Vinai)
- Introduction of overall goals of WP2 validation exercise and use within overall CORTEX project
- Definition of various type of noise source considered in WP2
- Definition of the validation QOI
- Some remarks on the general agreement between various computational approaches (code-to-code comparison) for validation QOI.

9:15 –10:00 IIIa - Determination of the experimental QOI (V. Lamirand / S. Huebner)
- Review of the detectors/DAQ setup in CROCUS/COLIBRI
- Detailed description of the time series postprocessing to obtain QoI
- Determination of the experimental uncertainty
- Difference (if any) between CROCUS / AKR-2 processing

10:00-10:15 Coffee break

10:15-12:00 IIIb - Practical exercise with experimental data (V. Lamirand/ S. Huebner)
- Using python scripts / experimental data of the first experimental campaign
- Illustrate the steps required to go from the raw data to the normalized CPSD amplitude plots.

12:00-13:30 Lunch Break

13:30-13:45 IVa - Determination of the computational QOI with deterministic code in time domain (A . Brighenti / T. Vidal)
- Modeling of noise sources with PARCS/FEMFFUSION/APOLLO3 (vibrating / variable strength absorber)
- Modeling of the detector responses with PARCS/FEMFFUSION/APOLLO3
- Postprocessing of the output (if any) to obtain the computational QoI

13:45-15:15 IVb - Practical exercise with pre-generated data from PARCS/FEMFFUSION/APOLLO3 (A. Brighenti / T. Vidal)

- Illustrate the steps required to model a COLIBRI experiment with PARCS/FEMFFUSION/APOLLO3;
- Participants should be able to produce the normalized CPSD amplitude plots based on existing computational time series.

15:15-15:30 Coffee break

15:30-15:45 Va - Determination of the computational QOI with deterministic code in frequency domain (A. Mylonakis)

- Modeling of noise sources with CORESIM (vibrating / variable strength absorber)
- Postprocessing of the output (if any) to obtain the computational QoI

15:45-18:00 Vb - Practical exercise with CORESIM (A. Mylonakis)

- Illustrate the steps required to model a COLIBRI experiment with CORESIM;
- Participants should be able to run a provided CORESIM input for COLIBRI and produce the normalized CPSD amplitude plots.

March 13th, 2020

8:30-9:15 VIa - Determination of the computational QOI with Monte Carlo codes (A. Zoia/ T. Yamamoto)

- Modeling of noise sources with MC codes (vibrating / variable strength absorber)
- Modeling of the detector responses with MC codes
- Postprocessing of the output (if any) to obtain the computational QoI

9:15-10:45 VIb - Practical exercise with TRIPOLI/MCNP (A. Zoia/ T. Yamamoto)

- Illustrate the steps required to model a COLIBRI experiment with MC codes;
- Participants should be able to produce the normalized CPSD amplitude plots based on existing MC output.

10:45-11:00 Coffee break

11:00-12:30 VII - Determination of the computational QOI uncertainty (S. Yum)

- Short version of the workshop given in 2019 focusing on the practical aspects, e.g. postprocessing of CORESIM outputs to determine CPSD amplitude uncertainty

12:30-14:00 Lunch Break

14:00-17:00 Extra time for discussion; for example:

- Some Aspects of Signal Analysis of CROCUS and AKR-2 Experiments in Comparison to NPP Goesgen Measurements
- Needs to be fulfilled by AKR-2 2nd campaign and COLIBRI 3rd campaign
- Code-to-code comparison
- Modeling of noise source

17:00 Adjourn

The material prepared for the hands-on exercise were distributed to the workshop participants. The content was organized as follows:

- Part I: Power reactor noise: Scriptum corresponding to C. Demaziere presentation
- Part II: Introduction and Motivations : Slides corresponding to M. Hursin and P. Vinai presentation
- Part III: Determination of the experimental QOI
    - Section_B: scripts corresponding to the practical exercise (with a README file for explanation)
- Part V: Deterministic codes in frequency domain

  - Section_A: slides corresponding to the theoretical part
  - Section_B: scripts corresponding to the practical exercise (with a README file for explanation)
- Part VI: Monte Carlo codes in frequency domain
  - Section_B: scripts corresponding to the practical exercise (with a README file for explanation)
- Part VII: Computational uncertainty propagation
  - Section_B: scripts corresponding to the practical exercise (with a README file for explanation)

2.5 Links to the developed materials

The presentations held during the workshop are available at the following link:
https://cortex-h2020.eu/workshop-training/presentations/#3

2.6 Learnt lessons

The workshop was held online, at the early stage of the Covid-19 epidemic. Even though the workshop participants were not (yet) used to this sort of settings for a meeting, it went extremely well. Its goals were met; and significant progress were made developing a common understanding between experimentalists and modelers as far as noise experiments and simulations are concerned.

This was made possible by the large amount of time available for discussion. Initially such time was not planned due to the hands-on exercises. The organization of a virtual meeting was a blessing in that respect. As a rule of thumb, each time slot dedicated to a presentation had its length doubled. In order to cover all the material listed in the agenda of Section 2.4, an additional day should have been planned for.

No evaluation of the workshop by its participants was organized.

3 TUD workshop on the neutron noise experiments at the research reactors and the validation of the neutronic tools

3.1 Introduction

The second CORTEX validation workshop was organized by TUD. The workshop was held in an online format. This workshop took place on 23.03.2021 and 24.03.2021. No prior knowledge was required to attend the workshop. The workshop attracted ca. 71 attendees: 13 engineers, 11 PhD students, 5 Professors, 20 research scientists, 5 Post-Doctoral students, 7 MSc/BSc students, and 10 persons not belonging to the previous categories.

3.2 Workshop objectives

In the framework of the CORTEX project, two validation workshops were planned, dealing with experiments performed at the research reactors CROCUS and AKR-2 and with the validation of the developed simulation tools simulating such experiments. These workshops are part of WP5 of CORTEX. The objective of the second validation workshop was that experimentalists and modellers present, describe and discuss their results. By offering the workshop to a large audience, the workshop also contributed to the dissemination and exploitation of the CORTEX results, with a special focus on the neutronic modelling of neutron noise, the noise experiments undertaken at the research facilities, and on the validation exercises.

3.3 Workshop format

The workshop took place in the form of a collection of presentations. Due to the COVID-19 pandemic, the workshop was held in an online format.

3.4 Workshop contents

The workshop covered the following topics: 1) some background information about noise theory in power reactors, 2) general information about validation, 3) description of the experiments carried out at the reactors, 4) methods employed for data analyses and 5) discussion of the obtained results.

The agenda of the workshop is given in Table 2 below.

Table 2: Agenda of the TUD workshop

Tue, 23.03.2021

Methods and results concerning AKR-2

Time	Speaker	Title/Contents
Introduction		
8:30-8:35	**C. Lange/A. Knospe**	Introduction and welcome remarks
8:35-9:10	**C. Demazière**	Noise theory • Some theoretical remarks on power reactor noise • Overview of the various approaches for modelling neutron noise • Importance of the noise source modelling
9:10-9:35	**P. Vinai/M. Hursin**	General info about validation and QoI • Definition of various type of noise source considered in WP2 • Definition of the validation QOI
AKR-2 session		
9:35-10:00	**A. Knospe/C. Lange**	Description of AKR-2 and the experimental setup, experiments, Lessons learned • Detailed description of the AKR-2 reactor, the detector setup and the DAQ • Description of the AKR-2 noise sources
Coffee Break		
10:30-10:55	**K. Ambrozic/A. Knospe**	Extracting QoI out of experimental data, Results of AKR-2 • Detailed description of the time series postprocessing to obtain QoI • Determination of the experimental uncertainty
10:55-11:25	**A. Mylonakis / T. Yamamoto**	Modelling an absorber of variable strength/vibrating absorber in the frequency domain with diffusion and transport theory • Modeling of noise sources with CORESIM+ / MCNP • Modeling of the detector responses (if any) • Postprocessing of the output (if any) to obtain the computational QoI
11:25-11:40	**S. Yum**	Uncertainty analysis of AKR-2/COLIBRI • Postprocessing of CORESIM outputs to determine CPSD amplitude uncertainty
11:40-11:55	**P.Vinai/M. Hursin**	Summary of validation exercise for absorber of variable strength (AKR-2)
11:55-12:40	**All**	General discussion

Wed, 24.03.2021

Methods and results concerning CROCUS/COLIBRI

Time	Speaker	Title/Contents
CROCUS/COLIBRI session		
8:30-8:35	**C. Lange/A. Knospe**	Welcome remarks
8:35-9:10	**V. Lamirand/ K. Ambrozic**	Description of the CROCUS reactor/COLIBRI, experiments • Review of the detectors/DAQ setup in CROCUS/COLIBRI
9:10-9:35	**V. Lamirand/K. Ambrozic**	Results of Data analysis, Lessons learned • Detailed description of the time series postprocessing to obtain QoI • Determination of the experimental uncertainty
9:35-10:20	**A. Mylonakis / T. Yamamoto / A. Zoia**	Modelling a vibrating absorber in the frequency domain with diffusion and transport theory • Modeling of noise sources with CORESIM+ / MCNP • Modeling of the detector responses (if any) • Postprocessing of the output (if any) to obtain the computational QoI
Coffee Break		
10:40-11:25	**A. Brighenti / T. Vidal**	Modelling a vibrating absorber in the time domain with diffusion and transport theory • Modeling of noise sources (real oscillations) • Modeling of the detector responses • Postprocessing of the output (if any) to obtain the computational QoI
11:25-11:55	**P.Vinai/M. Hursin**	Summary of validation exercise for vibrating absorber (CROCUS/AKR-2)
11:55-12:40	**All**	Q&A, General Discussion

3.5 Links to the developed materials

The presentations held during the workshop are available at the following link:
https://cortex-h2020.eu/workshop-training/presentations/#2

3.6 Learnt lessons

The workshop was held online, which is generally not ideal for discussion. The workshop went straight through all presentations. Online workshops should explicitly allow more room for discussion and for more engaging activities from the audience.

4 Final workshop on the demonstration of the methods for reactor noise analysis against plant data

4.1 Introduction

The workshop was held on June 22nd and 23rd, 2021 as morning sessions and online because of the outbreak of Covid-19. The workshop was widely advertised via different channels. The target audience of the workshop was the potential end-users of the neutron noise-based core monitoring technique developed within CORTEX. 96 persons had registered to the meeting. About 60-70 persons attended simultaneously the meeting. An online evaluation questionnaire was distributed right after the meeting, to which 35 persons responded.

The profile of the persons who attended the meeting is represented in Figure 1, whereas the geographical regions where the attendees work is given in Figure 2.

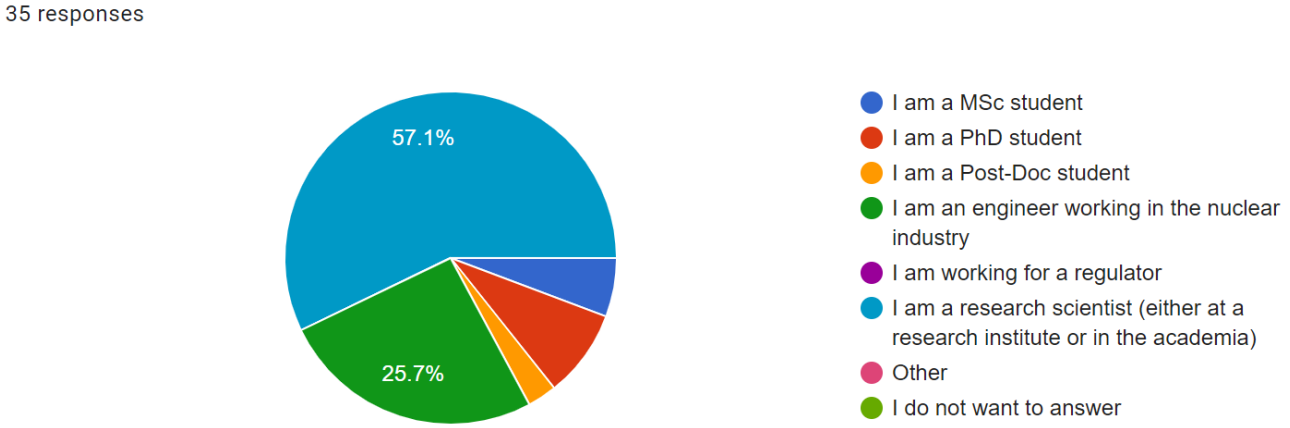

Figure 1: Profile of the attendees to the final CORTEX workshop.

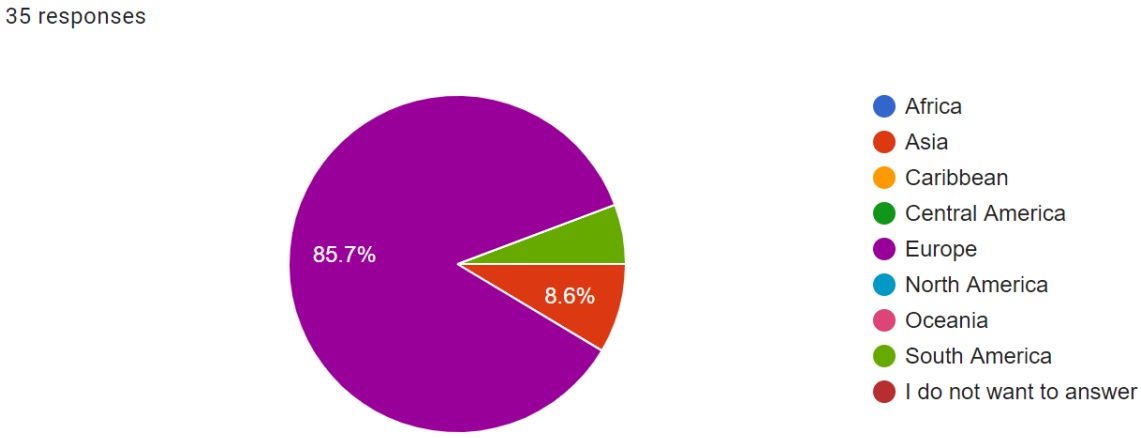

Figure 2: Geographical regions where the attendees to the final CORTEX workshop work.

60% of the attendees who answered the evaluation questionnaire belonged to the CORTEX consortium.

Since the target audience of the workshop was potential end-users of the methods developed within CORTEX, the workshop was designed for nuclear engineers. Nevertheless, no prior knowledge in noise analysis and machine learning was necessary. The necessary concepts needed to understand the presented results were introduced. The presentations were also designed so that the contents could be easily understood by non-experts.

4.2 Workshop objectives

The objectives of the workshop were as follows:

- To summarize the findings and the lessons learnt throughout the CORTEX project.
- To make some recommendations on techniques and instrumentations for core monitoring and surveillance.
- To introduce some theoretical background to the methods.
- To present the applicability of the methods.

4.3 Workshop format

The workshop was designed as short introductory lectures by very few speakers, presenting in a summative and easy-to-understand manner the main techniques used and developed within CORTEX and the most significant results. Since the emphasis of the workshop was on possible use of the techniques on plant data and which corresponds to the WP4, the second half day of the workshop was entirely devoted to this topic, with lectures given by the leaders of the various corresponding tasks in WP4. The first half day, on the other hand, focused on summarizing the three first WP of the project, with only the WP leaders providing lectures.

Ample time for discussions and questions was allocated after each lecture, as well as at the end of each half day session.

The meeting was held online via Teams, and the meeting attendees could ask questions using audio/video, as well as using the chat function.

All presenters had to submit their presentation ahead of time, so that the presentations could be checked for consistency and easiness of understanding for non-experts.

4.4 Workshop contents

The workshop focused on summarizing the main developments achieved in the three first WP, namely:

- WP1: Developing high fidelity tools for simulating stationary fluctuations;
- WP2: Validating those tools against experiments to performed at research reactors;
- WP3: Developing advanced signal processing and machine learning techniques (combined with the simulation tools);

and on detailing the applicability of the neutron noise-based core monitoring technique developed in CORTEX to commercial reactors, which corresponds to WP4.

The detailed timetable of the meeting with the speakers and the title of their presentations is given in Table 3 below.

Table 3: Agenda of the final workshop

June 21, 2021 – CORTEX in a nutshell
08:30 – 08:45: Welcome and project overview (C. Demazière, Chalmers University of Technology, Sweden)
08:45 – 09:00: Theoretical basis of neutron noise and core diagnostics (C. Demazière, Chalmers University of Technology, Sweden)
09:00 – 11:00: Development, verification and validation of neutron noise-specific modelling tools
09:00 – 09:45: Overview of the modelling tools used or developed in CORTEX and their verification (P. Vinai, Chalmers University of Technology, Sweden)
09:45 – 10:15: Break
10:15 – 11:00: Overview of the validation exercises undertaken in CORTEX (M. Hursin, Ecole Polytechnique Fédérale de Lausanne, Switzerland)
11:00 – 11:45: Development of advanced signal analysis and machine learning techniques in support to core diagnostics (S. Kollias, University of Lincoln, United Kingdom)
11:45 – 12:30: Questions and wrap-up (C. Demazière, Chalmers University of Technology, Sweden)
June 22, 2021 – Neutron noise-based core diagnostics applied to commercial nuclear reactors
08:30 – 08:35: Welcome and introduction (J. Herb, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Germany)
08:35 – 09:05: Required instrumentation and data acquisition system (G. Girardin, Kernkraftwerk Gösge-Daniken AG, Switzerland)
09:05 – 09:15: Required data for modelling the reactor transfer function (C. Demazière, Chalmers University of Technology, Sweden)
09:15 – 09:45: Necessary signal processing (C. Montalvo, Universidad Politécnica de Madrid, Spain)
09:45 – 10:15: Break
10:15 – 11:45: Machine learning architectures versus diagnostic tasks (G. Leontidis, University of Aberdeen, United Kingdom; M. Yu, University of Lincoln, United Kingdom; G. Alexandridis, Institute of Communication and Computer Systems, Greece)
11:45 – 12:15: Examples of applications on commercial reactors within CORTEX (J. Herb, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Germany)
12:15 – 12:45: Questions and wrap-up (J. Herb, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Germany; C. Demazière, Chalmers University of Technology, Sweden)

4.5 Links to the developed materials

The presentations held during the workshop are available at the following link:
https://cortex-h2020.eu/workshop-training/presentations/#1

4.6 Learnt lessons

The workshop was considered by the workshop participants as a successful event. The overall quality of the workshop was deemed good to very good, as Figure 3 demonstrates. Likewise, the technical content of the workshop in relation to the background knowledge of the participants was considered as adequate, as Figure 4 highlights, which a tendency to have presented slightly too complex materials.

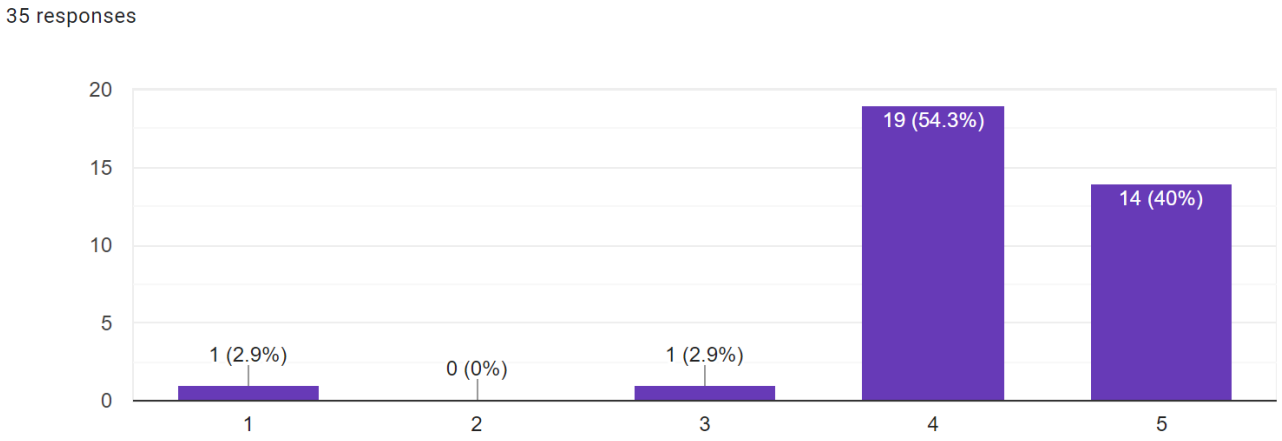

Figure 3: Participants' overall impression of the final CORTEX workshop. The scale is as follows: 1 = "very bad" and 5 = "very good".

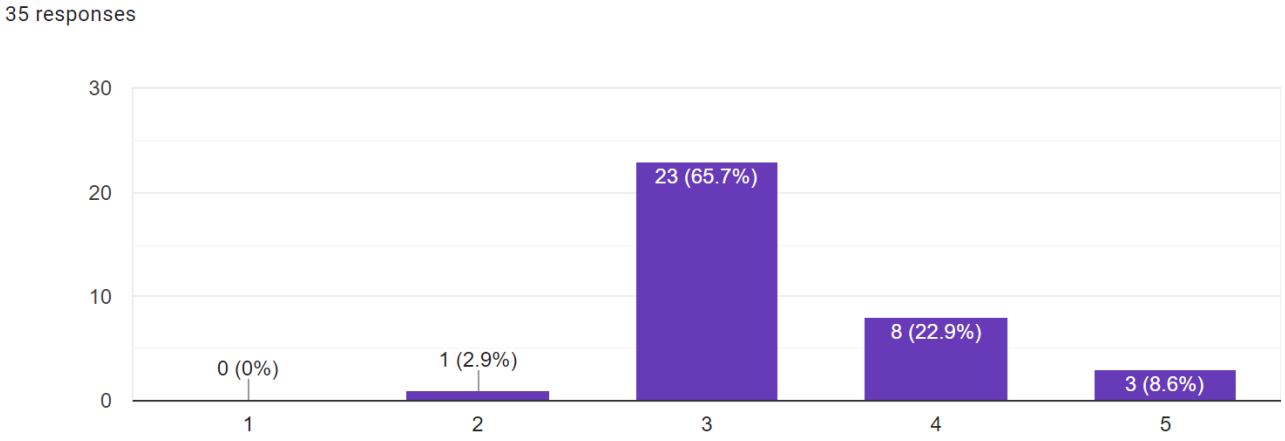

Figure 4: Participants' impression of the content of the final CORTEX workshop in relation to their background knowledge.
The scale is as follows: 1 = "The technical content was far too simple" and 5 = "The technical content was far too complicated".

Out of the respondents to the evaluation questionnaire who had questions, 95% considered that their questions were answered.

Overall, the workshop was extremely well received and appreciated by the workshop attendees. Being able to present sometimes difficult concepts in a condensed manner was definitely a challenge, which required careful preparation and iterations with the lecturers. Remaining aligned with the objectives of the workshop while having a variety of backgrounds in the workshop attendees was an aspect considered during the entire preparation of the workshop.

5 Conclusions

As demonstrated in this report, the objectives of the three workshops were achieved, with a high participation to all three events. Although the Covid-19 outbreak forced to have online meetings, this allowed to offer the workshops to stakeholders who might not have had the opportunity to attend the workshops onsite. Thanks to targeted advertising campaigns for the open workshops using various communication channels (e-mails, newsletter, website, social media, contact to other networks), the visibility of the events was high, and the applicability of the methods developed within CORTEX could be demonstrated to a large audience.