REPORT on the PIANOFORTE-funded training course

MESH phantom development and implementation for radiation physics calculations

Organized by: EURADOS, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), and United Kingdom Health Security Agency (UKHSA), and hosted by CIEMAT, Madrid, Spain, 30 September – 4 October 2024.

The course on MESH phantom development and implementation for radiation physics calculations was organised within the framework of EURADOS working group 6 on computational dosimetry. The course aimed at building up competences on numerical MESH phantoms within Europe. The school gave participants the knowledge to: build MESH phantoms; implement them in their MC codes; and perform dosimetric calculations with these phantoms. In addition, participants learned how the ICRP reference MESH phantoms (ICRP publication 145) have been developed and how to implement them in three different Monte Carlo codes.

REGISTRATION, AUDIENCE, AND LECTURERS

Registration was managed by Kerstin Hürkamp (EURADOS). An online registration form was made available on the EURADOS website. Twenty three people registered, but only sixteen participants confirmed their participation. The week before the training course, one student cancelled her participation due to personal issues. Thus, a total of 15 doctoral students, medical physicists and scientists from ten different countries (Austria (1), Croatia (1), Czech Republic (1), France (2), Georgia (1), Germany (3), Italy (1), Poland (2), Spain (2), United Kingdom (1)) participated in the course.

The lectures and hands-on sessions were given by international and European experts in the field of computational phantoms. Six lecturers attended in person: Chansoo Choi (University of Florida), Jonathan Eakins (UKHSA), José-María Gómez-Ros (CIEMAT), Christelle Huet (IRSN), Pasquale Lombardo (SCK-CEN) and Montse Moraleda (CIEMAT). In addition, lectures were given remotely by Chan Hyeong Kim (Hanyang University), Hyeonil Kim (Hanyang University), Suhyeon Kim (Hanyang University), Bangho Shin (University of Florida), Gahee Son (Hanyang University), Reid Townson (National Research Council Canada) and Yeon Soo Yeom (Yonsei University).

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Thanks to the involvement of these numerous speakers, it was possible to investigate all the topics related to MESH phantom development and their implementation in radiation transport Monte Carlo codes, and to explore the various aspects in depth through lectures, tutorials and hands-on sessions.

LECTURES AND HANDS-ON SESSIONS

The course was delivered in 4.5 days through lectures, tutorials and hands-on sessions for a total of about 30 hours, including 18 hours of hands-on practical work, 4 hours of tutorials, and 8 hours of lectures.

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The topics covered were:

- General information on MESH type phantoms
- ICRP 145 reference MESH phantoms
- Steps needed to create a MESH phantom from image data and from scratch
- Animation of MESH phantoms
- Conversion into formats compatible with Monte Carlo codes
- Implementation in different Monte Carlo codes
- Dosimetric calculations with MESH phantoms

For the hands-on session, a list of software to be installed on their laptops prior to the course was provided to the participants. All materials used during the lectures and hands-on sessions were made available to the students in a shared folder online.

A certificate of attendance has been sent to all the participants at the end of the training course.

The detailed program of the course is presented below.

Monday 30.09.2024:
13:45-14:00: welcome and introduction
14:00-14:45: History of computational phantoms, lecture
14:45-15:45: Overview of MESH type phantoms, lecture
14:45-16:15: coffee break
16:15-17:45: Introduction to DICOM segmentation with 3DSlicer software, lecture + tutorial

Tuesday 01.10.2024:
9:00-9:20: Overview on ICRP Mesh-type Reference Computational Phantoms and Phantom Libraries, lecture
9:20-9:40: Adult male and female Reference MESH adopted by ICRP (ICRP Publication 145), lecture
9:40-10:00: ICRP Publication 145 - Supplementary Files, lecture
10:00-10:20: coffee break
10:20-12:20: How to Use ICRP Mesh Phantoms in Geant4, PHITS, and MCNP6, lecture
12:20-13:20: lunch break
13:20-16:20: Creation of a dataset to model organs and export of the dataset, tutorial + practical
16:20-16:40: coffee break
16:40-17:50: Introduction to Blender software, lecture + tutorial

Wednesday 02.10.2024:
9:00-9:15: Q&A session on ICRP MESH phantoms, Q&A
9:15-9:30: McSEE - Visual-aided Mesh Phantom-based Monte Carlo Simulation Code for External Exposure, lecture
9:30-9:45: VIR - Mesh Phantom-based 4D Virtual Dose Monitoring System for Interventional Radiology, lecture

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9:45-10:00: coffee break
10:00-12:30: Polygon MESH modeling with Blender, tutorial+practical
12:30-13:30: lunch break
13:30-15:30: Polygon MESH modeling with Blender (continued), tutorial+practical
15:30-15:45: coffee break
15:45-17:15: Polygon MESH modeling with Blender (continued), tutorial+practical
17:15-17:45: Practical applications: nuclear medicine, lecture

Thursday 03.10.2024:
9:00-10:00: Animation of polygonal MESH phantoms: principle and overview of available tools, lecture
10:00-11:00: Animation of polygonal MESH phantoms, tutorial+practical
11:00-11:15: coffee break
11:15-12:45: Animation of polygonal MESH phantoms (continued), tutorial+practical
12:45-13:45: lunch break
13:45-16:00: Animation of polygonal MESH phantoms (continued), tutorial+practical
16:00-16:15: coffee break
16:15-16:45: Conversion to Monte Carlo compatible formats: principle, overview of formats available, lecture
16:45-17:30: Conversion to Monte Carlo compatible formats: EGS, lecture

Friday 04.10.2024:
9:00-10:30: Conversion to Monte Carlo compatible format: voxelization, tutorial+practical
10:30-10:45: coffee break
10:45-11:45: Conversion to Monte Carlo compatible format: tetrahedral mesh, tutorial+practical
11:45-12:45: Mesh Phantom PHITS Tutorial and Practice, tutorial+practical
12:45-13:45: lunch break
13:45-15:30: Conversion to Monte Carlo compatible format: polygonal MESH, tutorial+practical
15:30-15:45: closing remarks

FEEDBACK FROM PARTICIPANTS

On the last day of the course, students anonymously completed an evaluation form to assess the quality of the course, lectures and practical work. The results are shown below. The feedback is very positive. The participants rated the overall quality of the course, the organization, the balance between lectures and hands-on, and the quality of the lectures and hands-on sessions, as being *very good* to *good*. All topics of the course were relevant.

The overall conclusion is therefore that the course has been a success, and has fulfilled its planned intentions. Nevertheless, the students also suggested some areas of potential improvement. Although the nature of this feedback is somewhat subjective, with different individuals likely favouring different learning styles, it provides valuable insight into how the

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content might be developed and refined if this course (or a similar one) were repeated in the future.

General evaluation of the course	Average score 1= lowest, 5 = highest 1 =no; 5=yes
What is your general view about the organization of the course?	**4.7**
What is your general view about the quality of the course?	**4.7**
Did the content of the course match your expectations?	**4.5**
How difficult was it to follow the lectures?	**2.7**
Did you have enough basic knowledge to follow the course?	**3.5**
Would you have preferred to hear more lectures?	**2.5**
Would you have preferred to do more practical work? If yes, on what subject in particular?	8 participants answered NO; YES answers were suggesting the following topics: • conversion into MC compatible format • implementation in MC codes
How much knowledge did you acquire from the course?	**4.4**
Did you miss certain subjects that you think would have been relevant? If yes, what in particular?	13 participants answered NO YES answers were suggesting: • Use of MESH phantoms in MC codes • Phantom animation like breathing for simulation
Do you think that this course will help you on your work?	**4.6**

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Specific evaluation of the course Rate the following lectures/tutorials/hands-on in terms of content and usefulness	**Average score** 1= lowest, 5 = highest
History of computational phantoms and overview of MESH type phantoms	**4.4**
ICRP reference MESH phantoms	**4.6**
Creation of a dataset to model organs with 3DSlicer	**4.5**
Applications: McSEE, VIR, nuclear medicine	**4.2**
Polygon MESH modelling with Blender	**4.7**
Animation of polygonal MESH phantoms	**4.3**
Conversion to Monte Carlo compatible formats	**4.3**

The evaluation identified some suggestions for improvement:

- Expand the time and the practical devoted to conversion into MC compatible format, implementation in MC codes and calculations (8 participants)
- Some practical could be shortened (animation/weighting phantom, segmentation for instance) (4 participants)
- More step-by-step instructions in the tutorials (4 participants)

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