EUTEMPE-RX — MODULE 03

Monte Carlo simulation of x-ray imaging and dosimetry

Summary

This document describes the aim of the course, its structure and some logistic and practical issues. For registrations please visit this link.

Introduction

Monte Carlo simulation of radiation transport has numerous applications in medical radiation physics, largely due to its accurate modeling of the interaction of ionizing radiation with matter, its suitability for dealing with complex geometries and its conceptual simplicity.

This course aims at providing medical physics experts with the theoretical and practical abilities required to efficiently use the well-known general-purpose Monte Carlo code PENELOPE/penEasy to simulate x-ray imaging problems and their dosimetry. Furthermore, the coupling between ionizing radiation and light in indirect x-ray digital detectors will be addressed in the context of the MANTIS family of Monte Carlo codes.

Course contents

The topics to be covered are organized in the following chapters:

1. Monte Carlo simulation of radiation transport
   The Monte Carlo method. Radiation transport. Variance reduction techniques.
2. X-ray and electron physics
   Interaction models. Condensed simulation of charged particles. General-purpose simulation codes.
3. The PENELOPE/penEasy system
   Structure, installation and operation. Material data files. Quadric geometry package. Voxelized geometries.
4. Physics of imaging detectors
   Detector models. Imaging metrics. Indirect detectors. Direct detectors.
5. Packages for imaging detectors
   The MANTIS family of codes. ARTEMIS and other codes.
6. Exercises
   Absorbed dose distribution. Spectrometry. X-ray tube. Image formation & patient dosimetry. Point spread functions. Optical pulse-height spectra.
7. Other applications
   The use of MC simulation in radiology.

The main expected learning outcomes are:

- Assess Monte Carlo algorithms for applications in x-ray imaging: explain the theoretical foundations of the method and how it is applied in practice.
- Construct simplified models of x-ray transport problems to efficiently simulate them with the PENELOPE/penEasy and MANTIS codes.
- Apply Monte Carlo simulation methods for the estimation of absorbed dose distributions in patients.
- Evaluate optimization strategies to obtain accurate simulation results in an efficient manner.
- Manage a simulation project from beginning (conceptual modeling) to end (analysis of results).

Course structure

The course is structured in three phases. The first phase is presented online. During this phase reading material intended to be preparatory for the topics covered during the on-site phase will be distributed. Simple activities designed to get acquainted with some software tools that will be intensively used during the exercises are also included here.

The central components of the course, including theoretical lectures and guided practical exercises, will be presented on-site (*i.e.*, face to face) during the second phase in Barcelona, Spain. Basic and advanced concepts will be presented from a self-contained perspective that does not assume previous knowledge on the subject. Sessions are distributed from Monday to Friday, 09:00 to 18:00 each day, with one-hour lunch breaks.

Finally, the third (named 'post') phase addresses advanced exercises and further issues on the use of the simulation codes. During this phase participants will get support from the lecturers via one-to-one virtual meetings.

The estimated workload of the online, on-site and post phases is 10 h, 30 h and 40 h, respectively. The total expected effort is thus 80 h.

Important dates

- 2019-03-18
  Go/NoGo decission: latest possible date for course confirmation. The decission will depend on the number of registrations. In case of cancellation the registration fee will be fully reimbursed.
- 2019-06-10
  Start of the online phase.
- 2019-07-08 through 12
  On-site phase in Barcelona. Sessions start at 09:00 h. Please see location, accommodation and other logistic details below.
- 2019-07-15
  Start of the post phase.
- 2019-08-02
  End of the course.

Teaching team

EUTEMPE-RX coordinator

- Prof. Hilde Bosmans, Katholieke Universiteit Leuven.
  Head of Medical Physics and Quality Assurance.
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Module leader

- Dr. Josep Sempau, associate professor at the Technical University of Catalonia.
  Coauthor of the penEasy and MANTIS codes and of previous versions of the PENELOPE code.
  Email: josep.sempau@upc.es

Lecturers

- Dr. José M. Fernández-Varea, associate professor at the University of Barcelona.
  Coauthor of previous versions of the PENELOPE code.
  Email: jose@fqa.ub.edu

- Dr. Aldo Badano, Acting Deputy Director of the Division of Imaging, Diagnostics, and Software Reliability (DIDSR/OSEL/CDRH/OMPT) of the U. S. Food and Drug Administration.
  Coauthor of the ARTEMIS and MANTIS family of codes.
  Email: aldo.badano@fda.hhs.gov

Computing

Or, should I take my laptop computer to Barcelona?

Yes. All the course material, including lecturers' presentations, will be distributed in electronic format so that participants will be able to follow the sessions from their laptop screens. Furthermore, the practical exercises, which are crucial for a thorough understanding of the presented concepts, will be carried out on personal computers. Detailed instructions on the software to install, on how to use it and introductory exercises for the online phase will be communicated in due time.

The participants' computers will work in conjuction with our local computing infrastructure, which is based on a Linux cluster. This resource will be presented during the on-site phase. Initially, attendees are expected to know only the operation of a typical Windows system. All the necessary additional information will be delivered during the course. Some background in computer programing (Fortran, C, etc.) may be advantageous to grasp some concepts and work out some exercises in detail, although this is not a prerequisite.

Assessment and diploma

The assessment will consist of three parts: (i) A written exam (30% weight in the final grade); (ii) a problem case to be simulated (40% weight); and (iii) a written report of a more advanced case (30% weight). Parts (i) and (ii) will be carried out on the last day of the on-site phase in Barcelona. Part (iii) will be delivered by email at the end of the post phase. All tests are with open books, that is, participants will be allowed to use all the printed and electronic material they wish; parts (i) and (ii) will be strictly without external connectivity (wi-fi, bluetooth, phones, etc.).

The range of evaluation grades are:

- not evaluated
- fail (less than 50% mark)
- pass (50%–64%)
- merit (65%–79%)
- distinction (80%–100%).

This course has been accredited by the European Board for Accreditation in Medical Physics (EBAMP) for Medical Physicists at European Qualifications Framework[1] (EQF) level 7. The EBAMP accreditation code for the course is APP00029.

[1] See, *e.g.*, https://en.wikipedia.org/wiki/European_Qualifications_Framework.

A Continuing Professional Development (CPD) certificate with 105 credit points will be issued for those that attend the course and complete the evaluation process successfully (50% or more). A CPD certificate with 53 credit points will be issued for those attending the course that do not complete or do not pass the examination. There will be only one opportunity to take the exam—no second-chance exam will be organized.

Venue for the on-site phase

School of Industrial Engineering of Barcelona
Av. Diagonal 647, 08028 Barcelona, Spain
Technical University of Catalonia (UPC)
http://www.upc.edu

Location:
The building is at about 100 m from the closest metro station, named *Palau Reial*, L3 (green). You can see it on the map here.

Accommodation

Summer is an hectic period in Barcelona and hotel occupancies are at a peak. Therefore, it is highly advisable to make hotel reservations well in advance[2]. The university residences RESA are a convenient and affordable option. RESA has several residences located downtown, all of them close either to the course venue or to a metro station. To see all the possibilities follow this link.

Transportation

Barcelona has an interconnected network of metro, tram and suburban trains. Lines starting with an L are metro lines, those starting with a T are tram lines and those with an R or S are suburban trains. A map of the network can be found here.

Eating

Coffee breaks and lunches will be available at your discretion in the cafeteria of the same building where the course takes place. Costs are not covered by the organization. The price of the lunch menu is 7.5 EUR.

Social program and touristic information

The course includes a group dinner in a nice restaurant. The cost of the dinner is covered by the organizers.

More information on important events, activities, accommodation, etc. in Barcelona can be found here. In particular, this link contains an extensive list of touristic attractions.

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[2]We strongly recommend not to make any travel arrangements prior to receiving the course confirmation—see previous section on important dates.