Application of Artificial Intelligence and Bayesian methods to the analysis of neutron spectra measurements

Start date: preferably before the end of June 2023
Duration: 18 months
Workplace: Cadarache (St Paul lez Durance -13), with travel to the IRSN site in Fontenay-aux -roses (92) and the CNRS/LULI site in Gif sur Yvette (91).

Context :

IRSN is the public expert in the field of radiation protection and nuclear safety. In this context, the Laboratoire de micro-irradiation, Métrologie et Dosimétrie des Neutrons (LMDN) contributes to the establishment of reference neutron beams and participates in the development of new detectors for the characterization of various neutron fields produced in industry and the medical field. In this perspective, a collaboration between the Laboratoire pour l'Utilisation des Lasers Intenses (CNRS/LULI) and the LMDN aims to characterize the neutron emission produced by the laser of the CNRS APOLLON facility and to design an activation neutron spectrometer consisting of several targets arranged in series.
To this end, we wish to use AI tools to optimize the performance of the spectrometer and to analyze the associated measurements by relying on recent developments carried out at IRSN, with methods for reconstructing the neutron spectrum using convolutional neural networks (CNN). The aim is to confirm these promising results with data sets from measurements, impacted by experimental uncertainties. The characterization of the neutron field of the APOLLON laser is an opportunity to extend the application domain of the studied AI algorithms and to propose new analysis approaches.

Objectives:

Gamma-ray spectrometry measurements of the activation of the metal foils constituting the neutron spectrometer provide only integral and not spectral data of the activity. Thus, the determination of the neutron spectrum is indirect and is usually carried out using so-called "deconvolution" software, which makes it possible to obtain knowledge of the neutron spectrum from the activation measurements, knowing the response functions of the targets as a function of the incident neutron energy. The determination of these response functions is one of the tasks of a thesis currently being carried out at LULI in close collaboration with the LMDN. To date, the codes used by the LMDN for the determination of neutron spectra require prior knowledge of the type of neutron spectrum. These deconvolution codes are based on either Bayesian approaches or iterative algorithms.
The aim of this post-doctoral contract is therefore to
- to participate in the design of the neutron spectrometer (choice of target materials, thicknesses and their order relative to the incident beam) with AI methods to be defined,
- to use the AI approach already studied to reconstruct the neutron spectra emitted in the Apollon installation by transposing these complementary and innovative methodologies (thanks to the establishment of detector response functions)
- to combine and compare Bayesian approaches and AI-based methods for spectrometer optimization.

The different steps of this post-doctoral position will therefore be:
A) to appropriate the different algorithms and neural network architectures already validated,
B) to adapt the codes based on the Bayesian models by using the expertise of LULI (simulations, other measurements)

C) to build and enrich a learning base for neural networks derived from simulations,
D) to optimize the neural network architecture,
E) to consider the use of AI or optimization tools useful in the design of the detector.
F) To potentially adapt the developed tools for other types of reference detectors owned by the laboratory (scintillators, Bonner spheres, etc..)

Supervision and Collaboration :

The day-to-day supervision of the post-doc will be carried out by the Laboratoire de micro-irradiation, de Métrologie et de Dosimétrie des Neutrons (IRSN/SDOS/LMDN) at Cadarache. This work will be carried out in strong synergy with:
- The Ionizing Radiation Dosimetry Laboratory (IRSN/SDOS/LDRI, Fontenay-aux-Roses)
- The Neutronics Laboratory (IRSN/SNC/LN, Fontenay-aux-Roses)
- The Laboratory for the Use of Intense Lasers (CNRS/Polytechnique/LULI)

The regular interactions between laboratories will be done remotely and face-to-face according to the needs (participation in measurement campaigns, training, ...).

Profile required:

The candidate must have a PhD in physics, have used applied mathematics (statistical approaches, data analysis, data science, etc.) and ideally have dealt with Machine Learning approaches. Knowledge of Python and/or C++ is a prerequisite. Knowledge of Python-based Machine Learning tools would be an additional asset. The candidate should have a good level of written and spoken English and will be required to communicate his/her work at scientific meetings and conferences. Even if the position does not consist in carrying out experimental campaigns, an interest in them will be necessary and the candidate may also be asked to participate in experimental campaigns during his post-doctoral position to better understand the outcomes of the subject.

Practical details :

The start date of the contract is set at the end of June 2023 at the latest. The duration of the contract is 18 months. The position is located at IRSN Cadarache (13). The salary is based on qualification and experience according to the IRSN salary scale. Candidates are encouraged to send their CV, a summary and references of their previous research, and the names of 1 or 2 referees. Please send applications and any queries to Thibaut VINCHON (thibaut.vinchon@irsn.fr)