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# PROPOSITION DE STAGE M2
## Janvier 2022

5-6 months MSc or BSc (EI) internship

## Mining Arronax accelerator data for anomaly detection

**Keywords:** Data mining, particle accelerator, machine learning, anomaly detection

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**Context**

ARRONAX (Accélérateur pour la Recherche en Radiochimie et Oncologie à Nantes Atlantique) is a particle accelerator located in Saint-Herblain, Arronax produces innovative radioisotopes (radioactive atoms) for nuclear medicine research. Its main application domains are oncological diagnostic and therapeutic imaging, as well as oncology, through PET (Positron Emission Tomography). ARRONAX is a joint initiative between Subatech lab and the CRCINA (Centre Recherche en Cancérologie et en Immunologie de Nantes (CRCINA).

**Abstract**

Providing precise irradiation for radioisotopes relies on the knowledge of the impact of the most effective settings of the accelerator. This is essential to secure irradiation within some time and specifications. Towards this end, the accelerator environment has been strengthened with an additional control and acquisition system, as well as a new diagnostic tools, both bringing additional data to the large data framework EPICS (Experimental Physics and Industrial Control System).

The aim of this internship is to perform data mining on the extended data collected from the accelerator, by studying the pertinence of different machine learning algorithms to monitor the accelerator settings and thus improve secure irradiation. The **primary** goals are the application of the algorithms to the accelerator operation, to explore:

- significant events and detect anomalies,
- alarm handling and prognostics.

**Secondary** goals tackle tuning and optimisation of the accelerator settings for operation.

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**Project description**

Large amount of data of the cyclotron environment are now being recorded and synchronized through the EPICS framework installed at ARRONAX [1], with the idea of analysing past and potential damages. The student will continue and extend a previous work performed on data mining assembling. He will constitute, for this, batches of data to be analysed using machine learning techniques to detect anomalies.

There has been a recent increase of Machine learning methods designed for the analysis of accelerators operation [2, 3, 4], including for large machines [5,6]. It is expected that machine learning will not only contribute to further secure target irradiation but also be part of the study that helps to increase the number of particles hitting the target i.e. increase of radioisotope production and stability. In this project, the intern will focus on implementing machine learning methods adapted to a small to intermediate industrial machine with a limited amount of data (~0.4 Tb per year of data at Arronax). Both unsupervised and supervised algorithms will be studied. In particular, Bayesian approaches for anomaly detection (such as PCA, k-means, DBSCAN and isolation forest techniques already part of the study), one-class Support Vector Machines (SVM) for outlier detection, convolution neural network [7] or supervised survival analysis [8]. The application has to take into account changes with time and the algorithm robustness, for example through dedicated indices, will have to be calculated.

Hypothesis based on beam dynamics from previous simulations may be used, i.e. focal points of the beam close to the target to cope with the reduced amount of data for learning. The project could be transferable to other small machine that perform irradiation of targets.

**Requirements**

The applicant should have a BAC+4 (Master 2 or EI2, EI3), an excellent background knowledge in python programming, and/or machine learning, as well as good communication skills.

**Bibliography**

[1] F. Poirier et al., “Studies and Upgrades on the C70 Cyclotron Arronax”, in Proc. Cyclotrons'16, Zurich, Switzerland, Sep. 2016, pp. 235-237. doi:10.18429/JACoW-Cyclotrons2016-TUD02.
[2] “Intelligent Controls for Particle Accelerators,” held 30-31 January 2018 at Daresbury Laboratory www.cockcroft.ac.uk/events/ICPA/
[3] “ICFA Beam Dynamics Mini-Workshop: Machine Learning Applications for Particle Accelerators 2018 at SLAC https://conf.slac.stanford.edu/icfa-ml-2018/
[4] “2nd ICFA Workshop on Machine Learning for Charged Particle Accelerators,” held from 26 February 2019 to 1 March 2019 at PSI https://indico.psi.ch/event/6698/
[5] A.L. Edelen, S.G. Biedron, B.E. Chase, D. Edstrom, S.V. Milton, P. Stabile, 2016, “Neural Networks for Modeling and Control of Particle Accelerators,” IEEE Transactions on Nuclear Science 63(2), 878-897.Invited
[6] S.G. Biedron, “Machine Learning, Data Mining and Big Data Handling for Accelerators”, in Proc. IPAC19, Melbourne, Australia, May 2019, TUZPLM1.
[7] Scheinker, A., Cropp, F., Paiagua, S. et al. An adaptive approach to machine learning for compact particle accelerators. Sci Rep 11, 19187 (2021).
[8] Leveraging Random Survival Forests and PET images for prognosis of Multiple Myeloma at diagnosis, Ludivine Morvan et al., IPCAI 2019