Hybrid AI for interference mitigation in SKA data

– Ph.D. proposal in machine learning and signal/image processing –

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Abstract

Context – Radio-chronometry of ultra-stable rotating pulsars, used to test gravitational theories or detect very low frequency gravitational waves, requires significant real-time processing right out of the receivers. The processing chain of the new global Square Kilometer Array (SKA) radio telescope will only achieve the desired sensitivity and precision if we are able to process automatically and intelligently the multitude of interferences mixed with the scientific signal, whether they are of internal origin to the instrumentation, linked to the immediate terrestrial electromagnetic environment or to the regular passage of planes and satellites over observation sites. We propose to use machine learning methods, especially deep learning, to capitalize on large databases already labeled. The hybrid artificial intelligence methods developed will combine the versatility and power of deep learning methods and the scientific expertise of thematicists, implicitly regularizing the obtained solutions.

Objectives – The methods and algorithms will be applied to real data sets and integrated into the observation chain of the decimetric radio telescope (NRT), in particular for the chronometry of ultra-stable millisecond pulsars of the "Pulsar Timing Array" program. The performances can be directly evaluated in terms of impact on the sensitivity to the background of low frequency gravitational waves, by estimating the instrumental noise component for each observation subband. The techniques will be tested in particular in very broadband, and implemented in the new NUPPI-2GHz back-end, currently under development at LPC2E within the ANR funded PTA-France project. The new cleaned data will be made directly available to the global IPTA (International Pulsar Timing Array) consortium for integration into the collaboration's gravitational wave analysis, following the protocol provided for in international agreements. The work of the doctoral student will produce at least two articles in peer-reviewed journals, to expose on the one hand the method and on the other hand the impact in astrophysical terms.

Scientific environment

The two main teams involved are the "Astrophysics" team from LPC2E (CNRS and University of Orléans) and the "Signal and Communications" (SC) group from IRIT (CNRS and Toulouse INP). The Astrophysics group brings its long-standing expertise in the observation and multi-wavelength chronometry of pulsars and its involvement in major instrumental projects : NRT, LOFAR and NenuFAR in France, MeerKAT in South Africa, and the future scientific exploitation of the SKA Observatory (TGIR, global project). The SC group brings its expertise in the development of state-of-the-art learning methods, in particular on hybrid artificial intelligence techniques which make it possible to integrate deep learning methods while preserving the constraints imposed by the astrophysical background and signal physics. These hybrid methods are at the heart of research carried out in the Artificial and Natural Intelligence Toulouse Institute (3IA ANITI).

The doctoral student will therefore benefit from a favorable context and will be able to rely on the most recent results obtained on hybrid artificial intelligence methods. More generally, he/she will feed on both disciplines and provide solutions in terms of processing SKA data, in the context of ultra-precise pulsar chronometry for applications in fundamental physics : tests of the theories of Gravitation in the compact binary systems and characterization of the background of gravitational waves in the range of nHz to μHz).

The Ph.D. student will be co-advised by

- Ismaël Cognard, CNRS Research Director within the Astrophysics group at LPC2E laboratory (UMR CNRS 7328, Orléans)
- Nicolas Dobigeon, Professor within the SC group at IRIT laboratory (UMR CNRS 5505, Toulouse) and AI Research Chair at the Artificial and Natural Intelligence Toulouse Institute (ANITI)

in collaboration with

- Damien Gratadour, Associate Professor within the LESIA laboratory (UMR CNRS 8109, Paris)
- Lucas Guillemot, Astronomer within the LPC2E laboratory (UMR CNRS 7328, Orléans)
- Gilles Theureau, Astronomer within the LPC2E laboratory (UMR CNRS 7328, Orléans)

Funding

Fully funded by CNRS under the 80|PRIME program, this Ph.D. position is part of the AI4IMSKA project. The monthly gross salary is 2135 euros. It comes with health insurance and other social benefits.

Keywords

Radioastronomy, SKA (Square Kilometer Array), machine learning.

Profile & requirements

Master or engineering school students with major in applied mathematics, computer science or electrical engineering.

The knowledge needed for this work includes a strong background in **machine learning** and **signal & image processing**. Experience in **deep learning** and/or interests in **astrophysics/astronomy** will be appreciated.

Contact & application procedure

Applications should be conducted through the CNRS portal using the following link

https://emploi.cnrs.fr/Offres/Doctorant/UMR7328-ISALAN-013/Default.aspx.

Beforehand, applicants are also invited to send (as pdf files)

- a detailed curriculum,
- up to three recommendation letters stating your ability for research,
- official transcripts from each institution you have attended (in French or English).

to the main co-advisors

- Ismaël Cognard, icognard@cnrs-orleans.fr
- Nicolas Dobigeon, nicolas.dobigeon@enseeiht.fr

You will be contacted if your profile meets the expectations. Review of applications will be closed when the position is filled.