Profile for EXTRACT TASKA

Deep Learning expert developer position

<u>Position title:</u> DL Expert to develop multi-dimensional image restoration in radio astronomy

<u>Contract duration:</u> 18 to 24 months

<u>Location</u>: LESIA, Observatoire de Paris, Meudon

<u>Working team</u>: 2-4 people

<u>Contacts:</u>

- Baptiste Cecconi (baptiste.cecconi@obspm.fr)
- Julien Girard (julien.girard@obspm.fr)

<u>Monthly gross salary:</u> 3347 to 4085 €

<u>Application deadline:</u> January 31st, 2024

The applicants should send to the contact persons : a resume, a cover letter, and any relevant documents or resources supporting their application.

<u>Requested profile:</u>

(M/F) Post-Doc OR Research Engineer degree (>= 2 years experience in image processing)

We require candidates to have an moderate or advanced level of expertise in the following fields:

- Python/C++
- General knowledge in DL networks (e.g. CNN, GAN, Unet, mainly focused on image processing, image restoration or time series analysis etc.
- Knowledge of DL Frameworks (e.g. TensorFlow, keras, PyTorch)
- (Optional) Inverse problem formulation and resolution
- (Optional) Fourier analysis and Fourier sampling
- (Optional) Data workflow management systems
- (Optional) Knowledge on edge/cloud technologies

Application domain : Applicant profile may come from various image processing and image restoration fields, such as medical imaging, astronomy, video restoration, industry, etc. Applications with a general scientific or signal processing background will be favored.

Academic background : PhD or MsC degree in Computer Science or similar.

Context

The EXTRACT project (EU, https://extract-project.eu) is currently conducting the design of an edge-to-cloud solution for heavy data processing based on Deep learning methodologies. One of the use case is the project Transient Astrophysics using SKA pathfinders (TASKA) that covers the processing of dynamical astronomical imaging data in radio using deep learning.

Radio astronomy imaging involves the inversion of set of Fourier domain samples acquired by an interferometer, observing a certain direction of the sky at a specific temporal and spectral rate.

The transformation from the recorded data (set of sparse and incomplete Fourier samples) to a multidimensional[1] image cube containing scientific information, is a strong and ill-posed inverse problem.

For decades, « classical » radio interferometric imaging usually involved the production of single 2D image from the averaging (in time and frequency) of Fourier samples and solving the deconvolution problem to remove the instrumental impulse response. The target was to obtain a static image of the sky in radio. The classical CLEAN algorithm (1974) and CLEAN derivatives methods were historically the most widespread methods used to solve for the problem, mainly in the image space.

Specific problematic covered by this project

When the observed sky is steady, the accumulation of Fourier samples helps getting better images with improved signal-to-noise ratio (SNR) and image fidelity. However, if an astrophysical event (a.k.a. a radio « transient ») occurs during the observation, a long time integration can average out and prevent the detection of such short-lived event. Fast snapshot imaging using the same methods trying to follow fast variations of the sky provide a very limited SNR that would limit the detection level to only powerful astrophysical transients. In addition, extended time-variable emission (e.g., Solar flares, planetary emissions, etc.) are only poorly imaged using classical 2D imaging at a higher rate.

With the development of machine learning and deep learning (ML/DL) methodologies, solving for the imaging and deconvolution can be revisited to produce images cubes with the lowest possible bias while maintaining the integrity of the physical information measured from the sky. The imaging problem is analog to a video restoration problem where identified features are restored and tracked in time and spectral domains.

Hopefully, the astrophysical transients usually have a smooth behavior in time and spectral domains and can be located in a region of the sky. Therefore, the approach of this project is to model the varying source as a 4D structured signal that could be detected and restored with the appropriate approach of the data.

The developed networks will use trainings sets composed of simulated data as well as real data.

[1] 4-dimensional cube : 2 directions on the sky, 1 time axis, 1 spectral axis

Description of the tasks and products

We propose to follow the following challenging steps:

1) Survey the current methods that already use some ML/DL methods applied to image restoration & deconvolution (in radio astronomy) for a steady sky or a transient sky.

2) Develop a new method for imaging and deconvolution based on the 4-D structure of the transient event to enable: i) transient detection, ii) classification and iii) proper rendering of the variable source in an 4D image cube.

3) The next step is to study the feasibility to detect such transient directly in the set of Fourier domain samples without the need to imaging.

4) Use the detected signal to trigger other receivers and provide input for source classification in the image domain or in the temporal/spectral domain.

Step 3) is more difficult as it requires restoration and detection of a signal not living in a space that promotes signal sparsity. However, having this capability would improve dramatically the capabilities to detect transient sources unambiguously in the « online » data flow.

Step 4) This step is key when the triggered receivers can record data at very high temporal and spectral resolution but over a limited time.

The work will also be in strong interactions with the other developers of the EXTRACT project involved in data integration and workflow management.

The position will be supported by experts in radio astronomy and radio interferometry to build training data set and to interface the DL network to the real case.

Research group, computing facilities and travel

The recruited person will work within the HPA team (*Heliosphere et Plasmas Astrophysiques* - Heliosphere and astrophysical plasmas) of LESIA, in Meudon. This group hosts the PI team of the NenuFAR (New Extension in Nançay Upgrading LOFAR, an SKA pathfinder) instrument, with which the data used for this work is acquired. He/she will be primarily working with Julien N.Girard (assistant professor and radio interferometry expert), and B. Cecconi (professor and data management expert).

He/she will be provided with a personal computer. He/she will have access to the LESIA, Observatoire de Paris and EXTRACT provided computing facilities. He/she will also work with the EXTRACT project team, participate to regular meetings, including face-to-face meetings, twice per year. He/she will present his work in national and international meetings, with travel expenses covered by the EXTRACT project.

Useful links

– Extract project : https://extract-project.eu
– NenuFAR : https://nenufar.obs-nancay.fr
– LESIA : https://www.lesia.obspm.fr/