NASSP Honours Project 2024

Level : Honours

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Deep Learning Techniques for Strong Gravitational Lensing Studies

Astrophysics is undergoing a data deluge. Over the past decade, the advent of digital detectors, automated survey telescopes and efficient data processing tools have increased the size and complexity of datasets available for astrophysical studies by several orders of magnitude. Making sense of these very large datasets calls for a new approach toward the automated characterization of many millions (and soon billions) of astronomical sources. This has led to the rapid adoption of techniques from other sciences and to the birth of the new disciplines of Astroinformatics and Astrostatistics. A field of particular interest is that of Machine Learning, i.e. the development and application of algorithms that can 'learn' from the data with a small degree (if any) of interaction/supervision on the scientist's side. Specifically, Deep Learning is a subfield of Machine Learning that involves training artificial neural networks with multiple layers to analyze and understand complex patterns in data. These neural networks are designed to mimic the behaviour of the human brain, with each layer of neurons processing and extracting increasingly abstract features from the input data. In this Honours project, we will carry out a comparative study of deep learning techniques for identifying and characterizing strong gravitational galaxy-galaxy lensing systems in Euclid (ongoing ESA Space Mission) and Rubin/LSST (upcoming ground-based survey project) images. In order to do that, we will use the Bologna Lens Factory (BLF) Simulations. Our group's experience in the applications of deep learning to astronomy (Alhassan+ 2018, Becker+ 2021, Fielding+ 2022ab, Brand+ 2023) as well as in interdisciplinary applications of "simpler" classifiers on other datasets (Hussein+ 2020, 2021, 2022, Isingizwe-Nturambirwe+ 2023) will allow us to demonstrate and quantify the relative benefits of different approaches and explore some open questions such as:

- Investigate the performance of "simple" classifiers compared to the more complex deep learning models;
- Use k-fold cross-validation techniques to estimate model uncertainties;
- Experiment with different types of data pre-processing;
- Experiment with using different bands (Euclid VIS/NISP and LSST *ugrizy*);
- Include an additional "irregular/uncertain" category in the binary (lens/non-lens) classification scheme;
- Include an additional regression module to estimate lens parameters;
- Learning feature importance for better visual explanation (e.g. interpretability).

This study will allow the student to develop skills in machine learning and in multi-wavelength astronomy. The student will be co-supervised by Prof Mattia Vaccari and Dr Lucia Marchetti within the HIPPO (`https://www.mattiavaccari.net/hippo`) research group at UCT/UWC/IDIA where (s)he will have access to the ilifu cloud computing facility (`https://docs.ilifu.ac.za`). The project requires a good understanding of extragalactic astronomy and a good proficiency in python software development as well as the willingness to develop both.

!!! Please get in touch with supervisors over e-mail to discuss the project in person!!!