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Classification of Planetary Nebulae through Deep Transfer Learning

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Abstract: This study investigate the effectiveness of using Deep Learning (DL) for the classification of planetary nebulae (PNe). It focusses on distinguishing PNe from other types of objects, as well as their morphological classification. We adopted the deep transfer learning approach using three ImageNet pre-trained algorithms. This study was conducted using images from the Hong Kong/Australian Astronomical Observatory/Strasbourg Observatory H-alpha Planetary Nebula research platform database (HASH DB) and the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS). We found that the algorithm has high success in distinguishing True PNe from other types of objects even without any parameter tuning. The Matthews correlation coefficient is 0.9. Our analysis shows that DenseNet201 is the most effective DL algorithm. For the morphological classification, we found for three classes, Bipolar, Elliptical and Round, half of objects are correctly classified. Further improvement may require more data and/or training. We discuss the trade-offs and potential avenues for future work and conclude that deep transfer learning can be utilized to classify wide-field astronomical images.

Keywords: deep learning; transfer learning; planetary nebulae; morphology; classification; HASH DB; Pan-STARRS

1. Introduction

A planetary nebulae (PN) forms when a sun-like star ejects its envelope at the end of its life. The ejected envelope forms an expanding nebula around the remnant core of the star which ionizes it. After some 10^4 years, the PN fades from view, both because of the expansion and dilution of the nebula and because of the fading of the ionizing star. Around 3000 PNe are known in the Galaxy. PNe show up as compact nebulosity on images of the sky, with typical spectra that are dominated by emission lines. They are commonly identified by comparing images taken at different wavelengths. However, they can be confused with other types of astronomical objects: confirmation that a nebula is indeed a PN requires follow-up spectroscopy. A significant fraction of cataloged PNe were later found to be misidentified. An overview of PNe discovery surveys can be found in Parker [1].

The most up-to-date catalog of PNe in our Milky Way Galaxy is the Hong Kong/Australian Astronomical Observatory/Strasbourg Observatory H-alpha Planetary Nebula research platform