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Simplifying and improving plasma diagnostics by combining Artificial Intelligence and emission spectroscopy techniques

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As Machine-Learning (ML) algorithms are becoming more and more attractive and their importance and recognition are largely increasing, they are now widely used in several scientific fields including astrophysics and plasma physics [1-7]. More precisely in the field of atomic spectroscopy of interest for magnetic fusion research, Kajita *et al* 2020 have recently applied a regression algorithm from the supervised Machine-Learning (ML) library package Sickit-Learn [8] to neutral helium emission lines in order to predict the plasma electron densities and temperatures. The technique was applied to experimental data from linear divertor simulators with independent diagnostic techniques like Thomson Scattering and Langmuir probe measurements as assessment/validation tools. In all these mentioned references, the Artificial Intelligence algorithms were not used to replace standard techniques based on physical models but they are aimed to improve them and extend their application, the ultimate objective being often to make predictions prior to future experiments and for situations where direct or indirect measurements are difficult or impossible. In a similar way, Koubiti and Kerebel [9] have recently proposed the use of machine-learning algorithms adopted from the end-to-end open source platform TensorFlow [10]. By considering the Balmer-α spectral lines emitted by hydrogen isotopes in tokamak divertor plasmas, the authors have in demonstrated the proof-of-principle of the isotopic ration determination using a new approach deep learning and to Hα/Dα line profiles synthetized with pre-determined parameters like neutral temperatures, the magnetic field strength and the $n_{\mathrm{H}}/(n_{\mathrm{H}}+n_{\mathrm{D}})$ isotopic ratio, n_{H} and n_{D} being respectively the number densities of neutral hydrogen and deuterium. This approach is based on the Balmer-α line emitted by hydrogen and deuterium but unlike the standard method it does not consist in fitting the Hα/Dα line spectra. Instead, only some basic spectroscopic features like the separation between peaks and intensities ratios between spectral peaks and dips of the line spectra are used by the algorithm for training. In the present paper, the new approach will be described and illustrated by considering typical experimental Balmer-α spectra. However, I will discuss further issues related to the application of deep-learning for the determination of isotopic ratios which are crucial for both plasma control and safety reasons when extrapolated to D-T mixtures in future fusion-based reactors such as DEMO. The ultimate objective of this work is to use deep-learning and more generally Artificial Intelligence tools to find underlying and hidden correlations between the H-D or D-T isotopic ratios from the huge available experimental data (present devices) to allow for safe and accurate predictions for future devices.

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