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Machine learning for solving the Boltzmann equation of charged particle swarms

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Artificial neural network (ANN) is one of the models used in the machine learning and has high ability for approximating a function. Recently, a novel numerical method for solving partial differential equations (PDEs) where the latent solution of PDE is approximated by ANN was proposed, and the method is called physics informed deep learning [1]. This method does not require the discretization of PDE and is therefore able to deal with complex geometry and high-dimensional PDEs easily. The Boltzmann equation is one of the most important PDEs in our community since this equation governs the velocity distribution function of charged particles, which specifies those transport coefficients and rate coefficients for reactions induced by charged particle collisions. We have developed a novel direct numerical solution method of the Boltzmann equation for electron swarms by applying the physics informed deep learning [2]. Our method does not require the expansion of the electron velocity distribution function (EVDF) by the orthogonal functions, such as Legendre polynomials. As a benchmark, the EVDF in Ar gas under a DC uniform electric field was calculated by our method and was found to agree with the EVDF calculated by the Monte Carlo method. Recent progress of our method will be also presented. [1] M Raissi, P Perdikaris, and G E Karniadakis, J. Compt. Phys. 378, 686 (2019) [2] S Kawaguchi, K Takahashi, H Ohkama and K Satoh, Plasma Sources Sci. Technol. 29, 025021 (2019)