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Machine learning optimization for laser driven implosions towards high gain fusion

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Laser-driven inertial confinement fusion is an important approach to achieve controllable nuclear fusion. It applies high-power laser pulses or X-rays to ablate the outer surface of a spherical target, leading to a centripetal implosion and an increase in pressure and temperature of the fuel. In order to reach the Lawson criterion and thus realize a self-sustaining burning plasma, we have to compress the fuel to several hundred times of the solid density and rise the target temperature to over 5 keV. Isentropic compression can realize such compression. However, it is not easy to design the optimum target structure and the corresponding laser pulse manually.

Firstly, to realize an efficient implosion, the driven laser pulse and target structure are designed using a random walk method for a given laser energy. It can quickly optimize the laser pulse and target structure parameters for an efficient isentropic compression of the target. A correlation matrix can also be constructed to analyze the correlation between the parameters.

Secondly, we propose a hybrid optimization method by combining the random walk and the Bayesian methods, to further improve the optimization efficiency. The series of laser pulses and target structures that produces relatively high areal density obtained by the random walk optimization are used as the basic sampling data of the Bayesian optimization. It greatly reduces the desired number of samples for Bayesian optimizations and the Bayesian optimization also makes up for the small step size and low efficiency of the random walk method in the later stage of optimization, and reduces the randomness in the optimization process. The hybrid optimization method greatly improves the optimization efficiency, and has been applied to the experiments of the Double-Cone ignition scheme. We believe that it will play a greater role in the future laser fusion experiments.

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[2] Z. Li, Z. Q. Zhao, X. H. Yang, G. B. Zhang, Y. Y. Ma, H. Xu, F. Y. Wu, F. Q. Shao, J. Zhang, Hybrid optimization of laser-driven fusion targets and laser profiles. Submitted.

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