5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Machine-learning optimization of laser-pulse shapes and target structures for direct-drive implosions

Fuyuan Wu[1,3,] Xiaohu Yang[2,3], Yanyun Ma[2,3], Zhengming Sheng[1,3], Jie Zhang[1,3*]
[1] School of Physics and Astronomy, Shanghai Jiao Tong University, China
[2] Department of physics, National University of Defense Technology, China
[3] Collaborative Innovation Center of IFSA, Shanghai Jiao Tong University, China
E-mail (speaker): fuyuan.wu@sjtu.edu.cn

Double-cone ignition (DCI) scheme is a fast-ignition scheme based on laser direct-drive configuration. DCI uses a relatively small drive energy in a direct-drive conical implosion to form a high-density colliding plasma, which is then be heated by magnetic field guided fast electron beams generated by PW laser pulses.

Genetic algorithm is an optimization algorithm which imitates the evolution process of population in biology. It has the advantages of high parallel efficiency and strong versatility. However, there is a risk of falling into local optimum in the optimization process. Random forest is a machine learning algorithm in data science based on decision trees. It can be used for big data classification, regression, prediction of complex physical system and feature importance analysis of independent variables.

Common radiation hydrodynamics programs in laser driven fusion include LASNEX, HYDRA, LARED, FLASH and MULTI. MULTI-IFE is an open-source program using one-dimensional double-temperature, multi-group model in Lagrangian coordinates with fusion package. MULTI-2D program is an open source program using separate temperature for ions and electrons, single-group model radiation transport in Arbitrary Lagrangian Eulerian (ALE) framework. Both of them can well meet the fluid simulation research required by double-cone ignition scheme

In this report, we propose an automated approach for designing laser-pulse shapes and target structures for the DCI scheme based on the machine-learning approach. The optimization workflow is illustrated in Figure 1. Apart from some basic step to set up a model, there are three key steps during the optimization. Firstly, the genetic algorithm (GA) is employed in combination with the radiation hydrodynamic code MULTI-IFE, to find a set of optimized laser-pulse and target configuration in a huge parameter space with 22 independent variables. Secondly, the random forest algorithm is used to explore physics relationship behind the data, e.g., making classification analysis to distinguish the detailed roles played by different laser-pulse shapes and making regression analysis to find the fitted relationship among critical physical variables.

This machine-learning design approach has been successfully demonstrated in the experimental campaign in 2020 conducted on the SG-II upgrade laser facility with a drive energy up to 12 kJ from 8 laser beams and will be applied to design the upcoming double-cone ignition experimental campaigns this year.

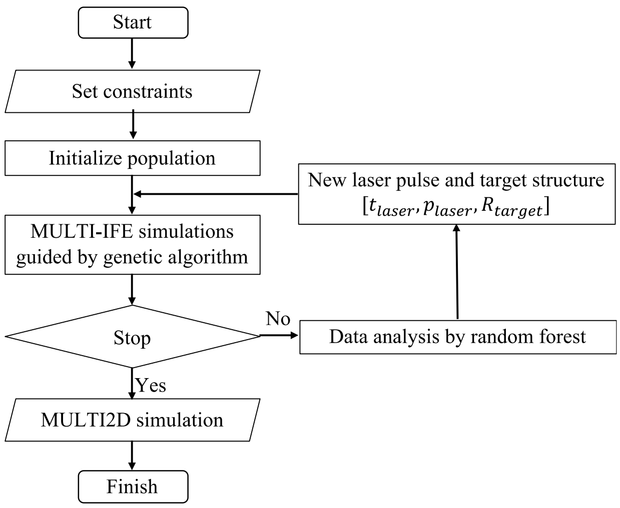

Figure 1 Intelligent optimization of laser pulse and target structure for laser direct-drive implosions in combination of hydrodynamics simulation and machine learning algorithm

References

[1] Zhang J, Wang W M, Yang X H, et al. Philosophical Transactions of the Royal Society A, 2020, 378(2184): 20200015.
[2] Fuyuan Wu, Rafael Ramis, Zhenghong Li, et al., Fusion Science and Technology, (2017) 72:4, 726-730.
[3] Ramis R, Meyer-ter-Vehn J, Ramírez J., Computer Physics Communications, 2009, 180(6): 977-994.
[4] Wu F, Ramis R, Li Z., Journal of Computational Physics, 2018, 357: 206-229.

Acknowledgement

This work was supported by the Strategic Priority Research Program of Chinese Academy of Sciences (Grant nos. XDA25050100, XDA25050200 and XDA25051200), Startup Fund for Young Faculty at SJTU (Grant no. 21X010500627).