F-I4 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Sparse modeling for a data-driven approach in Plasma Physics

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Recent progress in the technology of experimentation and measurement makes it possible to obtain a huge amount of high-dimensional data. Needless to say, this trend has forced scientists to change their attitudes toward data. Effective use of high-dimensional data involves a strong framework and a flexible methodology to make the tight connection of information science to the original purpose of data analysis derived from various scientific disciplines. This framework is called data-driven science, which is extending from biology and medical science to physics, including plasma physics [1-3].

We noticed that sparse modeling (SpM) is a key technology of data-driven science. SpM is a generic term for techniques that exploit the inherent sparseness that is common to all high-dimensional data, enabling the efficient extraction of the maximum amount of information from high-dimensional data in real. In concrete terms, the basic notions of SpM are as follows. First, high-dimensional data are sparse and can be essentially expressed by a small number of variables. Second, the number of explanatory variables should be reduced without loss of accuracy. Finally, explanatory variables are selected objectively, and models of target phenomena are constructed automatically.

In the field of information science, SpM has recently received much attention. So far, the data-driven approach based on SpM has achieved promising results in various fields such as medical science, astronomy and material science. If this technology can be strengthened by clarifying the common principles that apply in the background of each case, it will lead to innovative developments in all the natural sciences [1,2].

In this talk, to explain the effectivity of SpM in plasma physics, we show our study case applying SpM for prediction of high-beta disruptions, which is a critical phenomenon in a tokamak reactor [3]. Although disruption causes serious damage to the reactor, its physical mechanism remains unclear. To realize a tokamak reactor, it is necessary to understand and control the disruption phenomenon. The present research constructs a disruption predictor using experimental high-beta plasma data in the JT-60U tokamak. The predictor was constructed using a support vector machine as a linear discriminant, and we focus on a variable selection problem for the binary classification by SpM, specifically, exhaustively searching the best combinations of variables which maximize the predictor performance. We introduced 17 ~ 23 input parameters into SpM, including time derivatives of plasma parameters. By SpM, we have succeeded to find out several important parameters for predicting plasma disruption, e.g., poloidal beta, safety factor at 95% of poloidal flux, plasma elongation, the plasma density (relative to the Greenwald density limit) and ion temperature at around q=2 surface. We should notice that the combination with these plasma parameters is indispensable and remarkably make it possible to improve the performance of disruption prediction.

References

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