7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Development of 2D spatial displacement estimation method for turbulence velocimetry of gas puff imaging system on EAST

L.T. Li[1,2], S.C. Liu[2,*], N. Yan[2], X.J.Liu[2], X. Gao[2,*], EAST Team
[1]Anhui University, Hefei, People's Republic of China,
[2] Institute of Plasma Physics, Chinese Academy of Sciences
e-mail (speaker):letian.li@ipp.ac.cn

The edge turbulence could contribute to remarkable cross-field transport in magnetically confined plasmas, such as blobs or filaments [1]. During the propagation of blobs from the plasma edge to the scrape-off layer (SOL), a large amount of heat and particles across the last closed flux surface (LCFS) can reach the divertor plates in a short time and lead to heat deposition on the first plasma-facing materials. Some fast transient events, like edge-localized mode (ELM) can cause significant energy loss in the core plasma and high heat flux at the divertor target, which is a crucial issue for large fusion devices such as ITER. In consequence, the fine dynamic evolution of the edge turbulence is important for understanding edge cross-field transport and core plasma confinement.

Two-dimensional imaging technology is applied to the measurement of edge turbulence structure and its propagation velocity. Several 2D diagnostics for turbulence structure have been developed, including beam emission spectroscopy (BES) [2], Langmuir probe [3], electron cyclotron imaging (ECEI) [4], and gas puff imaging (GPI) [5]. Since the turbulence flow velocity is an essential parameter for the understanding of turbulence instability and radial transport, various methods are used in velocity estimation, such as the time-delay method (TDE) [6], optical flow [7], spatial displacement estimation (SDE) [8].

The SDE method calculates the spatial displacement from the spatial lag of the 2D spatial cross-correlation coefficient function. Since the SDE could be operated for two adjacent images, it has much higher temporal resolution than the TDE method, which is an advantage for the velocity estimation of fast structures. Due to the SDE method needing enough large image pixels, its spatial resolution is limited. Based on the SDE algorithm, we make some improvements, including an adaptive median filter and super-resolution technology. After the development of the algorithm, a straight-line movement and a curved-line movement are used to test the accuracy of the algorithm, and the calculated speed agrees well with preset speed. This SDE algorithm is applied to the EAST GPI data analysis, and the derived propagation velocity of turbulence is consistent with that from the TDE method, but with much higher temporal resolution.

We tested the accuracy of SDE algorithm through two sections of motion, as shown in Figure 1, and then applied the algorithm to GPI diagnosis on EAST.

References

[1] Piras F. et al 2010 Physical Review Letters 105 155003
[2] Harbour P. J. 1984 Nuclear Fusion 24 1211
[3] Chodura R. 1992 Contrib Plasm Phys 32 219
[4] Tobias B. et al 2010 Review of Scientific Instruments 81 10d928
[5] Liu S. C. et al 2012 Review of Scientific Instruments 83 123506
[6] Shao L. M. et al 2013 Plasma Physics and Controlled Fusion 55 105006
[7] Horn B. K. P. et al 1981 Artificial Intelligence 17 185
[8] Lampert M. et al 2021 Rev Sci Instrum 92 083508

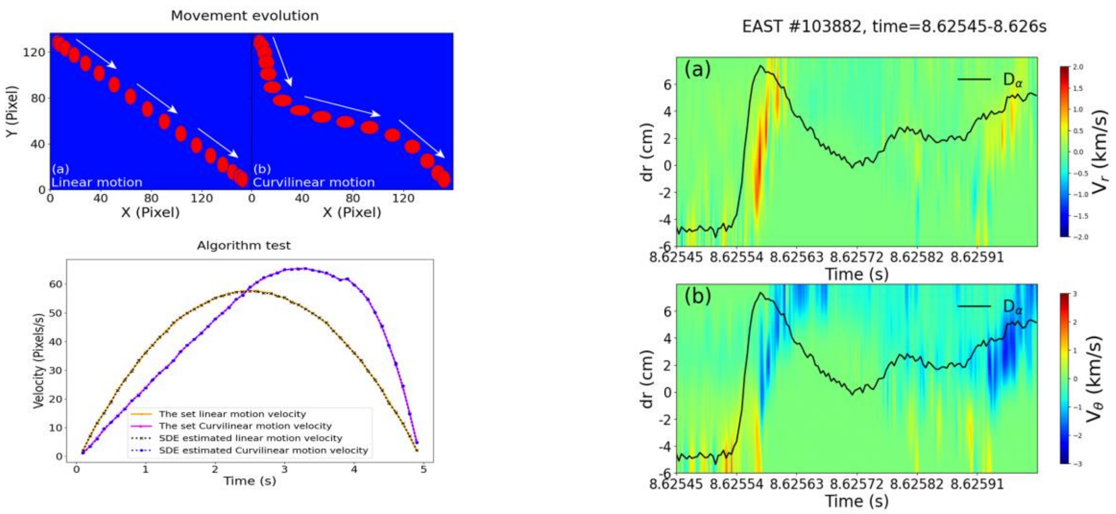

Figure 1. In the subgraph Movement evolution, (a) A linear motion; (b) A curvilinear motion. In the subgraph Algorithm test, The structure velocity for the straight and curvilinear motions calculated by the SDE method. The turbulence propagation velocities calculated by the TDE method for discharge 103882 (right). (a) Radial velocity, with positive value directed outside; (b) Poloidal velocity.