Fast modelling of turbulent transport using neural networks

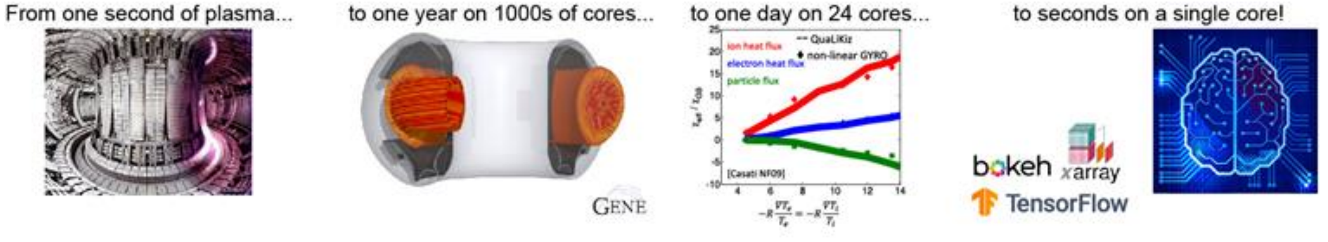
By combining a deep understanding of plasma physics with machine learning techniques, DIFFER researchers developed a new ultrafast neural network model of the turbulent plasma in a fusion reactor. The neural network can accurately predict heat and particle transport in the fusion reactor up to 100.000 times faster than before: a vital tool to optimize the performance of future fusion power plants. The prediction tool for heat and particle transport can also find applications in the following IPCs: for chemical and physical processes in general (stationary particles, moving particles, particles being subjected to vibrations or pulsations), where control of temperature is necessary

Description of the technology

Fusion reactors are fueled by a plasma: a hot, ionized gas of hydrogen isotopes that fuse together at extreme temperatures to form helium and release clean energy. The behavior of the plasma is not easy to predict: the charged plasma particles respond not only to the magnetic field that keeps them trapped inside the reactor, but also to the electromagnetic fields they create themselves through their own motion. That makes predicting a fusion plasma in order to optimize its state a difficult but rewarding problem to tackle.

Current nonlinear models to describe the complex turbulent behaviour of the plasma are very accurate, but require a lot of supercomputing time. Depending on how detailed the model is, this can range from 10.000 to 10 million CPU hours to simulate 1 millisecond of plasma behavior. Models with reduced physics complexity – but still valid for wide regimes in nuclear fusion plasmas – can predict tokamak plasma behavior within a few days using standard computers. By using neural networks, DIFFER-researchers Karel van de Plassche and Jonathan Citrin managed to reduce the simulation time even further, down to only a few tens of seconds.

DIFFER presents an ultrafast network model, QLKNN, which predicts core tokamak transport heat and particle fluxes. QLKNN is a surrogate model based on a database of 3 × 108 flux calculations of the quasilinear gyrokinetic transport model, QuaLiKiz. The database covers a wide range of realistic tokamak core parameters. Physical features such as the existence of a critical gradient for the onset of turbulent transport were integrated into the neural network training methodology. Differ have coupled QLKNN to the tokamak modeling framework JINTRAC and rapid control-oriented tokamak transport solver RAPTOR.



FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

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Innovation and advantages of the offer

The main interest of this technology is that simulations which take hours are reduced down to only a few tens of seconds. This considerable time-saving paves the way for extensive scenario design for fusion and non-fusion experiments, and speeds up the interpretation of the results. With fast and accurate simulations, it becomes possible to explore a larger operating space. You can even try more risky settings to find out what would happen if you go out of bounds.

Non-fusion Applications

The prediction tool for heat and particle transport can also find applications in the following IPCs: for chemical and physical processes in general (stationary particles, moving particles, particles being subjected to vibrations or pulsations), where control of temperature is necessary (particle spectrometers or separator tubes), electricity, medical preparations (emulsions, aerosols, foams, liposomes), fabrication procedures (mixing).

EUROfusion Heritage

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014–2018 and 2019–2020 under Grant Agreement No. 633053. Deployment of neural network surrogate models in multi-physics integrated tokamak modeling is a promising route toward enabling accurate and fast tokamak scenario optimization, uncertainty quantification, and control applications.

DIFFER has landed an Enabling Research grant from the Horizon2020 programme EUROfusion. The consortium between DIFFER, CEA Cadarache (France), and the Swiss Plasma Center, aims to significantly accelerate fusion reactor simulation through application of machine learning methods. DIFFER scientists in the Integrated Modelling and Transport group will receive EUROfusion support in 2019-2020 towards this goal.

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