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On the use of Synthetic Diagnostics as Persistent Actors in Integrated Modelling workflows

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Modelling the diagnostic signals for specific conditions of plasma operation is essential for an optimal and comprehensive analysis of the discharge behaviour and the preparation of the tools to design, optimize and validate scenarios on existing or future fusion devices.
This contribution gives a brief overview of the diagnostic models available in the Integrated Modelling and Analysis Suite IMAS [1] to model the ITER instrumentation systems. Some use cases will be described in which synthetic diagnostics are applied to perform physics data analysis and develop plasma modelling tools. A brief description of the use of diagnostic models in workflows doing Bayesian Inference analysis will be presented where the concept of persistent actor framework will be introduced. An emphasis will be made on using synthetic diagnostics to help the development of the ITER Plasma Control System (PCS) [2] and its Simulation Platform (PCSSP) [3] through the design of its support functions and the application of its control algorithms inside co-simulations combining IMAS models with Matlab/Simulink controllers. This type of co-simulation is made possible via the use of the Muscle3 coupling library within the so-called Persistent Actor Framework [4]. This framework facilitates the communication between various actors (models) in an integrated simulation across languages and domains. A closed-loop prototype will be presented where the plasma density measurement is simulated by an interferometer model that provides the signals through the real time data network (represented by the real_time_data Interface Data Structure or IDS) to a Matlab/Simulink controller. This controller in return sends a command, still through the real_time_data IDS, to a gas puff model that adjusts the gas injection. As such, an external source of particles is injected into a transport model, which evolves the plasma density accordingly.
Methods to extend this prototype to more sophisticated plasma simulators will be discussed, since the persistent actor framework can be used for co-simulations between PCSSP controllers and high fidelity or pulse design simulators, e.g. in the context of free-boundary control simulations for the validation and verification of models, workflows and controllers.

[1] F. Imbeaux, Nucl. Fusion 55 (2015) 123006
[2] J.A. Snipes, et al., Nucl. Fusion 61 (2021) 106036
[3] M. Walker, et al., Fus. Eng. Des. 96 (2014) 716
[4] L.E. Veen, A.G. Hoekstra, "Easing Multiscale Model Design and Coupling with MUSCLE 3", Comp. Science –ICCS 2020, 12142, pp 425-438, Springer, Cham.

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