Actuator Management in Tokamaks via Receding-Horizon Optimization

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For efficient and safe operation of reactor-grade tokamaks such as ITER, one of the main control-design challenges is the optimal management of the available actuators in order to fulfill the required control objectives. This is a particularly difficult problem due to the multitude of control tasks that share many of the device actuators. In addition, the appearance of off-normal events and exceptions (due to changes in the plasma state and/or actuator failures) normally makes off-line scenario planning insufficient and requires real-time optimization solutions.

Along the lines of previous efforts towards tackling this problem [1], this work proposes a novel actuator-management algorithm based on real-time optimization (see Fig. 1). The individual controllers send to the actuator manager high-level control requests, R_i, which are embedded into a finite receding-horizon optimization problem. This is done by equating R_i with its associated virtual-input function, F_i, which depends on the plasma state, x, actuator signals, u, and time t. Whereas the individual controllers compute R_i so that they fulfill their specific control goals, the main objective of the actuator manager is to find u so that as many of the control requests as possible are fulfilled. If all the constraints $F_i(x,u,t) = R_i$ cannot be exactly fulfilled simultaneously, then some of them are relaxed according to the relative priorities assigned to the control requests. At the same time, physical saturation limits are imposed on u, and a performance metric f is minimized over the prediction horizon. This metric f depends on the difference between the predicted and target states (i.e., it varies with x) as well as on the control effort (i.e., it varies with u). A key advantage of this scheme is that it allows for an independent high-level design of the controllers while ensuring their integration via optimal actuator allocation. The capabilities and performance of the proposed scheme are tested in one-dimensional simulations using COTSIM (Control Oriented Transport SIMulator).

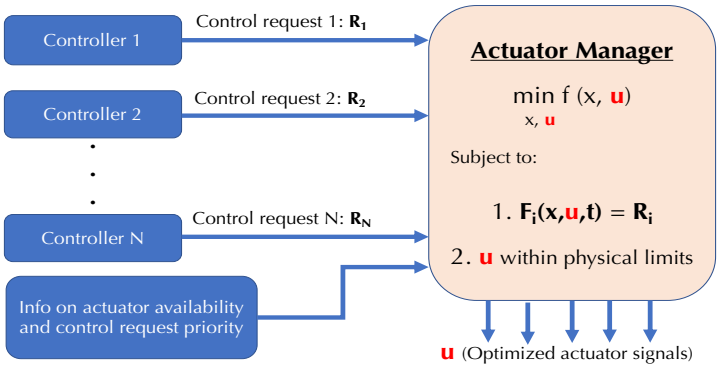

Figure 1: *Control architecture with actuator manager*

References

[1] A. Pajares and E. Schuster, *Actuator Management via Real-time Optimization for Integrated Control in Tokamaks*, in proceedings of the 46th European Physical Society Conference on Plasma Physics (2019)