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Full tokamak simulation global workflow case study

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Introduction

One of the main goals of the ITM is to provide a common vocabulary and framework amongst fusion research groups in Europe, in order to allow more efficient communication and collaboration. To do so, the ITM introduces two major concepts for tokamak modeling: Consistent Physical Objects (CPOs), which encapsulate tomakak-related data in an organised and common structure, and modular Actors, which encompass all possible actions on the CPOs.
The aim of this work consists of using this CPO-Actor approach around two full tokamak simulators, DINA-CH and RZIP, and draw conclusions as to the lessons learned from this exercise and the improvements required to the ITM data structure in order to make it fully adequate for such a task.

Statement of the problem

Prior status – DINA-CH

DINA-CH is a free-boundary equilibrium evolution full tokamak simulator. It is used as a black box in a Simulink diagram. The machine description, initial equilibrium, scenario, controller data, and all other relevant data are loaded from different files by a start-up script and fed to DINA-CH. The results are saved as a mat-file.
Two interface scripts, 'get' and 'put' were implemented, allowing interaction with the CPO-Actor framework and local or Gateway storage.

Overall prior status

While analysing the prior status of this workflow, the interactions between DINA-CH and RZIP appeared clearly. For example, the fact that DINA-CH required RZIP results for controller design was emphasised. Moreover, this analysis revealed the degree of intricacy of both workflows, and the fact that DINA-CH and RZIP data structures are different, separate, and sometimes inconsistent.

Prior status – RZIP

RZIP is a linear full tokamak simulator. It is used as a black box in a Simulink diagram. As for DINA-CH, all relevant data are loaded from different files via a start-up script, and the results are saved in a mat-file.

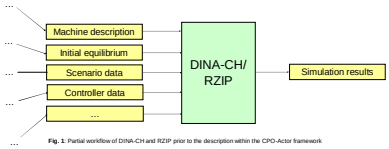


Fig. 1: Partial workflow of DINA-CH and RZIP prior to the description within the CPO-Actor framework

Usage example

A typical example of an application of this work would be the updating of the coil position in a tokamak. This is recognised to be a trivial, but unsolved problem.

Game plan

The goal of this work is to express the complete workflow of an RZIP simulation and a DINA-CH simulation lifecycle in terms of CPOs and Actors. The game plan consisted of the following:

1. Draw the CPO-Actor workflow *à la ITM*;
2. Create single data source for both DINA-CH and RZIP;
3. Evaluate the CPOs required for the new workflow;
4. Draw conclusions.

CPO-Actor framework

CPO-Actor workflow

When expressed in terms of CPOs and Actors, the RZIP – DINA-CH workflow is as shown.

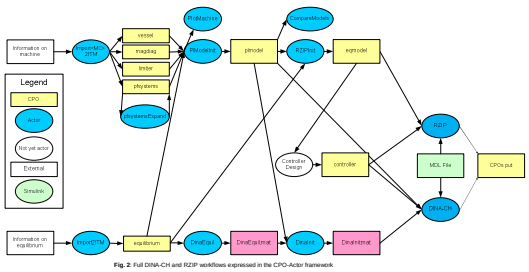


Fig. 2: Full DINA-CH and RZIP workflows expressed in the CPO-Actor framework

Areas perhaps needing attention

In the next phase, making remote access to the Gateway database available would add considerable value to the CPO-Actor approach, thus allowing users to interact with the database using the UAL, and any software (Matlab, Kepler, …).

Simulators as Actors

In this work, full tokamak simulators were treated as Actors, as they need not necessarily be split into smaller pieces. We also required the introduction of two additional CPOs in order to complete the workflow. They are:

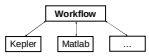
- *plmodel*: a plasmaless model allowing the description of the PF coil and surrounding systems using a vessel eigenmode decomposition or a filament description of the vessel;
- *eqmodel* an equilibrium model, including the plasma response.

During this work, some inconsistencies or incompleteness were also observed in existing CPOs:

- *pfsystems*: the description of passive structure did not allow the definition of a current passing through a vessel filament.

Higher level workflow

This work also revealed the possible usefulness of a higher level workflow description. At present, all this workflow was implemented in Matlab, but its translation to Kepler should be straightforward. This observation raised the question of a higher level workflow description, from which a Kepler workflow, a Matlab Simulink diagram, or the workflow of any other adequate tool could be generated.



Conclusion

The workflows of both DINA-CH and RZIP have been described using the CPO-Actor framework. This approach revealed itself to be simple and effective save some minor correction to the ITM data structure. Moreover, this method is surprisingly user-friendly, and provides quicker understanding of the underlying interdependences between simulators. It also provides a clear tracking of the origin of data.
In this work, full tokamak simulators were treated as actors, since they need not necessarily be split. This study also revealed the possible need of a higher level workflow description that would generate a Kepler workflow, a Matlab model file, or anything else that would be adequate.