Software Coupling and Orchestration Tool to the Modeling of Multi-physic Problems

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Abstract—We present in this paper Scot, which is a modular solution for weakly coupling models, methods and orchestration of the simulation. The goal behind this modular approach is to make easier the phase of modeling and to optimize the phase of simulation by tuning the solvers. Specifications and composition of Scot are exposed. To illustrate it, we have chosen the coupling of PEEC and MoM method to the modeling of an electromagnetic device.

Index Terms—Software component, weak coupling, PEEC and MoM method.

I. INTRODUCTION

The problem in the multi-physics modeling is that researchers attempt to model all the different parts of the system that don't appear from their research field, so the models they develop are often of poor quality and may contain many errors of modeling.

In this context, it appears interesting to improve the modeling of each physic by scientists in the same field of research, or to use specialized software to carry out the different models and then link them to rebuild the overall representation [1].

Scot (**S**oftware **C**oupling and **O**rchestration **T**ool) is a software tool with a modular architecture developed for the purpose of coupling weakly models, methods and specialized software. It includes some interfaces and makes easy to develop others as required. Models written in any language and embedded in Java, can be linked to Scot.

The test application concerns the modeling of a real electromagnetic device by coupling the PEEC (Partial Elements Equivalent Circuit method) and MoM (Method of Moments) method for respectively each of the electric and magnetic part.

II. SPECIFICATIONS OF SCOT

Coupling strategies are described in two ways in Scot; in the first, the models are implemented directly in Scot and both of the control and the simulation is done on Scot, however, in the second, there are two layers as shown in (Fig 1). The layer of supervision from where we configure and control the coupling and, the layer of simulation where the models exchange the unknowns variables.

When the desired convergence is reached, the layer of supervision calls the layer of simulation to get the results for post processing.
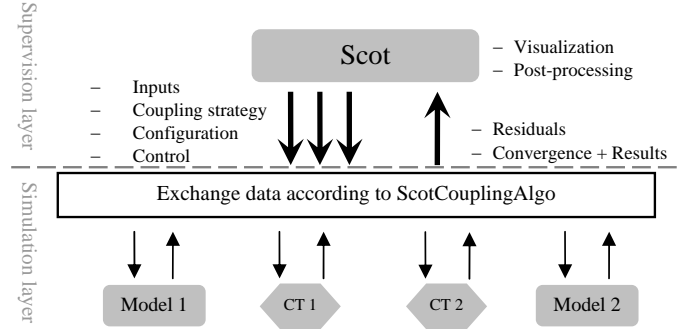

Fig. 1. General Scot Coupling scheme of two models using coupling terms.

A. Composition of Scot

1) variables: State variables, are tokens consumed or produced by an ScotComponent or ScotTransformer, characterized by its type (integer, real, boolean...), size, and value. Among Scot variables, there are also variables of configuration and control.

2) ScotComponent: Scot has two types of components. In the first one, the models are directly implemented on Scot, it contains specific solvers which will be tuned by the ScotCoupler regarding the ScotCouplingAlgo. The second one is an interface that allows controlling the external models simulation (Fig 2).
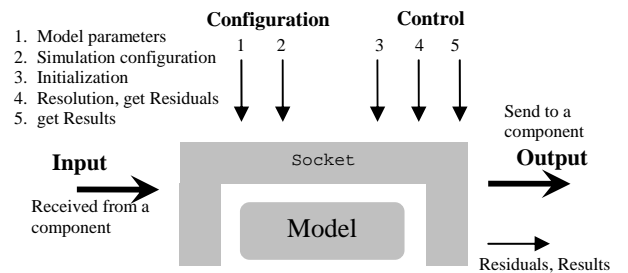

Fig. 2. Representation of Scot Coupling component, its parameters and interactions with Scot and other components.

3) ScotTransformer: Since the models are not necessarily designed to be coupled thus state variables produced by one model can not be consumed by another. In this case, it is necessary to use coupling terms "ScotTransformer". These

ScotTransformers may also be transition matrices to reduce the ordre of the state variables or, software that performs interpolation between different scale meshes such such as OASIS [2], MpCci [3].

4) ScotCoupler: At this level, we can specify the ScotComponents, ScotTransformers to build the different parts of the system and their coupling strategy (ScotCouplingAlgo).

III. COUPLING OF SCOT AND MATLAB

A Socket based communication is developed to couple and adapt the Matlab models to the ScotComponent (Fig 2), it contains 2 java classes and a ".dll" library. This ScotComponent Matlab caller implements 3 methods :

1) **Initialization** of the the Matlab models (build the models according to the model parameters).
2) **resolution** of the models and getting the residuals to test the convergence of the coupling.
3) **getResults** to recover the final results when the convergence criteria is achieved.

This Scot-Matlab interface has been used in the following test application.

IV. APPLICATION

We have chosen as an application the modeling of a micro-inductance [4](Fig 3) by coupling PEEC and MoM method to respectively model the electric inductance and magnetic materials in the devide.
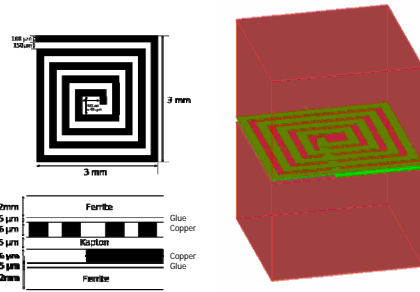

Fig. 3. Micro-inductance, composed by two magnetic regions (μ_r = 1000) and an electric inductance powered by a source voltage (V = 1volt, f = 1kHz).

The numerical model of the micro-inductance is given by the system of equations below (1).

$$\begin{cases} [MM] \cdot [\mathbf{M}] + [BS_m] \cdot [\mathbf{I}] = [0] \\ [Z_m] \cdot [\mathbf{I}] + [LF_m] \cdot [\mathbf{M}] = [V] \end{cases} , \quad (1)$$

where,

$[MM]$ Magnetostatic matrix, obtained with LOCAPI [5]
$[BS_m]$ Impact of the electric on magnetic, coupling term,
$[Z_m]$ Impedance matrix, obtained with INCA3D [6]
$[LF_m]$ Impact of the magnetic on electric, coupling term.

The resolution of the system (1) gives us the vector of material magnetizations [$\mathbf{M}$] and the electric current in the inductance [$\mathbf{I}$], according to the sources vector [V].

The model of the micro-inductance has been validated with the finite element approach in [4]. For the same results of magnetizations and electric current in the inductance, we have compared the time resolution of strong and tuned weak coupling regarding the number of unknowns (Fig 4).
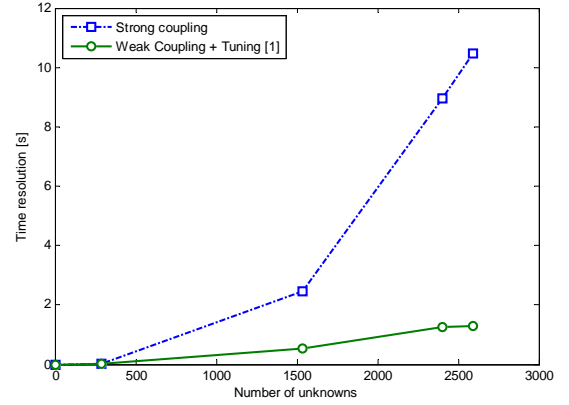

Fig. 4.   Curves of the time resolution regarding the number of unknowns.

The curves show that the simulation of the coupling system has found a good interest in orchestration, it has enhanced and sped up the convergence of the coupling.

V. CONCLUSION

Scot allows us to use the coupling strategies proposed in [1]-[3] and develop new efficient strategies to optimize the multi-physic systems simulation.

The concept of layers introduced in Scot minimises a lot exchanging data with the supervisor which vacates space memory and requests much less the processor. The architecture based software components of Scot promotes the reusing of models libraries and provides the modeling of multi-physic systems.

In the case application, we have used a static ScotComponent, our future research concerns the specification of dynamic ScotComponents to the co-simulation of temporal models with variable subcycling step time to accelerate and optimize these type of couplings.

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