Cyber-Physics Intrinsic Modelling for Smart Systems

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The studies of smart systems imply the systems with active and sensor-like capabilities, which fit within multiphysics framework. Of special interest here are studies of electro-magnetic-mechanical coupling. Such a coupling is a crucial step to achieve for giving life and intelligence to the passive materials which are usually being used to design majority of engineering components.

Coupled physical systems interact with each other and it is impossible to find a solution for one without solving the other at the same time. There are two main approaches for solving multiphysics problems - monolithic and partitioned. This work focuses on partitioned approach which is based on domain decomposition where two domains can be solved separately. The main advantage is that the standard discretization scheme that is most suitable for a particular sub-domain can be used. In this way, existing optimized codes can be used for each sub-domain and coupled only through the interface conditions.

The techniques presented for solving the contact problem between the fluid and the solid are the radial basis functions and the mortar element method. In fluid-structure interaction, the finite element method can be used for the solid and the finite volume method for the fluid. On the interface there should be a valid procedure to approximate the results between these two domains.

The other part of this work consists of electro-magneto-mechanical coupling as a multiphysics problem. Finite element method is used for mechanics and Whitney elements for electro-magnetic domain. The first step is to define theoretical formulations, then implement each formulation into the best possible code (based on the functionality of this code) and finally define the algorithm and technology to couple the different softwares to obtain the results.

Multiscale coupling for solving problems in mechanics can be achieved using the same software code executed parallel in several instances. Model is represented at two scales: macro and micro. Macro-scale represents the homogenized behavior of material for computing the global response and micro-scale allows us to capture the fine details of the microstructure. At both scales, finite element method is used, but different methods can be used for each scale. The goal is to achieve a more reliable interpretation of inelastic behavior mechanism, failure and plasticity models.

Solving the multiphysics and multiscale problems with a partitioned approach using existing software solutions can bring many benefits and deliver the results efficiently. Each of the software codes is already optimized for a specific domain. Parts of the codes can be executed in parallel and in that way improve execution time for constructing the final solution. With this approach, better quality solution should be obtained amenable for constructing higher order accurate solution needed for error estimates. The main focus that remains to achieve should be to guarantee stability, computational efficiency and robustness.