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Interface Relaxation Methods for the solution of Multi-Physics Problems¹

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Abstract

Multi-domain multi-physics problems simulate real world problems demanding efficient and high accuracy solutions. Domain Decomposition methods are well known methods that treat such kind of problems, but they first discretize the global problem (even if it is already partitioned by its physics) and then decompose it at the linear algebra level. Several techniques, mainly iteratively, are used to solve the set of the strongly coupled systems of linear equations that arise.

Interface Relaxation (IR) methodology is a different and relatively new way to study such problems. The idea behind IR is to confront the global problem as closer as possible to its nature by realizing and utilizing its basic properties and behavior. Subproblems arise either by the physics of the original problem or by computational and parallelization issues. These “small” problems are studied independently of each other and appropriate methods (FEM, FD etc.) are used for their solution. However these subproblems are coupled on the common interfaces so as to satisfy the conditions resulting from the global problem’s properties (e.g., continuity and smoothness of the solution of the global problem). Initial guesses are considered on the interfaces, passed as boundary conditions to the “small” problems. These are solved concurrently and the resulting approximations are used by an IR method to relax the value and/or the derivative to get better estimates of the solution on the interfaces. These new estimates are passed again as boundary conditions to the small problems and the procedure iterates until convergence is achieved.

When studying IR methods, one should consider issues from both mathematical analysis, computational complexity and software/hardware viewpoint. Mathematical analysis is often derived for model problems representatives of the original multiphysics applications since it is not possible and practical to get analysis for the realistic problems. A variety of software packages for the solution of simple non-multiphysics problems exist but they have to be combined under suitable software and hardware environments. Thus software reuse is of great importance when implementing IR methods.

In this review we consider the Interface Relaxation methods proposed for the solution of multi-domain multi-physics problems from both theoretical and implementation perspectives.

Key words: Interface relaxation, multiphysics problems, Elliptic PDEs, Parabolic PDEs, software reuse.

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