Computational Modelling Using Outer Loop Techniques, With Applications to Bio-Mechanics and Fracture Mechanics

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Abstract

The Grand Challenge Problems facing the world are now so complicated that their successful treatment using combined computational and experimental techniques often requires the use of computational schemes of Outer Loop form. By this we mean that the overall computation has an initial part where traditional numerical methods such as finite elements are employed in a Primary calculation. This is followed by another Secondary (outer loop) computation, where results from the primary computations are used in other numerical schemes to solve an additional part of the overall problem. Typically the outer loop parts can require the solving of inverse problems or the use of stochastic analyses. We first illustrate the use of outer loop schemes with an application for the acoustic localisation of coronary artery stenoses. For contrast we outline a problem to find the tensile strength of glass panels with surface fractures. Coronary Artery Disease (CAD) due to stenoses (partially blocked coronary arteries) is a world wide problem requiring ideally non-invasive methods for its detection, [1]. Our approach exploits the fact that, blood flow past a stenosis becomes disturbed, creating abnormal variations in wall shear stresses giving rise to acoustic waves. These can be measures on the chest surface with sensors, giving a non-invasive means of CAD diagnosis. To test the hypothesis we use a cylindrical phantom of tissue mimicking viscoelastic material (TMM) to represent the chest. Combined use is then made of computational modelling and experimentation; the computation treats the primary (forward) problem giving waves on the phantom surface. With this output mathematical inverse problems are then solved to locate wave sources within the phantom. In the primary problem high order spectral finite element in space and high order discontinuous Galerkin finite element discretisations in time are used. The linear systems of each time step are decoupled, see [2]. The localisation of the wave sources in the outer loop calculations is done using the Matlab fminsearch function. All the computational results are compared with others produced experimentally. In the second problem we aim to calculate the tensile strength of glass panels. This can be done using methods of computational mechanics when the panel surfaces are perfect, and similarly using computational fracture mechanics when the characteristics of surface flaws are known. Each of the above cases constitutes a primary computation. However, when the characteristics of the flaws are not known, following fracture computations stochastic methods have to be employed to provide the probability of failure of the panel. This latter is the outer loop calculation.

References

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