Computational Inverse Problems in Materials Characterization

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Direct estimation of material properties and their changes is many times infeasible, and even not desirable. For instance, in biomedical applications, it is of interest to estimate the mechanical properties of soft tissue in its natural, functioning state. In aerospace and civil structures, it is desirable to estimate changes in mechanical properties due to the onset of corrosion while the structure is in service. These and many other applications abound in engineering and science.

Indirect characterization of material properties can be cast as an inverse problem. Inverse problems arise when we observe the response of a system and try to infer the cause of this response from imperfect and partial information. Inverse problems are well known to present mathematical pathologies, which are encompassed in the common terminology of "ill-posedness." These problems may not have a solution, the solution may not be unique, and/or the solution may be very sensitive to errors in the input data. My work has focused in the last five years on the development and application of computational inverse problem techniques that tackle a range of inverse problems in applications related to damage identification, heat transfer, and vibroacoustics.

In this talk, I will give an overview of what inverse problems are, why they may be ill-posed, and computational techniques to approximate solutions of inverse problems. These techniques are drawn from the areas of statistical and machine learning, optimization, and numerical methods for the solution of partial differential equations, among others.
The talk will focus primarily on applications related to biomedical imaging. The first example will be drawn from viscoelastic characterization of soft tissue, and the second will address the problem of elasticity imaging. In both of these examples, the radiation force of ultrasound is used as the excitation, and acoustic fields are measured for reconstructing the inverse solution. At the end, if time permits, I will show my work-in-progress related to corrosion modeling and monitoring.