



McGill

Mechanical Engineering Colloquium

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Macdonald Engineering Building (MD) 267 from 11 - 12 pm

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Learning the Sparse Code of Solids with Anomalies

A Model-Agnostic Approach to Wave-Based Diagnostics

Abstract: In this work we illustrate an approach to structural and materials diagnostics revolving around the mechanistic reinterpretation of concepts and methods originated in the fields of image processing, computer vision and machine learning. In particular, we propose a pool of diagnostics techniques enabled by data learning algorithms and we investigate their applicability for anomaly detection in structural and material systems.

Anomalies and defects manifest in the dynamic response of a solid medium as a collection of salient and spatially localized events, which are reflected in the data structure of the response in the form of a set of behaviorally or topologically sparse features. We study two classes of methods, both exhibiting model-agnostic and baseline-free characteristics, i.e., requiring virtually no *a priori* knowledge of the medium's material properties and forsaking the need for any knowledge of the system's behavior in its pristine state. The agnostic attribute makes the methodologies powerful in dealing with media with heterogeneous or unknown property distribution, for which a material model is unsuitable or unreliable.

The first method exploits the concept of saliency and uses low-rank-plus-outlier models to identify regions of the domain that exhibit abnormal behavior, i.e., behavior that deviates significantly from the bulk response of the surrounding medium. The second method revolves around the construction of sparse representations of the dynamic response, which are obtained by learning instructive dictionaries that form a suitable basis for the response data. The resulting sparse coding task is recast as a modified dictionary learning problem with additional scarcity constraints enforced on the atoms of the dictionaries, which provides them with a prescribed spatial topology designed to unveil potential anomalous regions in the physical domain. The methods are validated using synthetically generated data as well as experimental data acquired using a scanning laser Doppler vibrometer.

Bio: Stefano Gonella received Ph.D. and M.S. degrees in aerospace engineering from the Georgia Institute of Technology in 2007 and 2005, respectively. Previously, he received a *Laurea*, also in aerospace engineering, from the *Politecnico di Torino*, Italy, in 2003. He joined the faculty of the Department of Civil Engineering at the University of Minnesota in 2010, after 3 years of post-doctoral and teaching experience at Northwestern University. His main research interests revolve around the modeling and simulation of complex wave phenomena in unconventional structures and materials, with emphasis on cellular solids, phononic and granular crystals, and acoustic metamaterials. Recently he has been interested in the development of new methodologies for structural and material diagnostics through the mechanistic adaptation of concepts of machine learning and computer vision.