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Detection of Sparse Damages in Structures

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Abstract

Structural damage is often a spatially sparse phenomenon, i.e. it occurs only in a small part of the structure. This property of damage has not been utilized in the field of structural damage identification until quite recently, when the sparsity-based regularization developed in compressed sensing problems found its application in this field.

In this paper we consider classical sensitivity-based finite element model updating combined with a regularization technique appropriate for the expected type of sparse damage. Traditionally, (I), l_2-norm regularization was used to solve the ill-posed inverse problems, such as damage identification. However, using already well established, (II), l_1-norm regularization or our proposed, (III), l_1-norm total variation regularization and, (IV), general dictionary-based regularization allows us to find damages with special spatial properties quite precisely using much fewer measurement locations than the number of possibly damaged elements of the structure. The validity of the proposed methods is demonstrated using simulations on a Kirchhoff plate model. The pros and cons of these methods are discussed.

Keywords: sparse damage; l_2-norm; l_1-norm; total variation; dictionary-based regularization, sensitivity

1. Introduction

This paper is devoted to identification of well-localized, or in other words, spatially sparse structural damages. In reinforced concrete structures, spatially sparse damage patterns can be associated with, for example, shear cracks. When such cracks develop, a brittle failure of the structure may be close — an inclined crack can find its way through a structure, without being prevented by reinforcement. It is of great interest to identify location and severity of such local cracks more precisely without smoothing the damage to the areas nearby and in this way to distinguish these cracks from other less severe cracks, such as e.g. bending cracks.

The damage identification methods presented here are based on the classical iterative sensitivity-based finite element model updating (FEMU) method combined with regularization techniques which help to detect damages with the expected properties [1-7].

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