7th International Conference on Seismology & Earthquake Engineering
18-21 May 2015
00658-SI

STRUCTURAL DAMAGE DETECTION USING BASIS PURSUIT AND EARTHQUAKE TIME HISTORY ANALYSIS

Saleheh GERIST
PhD Candidate, Dept. of Civil Engineering, Shiraz University, Shiraz, Iran
zgerist@gmail.com

Mahmoud Reza MAHERI
Professor of Civil Engineering, Shiraz University, Shiraz, Iran
maheri@shirazu.ac.ir

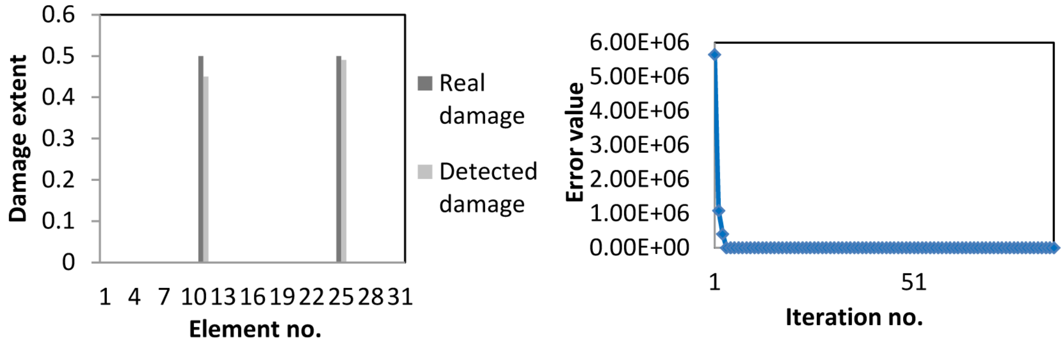
Keywords: Damage Detection, Basis Pursuit, Time-History Analysis, Monte Carlo

In this paper, a new method is proposed for structural damage detection using Basis Pursuit and earthquake time history analysis. In recent years a great deal of work has been carried out on development of methods to detect the location and extent of structural damage.A two stage method using basis pursuit and genetic algorithm was proposed (Gerist et al., 2012). In their method, the damage residual was first formed using the frequencies of real damaged and healthy structure to set a system of equations. The system of equations was then solved by basis pursuit (BP) method. In the final stage, they used the continuous genetic algorithm optimization method to improve the solution.

In structural damage detection problems to solve the set of equations, a set of damage variables should be found to equalize the analytical and measured responses of the structure in an optimal way. In classical theory of linear algebra, when measurements of an equation are fewer than unknowns, the problem is indeterminate and the solution is generally not unique. In principle, the solution vector, x, is known to be S-sparse and only S measurements are required to reconstruct it rather than the number of structural elements, *n*. Three criteria are related to the notion of sparsity: the l_0 , l_1 and the l_2 norms of **x.** The l_0 norm is the unique sparsest solution. Computation of l_2 minimization, which is in fact the least square solution, is efficiently less time-consuming than l_0 . But however, the result of l_2 minimization doesn't match the one that of l_0 . A new convex and tractable approach is presented as Basis Pursuit which uses l_1 minimization to solve the problem (Chen et al., 2001).

In this paper, the sensitivity matrix of structural responses with respect to elemental damage is established to be solved by BP method. The Simplex method is chosen as a linear programming method to solve the system of equations. The process detects the damage locations and extents using the time-history responses of structure. The efficiency of the proposed method is investigated using Monte Carlo simulation. The proposed method is applied to a cantilever beam and a planar truss.

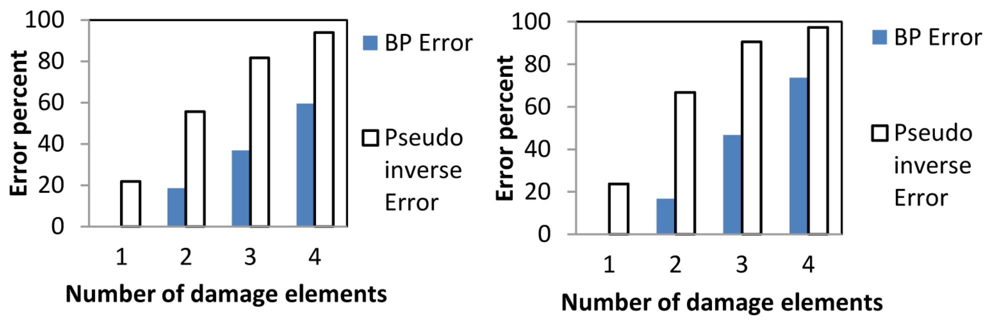
A 31-bar planar truss which has been studied by Messina et al. (1998) is selected to demonstrate the capability of the proposed algorithm. The Bam earthquake and average acceleration method is used for time-history analysis. The 11^{th} and 25^{th} elements of the planar truss are both considered to be damaged by the extent of 50%. The process results are shown in Figure 1. As it can be seen, the proposed method detects the damage elements efficiently.



(a) Damage identification results (b) Convergence history of basis pursuit

Figure 1. Solution results for the 31-element planar truss

The Monte Carlo simulation results with 10000 times run are shown in Figure 2. The damage extents of the elements affect the results of the BP method and the error percents increase by increasing the damage extents by BP method. The error percents of BP method are considerably less than the Pseudo-Inverse method (PI) for low number of damage elements.



(a) Damage extent is 20% (b) Damage extent is 30%

Figure 2. Monte Carlo results of Basis Pursuit and Sparse methods for 15-element beam

Also, run time of the proposed method is significantly less than CGA-SBI-MS (Naseralavi et al., 2010) and BP-CGA (Gerist Naseralavi et al., 2012) as shown in Table 1.

Table 1. The run time of 31-element planer truss

	First stage time (sec)	Second stage time (sec)	Total time (sec)
BP-CGA	6.46	7.03	13.49
CGA-SBI-MS	-	-	43.04
Proposed method	-	-	4.68

REFERENCES

Chen SS, Donoho DL and Saunders MA (2001) Atomic Decomposition by Basis Pursuit, *Society for Industrial and Applied Mathematics Review*, 43(1): 129-159

Gerist S, Naseralavi SS and Salajegheh E (2012) Basis Pursuit Based Genetic Algorithm for Damage Identification, *International Journal of Optimization in Civil Engineering*, 2(2): 301-319

Messina A, Williams EJ and Contursi T (1998) Structural Damage Detection by a Sensitivity and Statistical-Based Method, *Journal of Sound and Vibration*, 216(5): 791-808

Naseralavi SS, Salajegheh J, Salajegheh E and Fadaee MJ (2010) An Improved Genetic Algorithm Using Sensitivity Analysis and Micro Search for Damage Detection, *Asian Journal of Civil Engineering*, 11: 717-40