

Benefits of Implicit Redundant Genetic Algorithms for Structural Damage Detection in Noisy Environments

Anne Raich and Tamás Liszkai

Texas A&M University, Dept. of Civil Engineering, College Station, Texas, 77843, USA
{araich,tamas}@tamu.edu

Abstract. A robust structural damage detection method that can handle noisy frequency response function information is discussed. The inherent unstructured nature of damage detection problems is exploited by applying an implicit redundant representation (IRR) genetic algorithm. The unbraced frame structure results obtained show that the IRR GA is less sensitive to noise than a SGA.

1 Unstructured Problem Domain of FRF-Based Damage Detection

The goal of structural damage identification methods (SDIM) is to accurately assess the condition of structures. Most SDIMs assume that vibration signatures are sensitive indicators of structural integrity. In this research, FRF data was used to identify the location and severity of damage. An optimization problem was defined using an error function between the measured data and the discrete analytical model. Although the total number of structural elements typically is large, the number actually damaged is smaller. This unique situation defines an unstructured problem, in which the number of damages is unknown. The optimization problem is solved using genetic algorithms (GA) by altering member properties. A damage vector is obtained that identifies the location and severity of damage(s) in the structure. This formulation requires minimal measurement information. A comprehensive review of model parameter updating methods is provided in [1]. Two GA representations were investigated (Fig. 1). A fixed number of variables were encoded using a SGA representation to represent a complete solution by defining a damage indicator for each element. The IRR representation [2] considered the unstructured nature of damage detection by allowing the number of damaged elements to change during optimization, which is beneficial when the number and location of damages are unknown. A complete solution is encoded using only the damages for a small subset of the elements, instead of all elements.

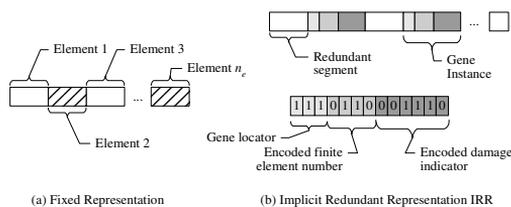


Fig. 1. Comparison of design variable encoding for SGA and IRR GA representations

2 Results of Cases Studies with Added Measurement Noise

Case studies were performed on a three-story, three-bay frame with 10% damage imposed on a first floor beam (Element 21). Three measurement locations and an excitation at the upper story were used to generate the simulated FRF data. Four noise levels were investigated by adding normally distributed random noise to the FRF data. A more detailed discussion of the case study and results is provided in [3]. Results obtained for the IRR GA trials after 300 generations are shown in Fig. 2. Without noise, the IRR GA found the global optimum in 241 generations. For all noise levels, the correct damaged element was identified with close to the exact 10 % damage value. The number of falsely identified elements with observable damage magnitude increased as the noise level increased.

The IRR GA outperformed the SGA in all trials. The SGA encoded all of the damage indicators in the finite element model. Therefore, the number of falsely identified damaged elements was large. In comparison, the adaptive characteristic of the IRR GA was beneficial since the number of damage indicators was not explicitly encoded. The IRR GA determined the number of damaged elements while minimizing the error function. For the noise free case, the best IRR individual initially encoded 15 gene instances, while the best IRR individual in the final population encoded 3 gene instances. One instance identified the correct damaged element and two others instances identified an element with zero damage. When noise was added, the number of gene instances changed from 15 in the initial population to 8-10 in the final population. In a noise free environment, the global optimum was always found. Overall, the IRR GA was considerably less sensitive to measurement noise compared with the SGA. Even on larger problems, the IRR GA was able to identify the damaged elements. Seeding the initial population with the zero damage individual was not necessary for the IRR GA to find the optimal solution, but was beneficial in many trials.

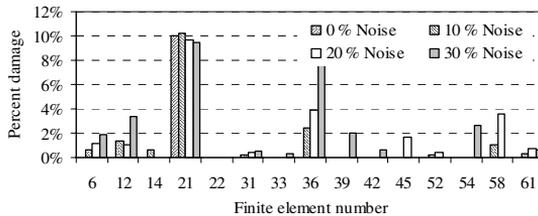


Fig. 2. Damage detection results for the frame problem (Element 21 - 10% damage)

References

1. Mottershead, J.E., Friswell, M.I.: Model updating in structural dynamics: A survey. *Journal of Sound and Vibration* 167(2) (1993) 347–375
2. Raich, A.M., Ghaboussi, J.: Implicit redundant representation in genetic algorithms. *Evolutionary Computation* 5(3) (1997) 277–302
3. Liszkai, Tamas R.. Modern heuristics in structural damage detection using frequency response functions. Ph.D. Dissertation, Texas A&M University (2003).