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DAMAGE DETECTION OF SKELETAL STRUCTURES BY AN ENHANCED META-HEURISTIC USING MODAL DATA

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Damage detection of structures is a rewarding task in many fields of engineering. One important application may be vulnerability analysis of a building system after undergoing unusual/severe loading such as destructive earthquakes. The natural period of structure is very important in evaluating its dynamic behaviour. Particularly, the period shifts due to repeating aftershocks (Schaff et al., 1998), can be utilized within a quantitative index to measure vulnerability and pursue rehabilitation of a damaged building. A common approach to localize and determine severity of the damage in a structure is formulating it as an inverse problem (Friswell, 2007; Kaveh and Zolghadr, 2015). It means generating alternate structural models with different damage states and seeking for the one that coincides with the actually-damaged structural condition. The present work applies such an approach via an optimization problem to find the best match of structural properties with the given damage state. The first treated cost function is thus defined as an error-sum over the difference between the consequent modal properties (Equation 1).

$$Min\ Err = \frac{1}{2\pi\ n}\sum_{j=1}^{n}\left|\omega_j^a - \omega_j^p\right| \tag{1}$$

where ω_j^a and ω_j^p denote the actual and predicted frequencies of the j^{th} mode, respectively. Traditional gradient-based methods are generally sensitive to their starting point and may simply get trapped in local optima regions. Meta-heuristic algorithms are well-known alternative solutions as they take advantage of intensification and diversification operators to explore true global optimum (Kang et al., 2012; Kaveh and Zolghadr, 2015; Shahrouzi and Sabzi, 2018; Yu and Wan, 2008).

In this regard, the present works concerns Teaching-Learning-Based Optimization and Jaya as widely applied methods for engineering problems (Rao, 2016a; b). An enhanced variant of Jaya is also proposed by embedding it a passive congregation operator. Performance of the proposed hybrid algorithm is then compared with TLBO and Jaya in a number of literature benchmarks including truss and frame examples with different damage scenarios (Kang et al., 2012; Kaveh and Zolghadr, 2015; Sedaghati, 2005).

As an illustrative example, well-studied 72-bar truss (Figure 1) is treated here with a damage scenario of 15% stiffness lost in the element number 55. Table 1 reports statistical results over a number of trial runs. As can be noticed, the proposed method has revealed better mean and median results than the others with considerably lower standard deviation that confirms the higher succeed rate. Figure 2 exhibits superiority of the proposed algorithm over Jaya and TLBO in

Table 1. Results of damage detection for 72-bar example by different algorithms.

Method	Mean cost	Median cost	Standard deviation	Succeed Rate (%)
JayaPC	8.09340e-07	1.72384e-08	1.6971716e-06	80
Jaya	814.19065	0.00521	1767.140	10
TLBO	114.01239	81.16887	113.995	0

overpassing local optima and stable convergence toward global optimum. It is while the required CPU times are in the same order. Therefore, the proposed algorithm seems affordable in capturing true damage state of such skeletal structures.

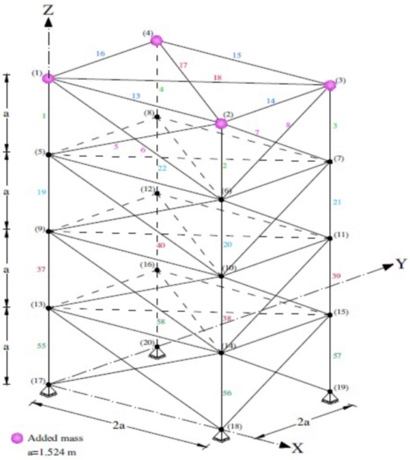
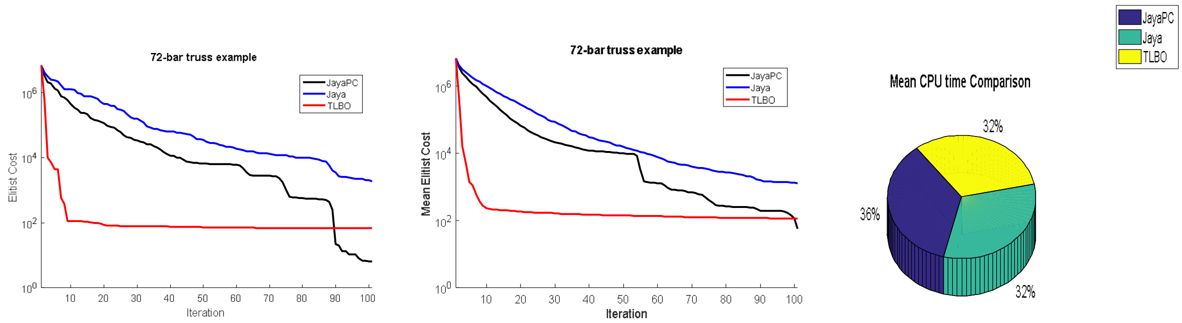


Figure 1. The 72-bar truss example (Kaveh and Zolghadr, 2015).



(a) (b) (c)

Figure 2. Comparison of the treated algorithms in 72-bar example: (a) the best cost, (b) mean cost, (c) CPU time.

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