

ABSTRACT

Since the first half of the last century, the scientific community was fascinated by the potentiality of structural optimization as an efficient tool to solve hard computational problems. Moreover, the need of adopting these strategies became more evident when traditional approaches and thumb rules derived by experience appeared to be insufficient to face society's new challenges for which counter-intuitive solutions and innovative methodologies were required. In a wide variety of fields, benefits derived from the development of this branch is worth of noting. Ranging from mechanical engineering to aerospace, from civil engineering up to architecture, and again from the biomedical field to medicine the effectiveness of optimization strategies has been widely demonstrated.

Especially, civil engineering seems to be benefited the most by the growth of this branch. Bold and unusual layouts of buildings with optimal structural and economic cost-impact or new sustainable solutions represent still nowadays the main target of this subject. Therefore, soft computing techniques results to be extremely useful for the identification of optimal properties of control devices, retrofitting systems and monitoring methodology applied to existing buildings.

At first, once the goodness of the results derived by optimization processes was largely proved for simple application case studies, an increasing complexity was addressed and the main focus moved towards the identification of the most efficient and robust methods for achieving the global optimum of the problem. Different deterministic or heuristic methods appeared in literature aiming to guarantee feasible solutions with high efficiency during the exploration phase as well as accuracy during the exploitation one.

When a certain level of maturity was achieved and a deep awareness of the most promising techniques has been attained, conventional optimization strategies for the assessment of the optimal solution in terms of least structural cost (i.e. weight or volume), highest performance rates, as well as competitive economical cost, have given way to problem statements in which constructability issues or practical design problems were accounted. The gap between theoretical approaches and practical ones represents the last obstacle to large-scale deployment in the common design of new or existing structures.

The goal of this thesis is to pursue this scope by showing how problems during industrial production processes or practical issues during the design and construction phase can be solved for a specific class of structures like steel trusses and frames. In order to deal with these problems efficiently, various already existing algorithms and novel methodologies were developed. If the first part of the thesis was dedicated to showing the improvement derived by coupling well-known optimization techniques with more efficient search strategies, the second part is focused on interesting applications where structural complexity during the assembly process or cutting pattern of steel members at the production stage become the variable parameters to be optimized.

The dissertation consists of eight chapters in total, plus the bibliography and three appendices that for clarity purposes were placed at the end of the corresponding chapter.

It is organized as follows: Chapter 1 provides an overview of the optimization strategies in which all the most interesting papers were classified into sub-categories and the most significant information for each contribution was summarized in thematic tables. Chapters 2 and 3 deal with the formulation of a new machine learning approach for non-penalty constraint handling in evolutionary algorithms and the

introduction of novel enhanced PSO with a Multy-Strategy Implementation, respectively. Optimal strengthening by steel truss arches in prestressed girder bridges is presented in Chapter 4 while in Chapter 5 results obtained by the size and shape optimization of a Guyed Mast Structure are illustrated. Problems related to constructability constraints for optimal sizing, geometry and topology of industrial buildings and the use of cutting stock problem in truss beam optimization are discussed in Chapters 6 and 7, respectively.

Finally, Chapter 8 contains the conclusions, the original contribution of the thesis, and directions for future research.