# Optimum Design of 2D Truss Structures with PSO and SAP2000

**Ioannis Iliadis[1*], Vagelis Plevris[2], Manolis Papadrakakis[1]**

[1]Institute of Structural Analysis & Antiseismic Research
School of Civil Engineering, National Technical University of Athens
Zografou Campus, Athens 15780
{iliadis,mpapadra}@central.ntua.gr

[2]Department of Civil Engineering
School of Pedagogical & Technological Education (ASPETE)
ASPETE Campus, Heraklion GR 14121, Athens, Greece
vplevris@aspete.gr

## ABSTRACT

The Particle Swarm Optimization (PSO) method is based on the behavior reflected in flocks of birds, bees and fish that adjust their physical movements to avoid predators and seek for food. In PSO, as in the Genetic Algorithm (GA), a population of potential solutions is considered and utilized to search within the design space. However, its members do not reproduce but rather communicate with each other their knowledge of solutions in order to reach the optimum. Each particle "flies" through the multi-dimensional design space, with a certain velocity for each iteration, in search of the optimum value of the objective function.

In the present study, a PSO algorithm is employed for the optimization of 2D truss structures. The problem considered is a single-objective, continuous, constrained structural engineering optimization problem where the aim is to minimize the weight of a truss structure given certain loading conditions, under various constraints on node displacements and truss member stresses.

The constraints are checked by performing a Finite Element (FE) analysis for every candidate optimum design. For this purpose, the analysis software SAP2000 has been employed and in particular the SAP2000 Application Programming Interface (API), a programming tool which aims to offer efficient access to the analysis and design technology of the SAP2000 structural analysis software by allowing, during run-time, a direct bind to be established, between a third-party application and the analysis software itself. The API consists of a software library that offers access to a collection of objects and functions capable of "externally" controlling the way that SAP2000 behaves, thus, overriding the standard point-and-click input procedure.

Using the API, one can perform complex and difficult modeling and analysis, without having to use the program's graphical user interface at all, thus significantly expanding the usage of the application into wider research fields beyond the standard structural analysis framework. In the present study, SAP2000 is used in order to perform the FE analysis which is essential for the constraints check of the structural optimization problem. During PSO optimization, the optimizer creates candidate designs (the current members of the population) that are then fed as inputs to SAP2000, serially, one at a time. The latter in turn performs the analysis for each individual and returns the results which now act as inputs for the optimizer. In every iteration the optimizer evaluates the population set using a penalized objective function, creates a new population and this procedure is repeated until the maximum number of PSO iterations is achieved.

Two test examples are considered, namely a simple 3-bar truss with two design variables and a 10-bar truss with 10 design variables, which is considered a standard benchmark engineering optimization problem. The results were compared to the corresponding results in the literature and it was found that for both problems the optimizer managed to produce excellent results in terms of optimum objective value achieved, while the convergence speed was also found to be satisfactory. The results show the great potential of using the SAP20000 API as a supplementary tool for engineering research purposes and particularly structural optimization.