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Review of Particle Swarm Optimization for Truss Structure

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Abstract

In this paper reviewed, the weight optimization of truss structure under displacement and stress constraints using Particle Swarm Optimization (PSO). It is a heuristic global optimization method which is inspired by social habits of fish schooling and bird flocks. PSO combines self-experience of individual and social experience of global population. In this technique the cross sectional area used as a design variable and which is continuously valued after few iteration to get optimal position.

Key Words: Particle Swarm Optimization, Truss Structure, Shape and Size Optimization.

Introduction

Truss-structure optimization has been an effective area of research in the field of optimization and search. Particle Swarm Optimization (PSO) algorithm is initialized by Dr.Kennedy & Dr.Eberhart in 1995 which is used for nonlinear optimization problems [(3)’]. This methodology implies that design iteration may be analyzed with greater confidence and doubtless at each step will created simpler.

PSO used in various engineering application such as route optimization in transportation engineering, to find best yield in agricultural engineering, to calculate best composition of fibers of concrete, to get optimal shape and sizing of the RCC and steel structures, to find minimum cost of the structure and topology optimization.

Optimization of Structure

Structural optimization aims at achieving the best structural performance by minimizing weight of structures under displacement, kinematic stability and stress constraints [(6)]. The design variables include geometry parameters (cross sectional area, position, etc.) and material parameters (density, Young's modulus, etc.). Initially the deflection and stresses of the structure is calculated by stiffness matrix analysis and checked whether which satisfied the constraint or not. The structure is optimized by changing cross sectional area of the member and finding appropriate best combination of sections for the structure.

Particle Swarm Optimization

PSO has processed by swarm intelligent such as bird flocks, fish schooling, etc. The social behavior of birds is copied and every individual particle exchanges their information to neighborhood about their fitness, velocity and position [(7)]. When movement of the particle at every time each particles has some best values that's called personal best value and in whole population one particle has best value then others which is called global best value. At every time, change of position it memories their solution to take better decision in future.

Algorithm

The PSO idea comprises of, at each time step, modifying the velocity of (accelerating) every particle towards its pbest and lbest position (nearby form of PSO). Acceleration is computed by a random particle, with independent random numbers being created for acceleration towards pbest and lbest position.

The particle swarm optimization consists of two terms, one is velocity and another one is position.

$$v_{n+1} = v_n + c_1 rand1(\,) * (p_{\text{best,n}} - \text{CurrentPosition}_\text{n}) + c_2 rand2(\,) * (g_{\text{best,n}} - \text{CurrentPosition}_\text{n})$$

v_{n+1}	:	Particle velocity at *n+1* th iteration
V_n	:	Particle velocity at *nth* iteration
c_1	:	factor of acceleration belonged to gbest
c_2	:	factor of acceleration belonged to lbest
rand1( )	:	random number (0 to 1)
rand2( )	:	random number (0 to 1)
gbest	:	swarm global best position
pbest	:	particle personal best position

Position[*n+1*] = Current Position [*n*] + *v*[*n+1*]

current position[*n+1*]: particle position at *n+1th* iteration
current position[*n*]: particle position at *nth* iteration
***v*[*n+1*]:** particle velocity at *n+1th* iteration
For each particle
Initialize particle by generating random numbers
End
Do For each particle
Compute the value of fitness

If the value of fitness is greater than the best value of fitness (**pbest**) in population.

Fix current value as a new **pbest**

End

Select which particle has best fitness value of all the particles as the **gbest**

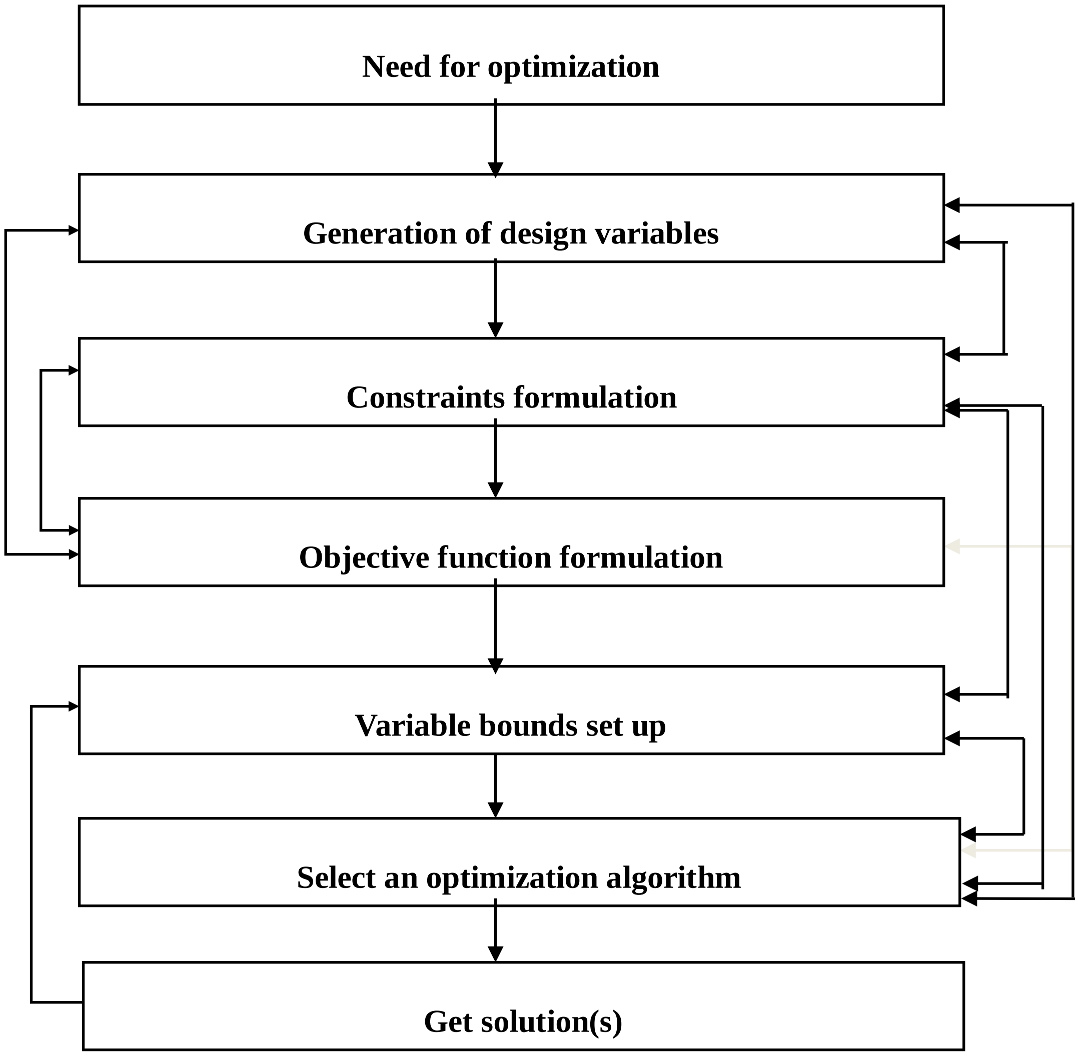
For each particle

Manipulate velocity of particle according to equation of velocity update Positions of particle updated using equation of position update

End

While minimum error criteria or maximum iterations is not occurred

Flowchart of Optimal Design Procedure



Literatures

Dimou et al. (2009) proposed on Particle Swarm Optimization used for Reliability-Based Optimal Design of Structures [(1)]'. Structural elements analyzed and Ditlevsen bounds used to calculate reliability index. Presented result for 30 bar arch and 25 bar truss. RBOD justified both optimization and reliability analysis.

Fourie et al. (2002) investigated on size and shape of structural optimization using Particle Swarm Optimization algorithm and implemented PSOA the social habit of swarm is mimicked [(2)]'. Introduced new terms namely elite velocity and the elite particle. PSOA is compared with genetic based algorithm and three gradient methods. Attained approximate optimal result and suggested PSOA is superior to genetic algorithm and comparable to gradient based algorithms.

Kesav et al. (2009) investigated on truss structure optimization using hybridization of ant colony strategy, PSO and harmony search (HS) scheme [(4)]'. Heuristic Particle Swarm Ant Colony Optimization (HPSACO) based on ant colony optimization, harmonic search scheme and particle swarm optimization with passive congregation (PSOPC). PSOPC used for global optimization problems and ant colony used for particles upgrade their position to get feasible solution. HPSACO has faster convergence than PSOPC and PSO.

Li et al. (2007) explored the paper on an improved particle swarm optimization (IPSO) for truss structure [(5)]'. The improved particle swarm optimization algorithm based on Harmonic Search (HS) Scheme and Particle Swarm Optimization which handles the issue determined limitations by a fly bird mechanism concept and variables. The IPSO was tested on planer truss structure and compared with Particle Swarm Optimization with Passive Congregation (PSOPC) and Particle Swarm Optimization (PSO). The IPSO methodology has quickest convergence rate among these three different algorithms.

Tong et al. (2001) investigated on an optimization problem for structures with dynamic constraints and discrete design variables [(8)]'. The weight minimization with discrete variables for truss structure with respected to the constraints on frequencies, stresses and natural frequency responses. Initially found the feasible basic point though determining global constraint function after that found design variables discrete value by estimating the design different part at basic effective point. The discrete truss structure weight minimization examples are presented.

Tong et al. (2000) discussed on frequency constraints is used to optimize the structure [(9)]'. The theory implies when a truss is modified uniformly the natural frequencies remain unchanged and when finding the result of truss structure. The natural frequency is used as a key constraint. Presented numerical examples based on the theory and finally found optimal solution.

Wang et al. (2004) proposed a paper on truss structure optimization for shape and sizing with natural frequency constraints author used three dimensional truss structures applied multiple constraints on natural frequencies [(10)]'. The element cross sectional areas and nodal coordinates has various type of nature and treated at the same time in a unified design for structural weight minimization. Introduced global sensitivity numbers to find multiple frequency conditions and neglecting Lagrange multiplier computation. Finally identified most appropriate variables and changed in priority. The optimal result obtained gradually from initial design.

Zeng et al. (2012) presented particle swarm-group search algorithm and its various applications to spatial structural design with discrete variables [(11)']. Combined group search algorithm and Particle Swarm Optimization algorithm found a new hybrid algorithm namely particle swarm group search algorithm which is used to analyze the spatial truss structures with discrete variables and compared with other truss optimization problems. Result shows particle swarm group search algorithm has effective faster convergence rate than particle swarm algorithm, hybrid particle swarm algorithm and group search algorithm.

Conclusion

Reviewed papers on particle swarm optimization algorithm for truss structures from that understood which is used in many engineering application. It is a swarm based algorithm and one of the effective simplest algorithm. In structural engineering which is used to optimize size and shape of RCC and Steel structures. In most of the truss structure optimization 10 bar simple truss is used as a bench mark truss then authors are verified their results by the bench mark truss and implemented the algorithm to their structure. PSO algorithm has been combined with other optimization algorithms and authors generated new hybrid algorithms. The hybrid algorithms perform better than single algorithm and also which has faster convergence rate.

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