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Weight Optimization of 3D Steel Trusses using Genetic Algorithm

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Abstract - Weight optimization of trusses is very important due to economic considerations. This paper presents optimum design of plane and space trusses using genetic algorithm. The objective function of the optimization problem is the total weight of the truss with displacement constraint. In this study rank based selection is used to minimize the number of iterations to reach the optimum solution. Algorithm for weight minimization of steel trusses has been developed in SCILAB using Genetic Algorithm. Genetic algorithm is a natural selection search method intended to combine good solutions to a problem from many generations to get best results. First generation is selected randomly and then crossover and mutation is applied. All the chromosomes are represented individually by a binary string and hence it is termed as Genetic programming. The algorithm was applied on a reference book problem and result in more optimized results with lesser mathematical effort.

INTRODUCTION

The material cost is one of the main factors in the construction of structures, the main objective of structural optimization is to save the material and hence the cost. it can be minimized by reducing the weight or volume of the structure. Genetic Algorithm is an oldest evolutionary algorithm which uses concept of Darwin's evolution and uses words like chromosomes, genes, selection, fitness, crossover, mutation etc. Genetic Algorithm is a search-based optimization technique based on the principles of Genetics. It is used to find optimal solution to difficult problems unlike other conservative techniques which take long calculations and time.

Truss optimization can be classified in to three categories: Topology, size and shape, this is a size optimization study, Size optimization deal with optimal cross section areas of the truss members where all the nodal locations are fixed unlike in topology optimization.

In this study a SCILAB code is developed using Genetic Algorithm, where objective function is weight of the truss and constraint is nodal deflection. The analysis of the truss is done using Stiffness Matrix method in the code itself, Programming is done using binary values.

Generally, the self-weight of the truss is being neglected in truss analysis because of very less impact compare to large nodal loads and less impact on the nodal deflections, but in the case of optimization maximum strength of the member is used and even less load will impact the structure, hence self-weight of the member is included to the nodal loads and distributes the self-weight of the member to its two end nodes equally.

GENETIC ALGORITHM

1. SELECTION

There are several methods of selection in genetic algorithm from that Rank selection is used, in rank base solution all the populations are ranked based on their fitness and best two solutions are carried forward to the next generation, this will give the optimum solution earlier than the normal method. and rest of all populations are reproduced using crossover and mutation.

2. CROSSOVER

With the hope of finding better solution individuals are crossed with the other individual and new children are derived from parents.

Multipoint crossover is used with 50% crossover probability, because bit size is set to four considering available sections in IS code, so every member of the truss is changed in next generation.

3. MUTATION

The purpose of the mutation is to maintain the diversity of the individuals and prevent the algorithm to stuck in to local minimum. Random mutation is picked up with 5% mutation rate.

POPULATION SIZE

Population size is selected based on the complexity of the problem and available computer power and time, with bigger population size computational effort and time in increased. Of course, more the population size earlier optimum solution can be derived, for present case population size is set to 20.

Weight is minimized using GA with parameters as below:

Population size 20, Generations 100, 0.5 crossover and 0.05 mutation probability.

The Algorithm is encoded with bit-string type, in which bit size is set to four to meet the available sections which are described by Indian standards.

The maximum area of the section is set 14 in^2 for the initial population.

6 Bar Truss

This is a bench mark truss used in most of the optimization problem for 2D approach.

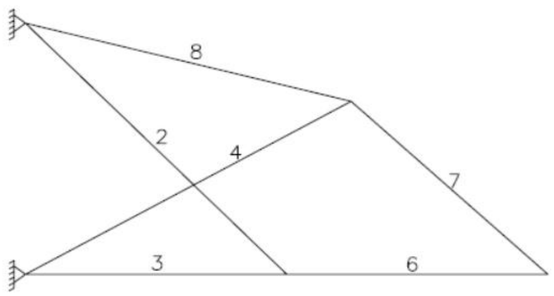

Fig 1: 6 bar truss

This is an optimized truss of 10 bar truss in which topology optimization is applied and it became 6 bar truss, our algorithm is based on weight optimization so optimized truss is picked up and solved using the algorithm.

As shown in figure the 6-bar truss has 5 nodes with 2 hinges and 2^{nd} and 3^{rd} nodes are having load of 1*10^5 lbs load on each node.

Aluminum truss with modulus of elasticity E =68.95 GPa and density, ρ = 2,768 kg/m3 (0.1 lb/in3) and the displacements are limited to 2 inches in both direction.

RESULTS

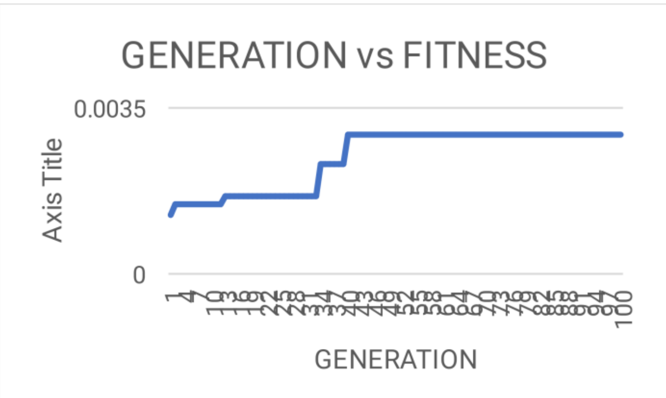

Chart 1: Generation vs Fitness

The chart shows that the fitness is getting increased as the generation increases and after generation reaches around 40 it became constant which shows optimal or nearer optimal solution is derived.

In this algorithm population size is set to 20, if it is increased then optimal solution can be derived in less generation.

25 Bar Truss

Developed Algorithm is applied on a 3D bench mark problem of truss optimization which is generally found in most of the researches

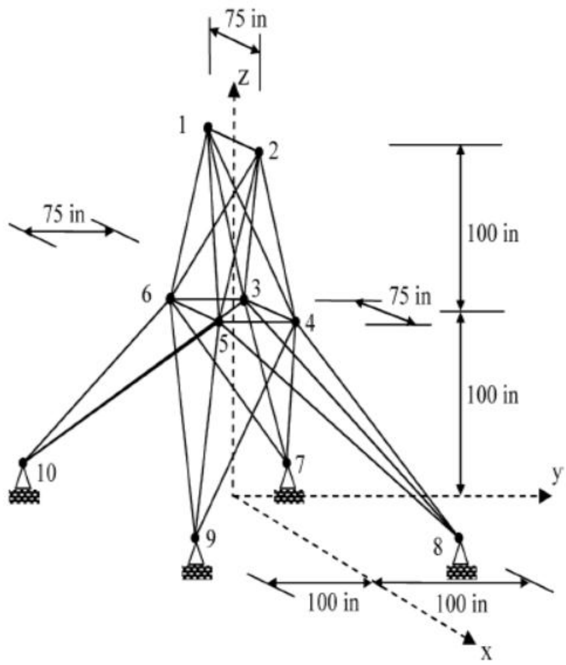

Fig 2: 25 bar truss

Table -1: DATA

Forces			
Node	Fx(lbs)	Fy(lbs)	Fz(lbs)
1	1000	-10000	-10000
2	0	-10000	-10000
3	500	0	0
6	600	0	0

25 bar truss as shown in figure has four hinges on the ground, it is an Aluminum truss with modulus of elasticity E =68.95 GPa and density, ρ = 2,768 kg/m3 (0.1 lb/in3) and The displacements are limited to 0.35 inches in all the directions.

RESULTS

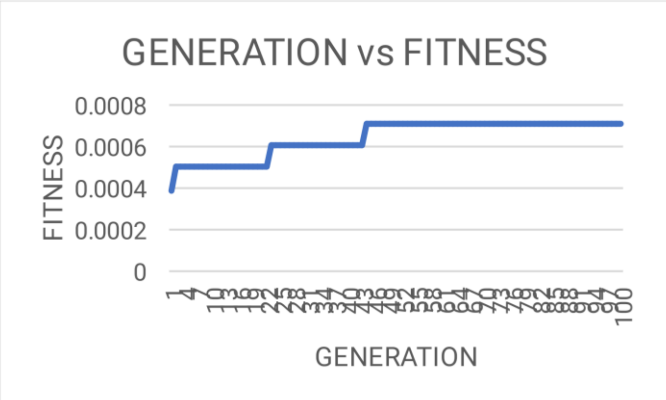

Chart -2: Generation vs Fitness

The generation vs fitness chart is shown above shows fitness is getting better as the generation increases, it never decreases because the best two solution from previous generation is ranked above and that's why fitness always increases or remain same in next generation. It is seen that when the generation reaches at 44 optimal or nearer optimal solution is derived and then the curve remains flat up to 100.

CONCLUSIONS

- The developed algorithm gives optimal or nearer optimal solution with including the self-weight of the truss unlike in other optimization studies.
- The self-weight is added to the nodal forces so it gives result in safer side.
- In this approach rank selection was used, so it ranks the best solution considering constraint and safety of the truss and take it forward in the next generation as it is, which keeps the value of fitness same or higher. It gives the optimum solution earlier than the normal methods.
- The algorithm developed in SCILAB was tested on several problems, showing the versatility of the approach and optimize their weight.
- The algorithm gives the solution in seconds which will decrease human efforts and time.

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