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Optimization of Trusses Using Genetic Algorithm

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Abstract

Optimization of trusses is very helpful in economic considerations. This study presents optimum design of 2D and 3D trusses using genetic algorithm. The objective function of the optimization algorithm is the weight of the truss with displacement constraint. Rank based selection is used to minimize the number of iterations to reach the optimum solution earlier. Algorithm for optimization of 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. Initial generation is selected randomly and then crossover and mutation is done. All the Individuals are represented by a binary string and hence it is termed as bit-string programming. The algorithm was tested on a reference book problem and result in more optimized results with lesser calculative efforts.

Keywords: Genetic Algorithm; Structural Optimization; Truss Optimization

1. Introduction

The cost is one of the main factors in the construction of trusses, the main objective of structural optimization is to save the material and hence the cost. it can be optimized by reducing the weight or volume of the structure. Genetic Algorithm is the 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 Genes. It is used to find optimal solution to complex problems unlike other conservative techniques which take long calculations and time.

Truss optimization can be divided in to three categories: Topology, size and shape, this is a size optimization study, Size optimization deals with optimal cross section areas of the truss members where all the nodal locations are locked, but in the case of topology optimization nodal locations can be changed.

In this work a SCILAB code is developed using Genetic Algorithm, where objective function is weight of the truss and constraint is deflection of the nodes. The analysis of the truss is done using Stiffness Matrix technique, Programming is done using binary strings.

Generally, the self-weight of the truss members is neglected in truss analysis and design because of very less affection compare to heavy point loads and less impact on the deflections, but in the case of optimization maximum capacity of the member is used and even lighter load will impact the truss, hence self-weight of the member is included to the point loads and divided the self-weight of the member to its end nodes equally.

2. Genetic Algorithm

1. Selection

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

2. Crossover

For finding better solution quickly, individuals are crossed with the other individual and new children are generated from two parents.

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

3. Mutation

The aim of the mutation is to keep the diversity of the individuals stable and prevent the code to stuck in to local minimum. Random mutation is picked up with 5% mutation rate.

3. Population Size

Population size can be selected based on the complexity of the problem and available computer memory and power, with bigger population size computational effort and time in increase and more the population size earlier optimum solution can be derived, for present case population size is set to 20 and if required it can be changed accordingly.

Weight is optimized using Genetic Algorithm with parameters as below.

The Algorithm is encoded with bit-string type, in which bit size is set to 4 to meet the availability of the sections described by Indian standards.

The maximum area of the section is set 14 in2 for the initial population as per IS code.

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

6 Bar 2D truss

This is a benchmark truss used in most of the optimization researches for 2D optimization problems.

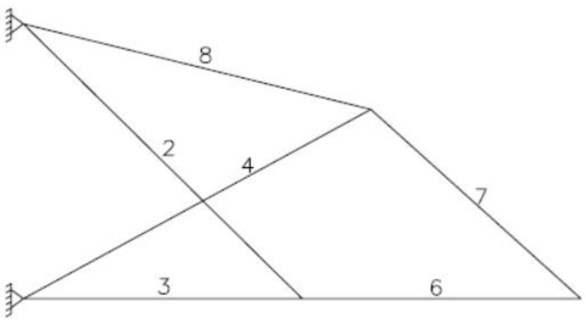

Fig 1: 6 bar truss

This is an optimized truss of 10 bar truss in which topology optimization is applied and converted to a 6 bar truss, this algorithm is based on weight optimization so optimized truss is picked up for application and solved using the code.

As shown in figure the 6-bar 2D truss has 5 nodes with 2 simple supports and 2nd and 3rd nodes are having load of 1*10^5 lbs load on each node as given in papers.

This 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 constrained to 2 inches in both the directions.

4. Results

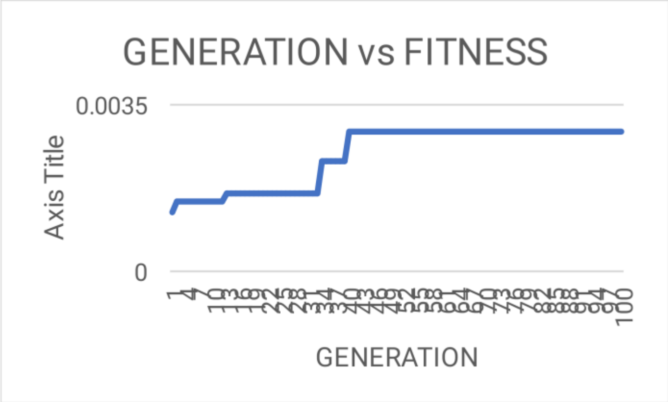

Chart 1: Generation vs Fitness

Upper chart shows that the fitness is getting better as the generation increases and after generation reaches around 42 it became constant which shows optimal or nearer optimal solution has been derived.

In this algorithm population size is set to 20, if it is increased then optimal solution can be reached in lesser generations.

25 Bar 3D Truss

Developed Algorithm is also applied on a 3D bench mark problem of structural optimization which is generally found in most of the studies.

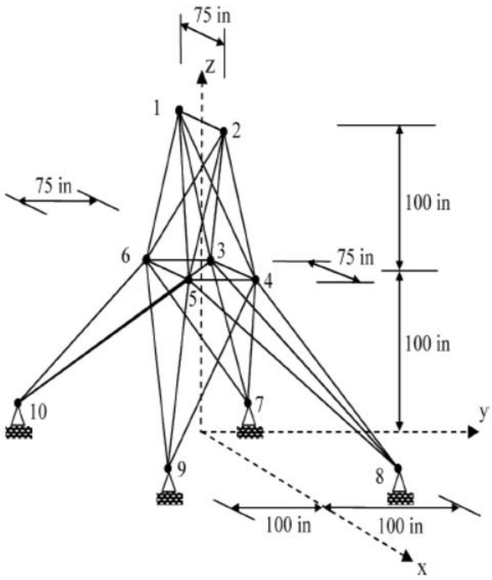

Fig 2: 25 bar truss

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 simple supports on the ground, it is an Aluminum truss with modulus of elasticity E =68.95 GPa and density, ρ = 2,768 kg/m3 and The displacements are contained to 0.35 inches in all the directions.

5. Results

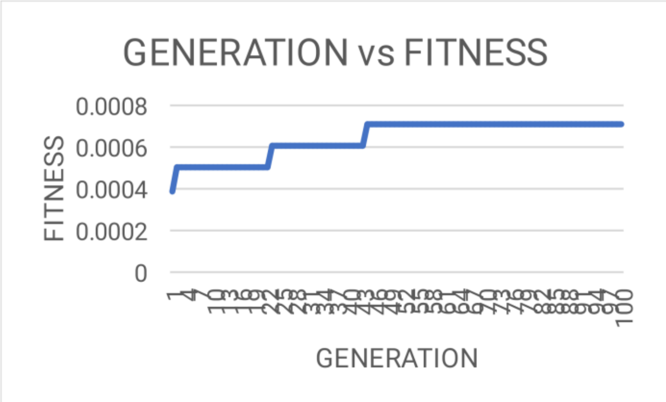

Chart -2: Generation vs Fitness

The generation vs fitness chart shown above indicates that fitness is increasing as the generation increases, but it never decreases because the best two solution from previous generation is ranked in descending order and that's why fitness always increases or remain same in upcoming generation. It has been observed that when the generation reaches at 46, optimal or nearer optimal solution is reached and then the curve remains flat up to 100.

6. Conclusions

- In this study rank selection was used, so it ranks the best solution in descending order considering constraint and safety of the structure and take it forward in the next generation as it is, which keeps the value of fitness same or higher. It provides the optimum results earlier than the normal methods.
- The algorithm developed in SCILAB was applied on some problems, showing the versatility of the algorithm and optimize their weight.
- The developed algorithm gives optimal or nearer optimal solution with including the self-weight of the trus which is a new initiative.
- The self-weight is added to the nodal loads so truss will not fail due to self-weight.
- The algorithm gives the solution in very less time which will decrease larger calculations and time.

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