Homework 4 : Design of Spatial Truss with Uncertainty

Due 2023.12.23

ME7129 Optimization in Engineering,

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A space structure with twenty-five bars as shown in Fig.1 is to be optimized. Each bar is represented by the connected nodes, for example 2-5. All bar members of this spatial truss are divided into eight groups, presented in Table 1. All bars have the same materials with the Young's modulus $E = 10^4$ ksi and the density $\rho = 0.10$ lb per in. with the applied loads listed in Table 2.

Table 1: Bars membership of the spatial truss

Group Number	Bar Members	Group Number	Bar Members
1	1-2	5	3-4, 5-6
2	1-4, 2-3, 1-5, 2-6	6	3-10, 6-7, 4-9, 5-8
3	2-5, 2-4, 1-3, 1-6	7	3-8, 4-7, 6-9, 5-10
4	3-6, 4-5	8	3-7, 4-8, 5-9, 6-10

The objective function of the problem is set to minimize the weight of the structure. The stress is constrained to ± 40 ksi and only the displacement at joints 1 and 2 are restricted both to less than $\pm$ 0.35 in. in the x and y directions. Let the design variables be the areas of the cross-sections of all 25 bars. The finite element analysis required as attached.

Due to manufacturing variations, all bars r_i follows Gaussian distribution as $N(\mu, 0.0052)$. Due to material variation, $E \sim N(10^4, 10^3)$ ksi. Constraints have to be satisfied 99% of the time.

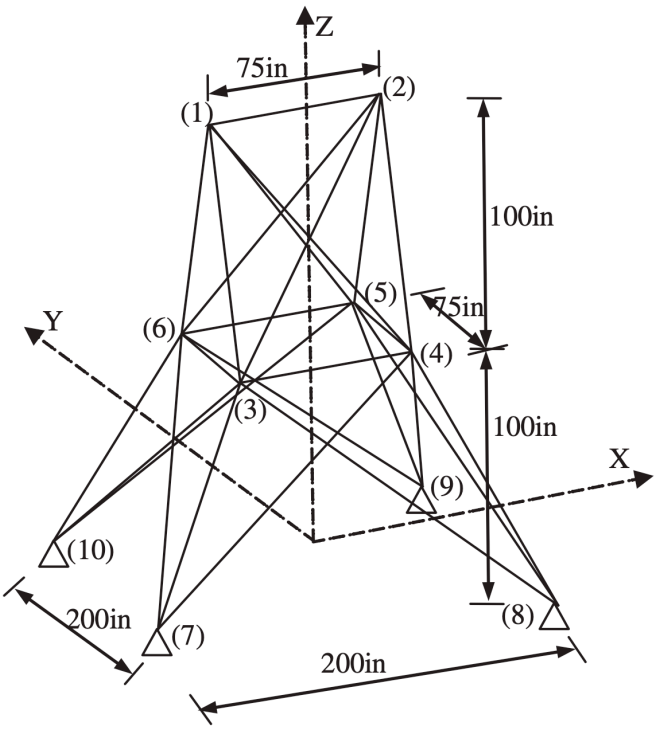

Figure 1: 25-bar Truss

1. (50%) Determine the optimal cross sections of all bar members with NO uncertainty. Identify active constraints.

2. (50%) What are the probability of violating active constraints when uncertainties in manufacturing and materials are considered? Please use Monte-Carlo with 1 million samples.

3. (10%) What's the changes in the overall weight when uncertainties are considered?

Table 2: Loading conditions for the 25-bar spatial truss

Node	F_x (kips)	F_y (kips)	F_z (kips)
1	1.0	-10.0	-10.0
2	0.0	-10.0	-10.0
3	0.5	0.0	0.0
6	0.6	0.0	0.0