CSE438 – Introduction to Meta Heuristics – Fall 2025 FINAL ASSIGNMENT
(Due date: 14/12/2025 Sunday, at 23:59)

- Project groups are allowed. A group can consist of **at most** 2 people.
- The code may be written in Python, C or Java (Python recommended).
- Report submission and source code submission are mandatory.

Surrogate-Assisted Optimization of a 10-Bar Truss Structure Optimization Problem

This project aims to provide students with practical experience in designing and implementing meta-heuristic algorithms for a sample optimization problem 10 Bar Truss Structure problem.

The *Truss Optimization Problem* is a classical structural engineering optimization problem that aims to minimize the total weight of a truss structure while satisfying strength and displacement constraints. For population based meta-heuristic implementations, each individual in the population represents a candidate truss design, where the design variables are typically the cross-sectional areas of the truss members. In a 10-bar truss, each individual can be represented as

$$X = [A_1, A_2, A_3, ..., A_{10}]$$

where $A_i$is the cross-sectional area of the *i*-th bar (in cm² or in²) set each A_i value as a random number between 0.01 and 35.0 .

With real values $X = [5.0, 10.0, 12.0, 8.0, 7.0, 9.0, 11.0, 6.0, 10.0, 13.0]$

$$\text{Minimize: } W(X) = \rho \sum_{i=1}^{10} A_i L_i$$

$$\sigma_i(X) \leq \sigma_{allow}, \quad \delta_j(X) \leq \delta_{allow}$$

Fitness function for 10-bar truss design problem is: $F(X) = W + P \times (C_{stress} + C_{disp})$

where

- $W(X)$is the total weight of the truss,
- ρ is the material density use this value as **0.1**,
- $L_i$is the **constant** length of each member use **[360, 360, 360, 360, 510, 510, 510, 510, 510, 510]**,
- $\sigma_i$are stresses in each bar use **0.08**,
- $\delta_j$are nodal displacements use **0.25**.
- P is the penaly contraint use it as **10^6**.
  Example W(X) calculation is as follows:
  W(X)=0.1×[(5×360)+(10×360)+(12×360)+(8×360)+(7×510)+(9×510)+(11×510)+(6×510)+….
  W=0.1×[(35×360)+(66×510)]≈0.1×[12600+33660]=4626 lb (lb = pound-force)

Sample Fitness function calculation for these values:

*F=4626+106×(0.08+0.25)=4626+330000=**334,626***

The application aims to find the X vector that produces the minimum fitness value F.

Instructions

1. [30 pts] Apply Genetic algorithm on 10 Bar Truss Design problem. You can analyze and use the projects that has done before[1].

Genetic Algorithm Implementation Details

- Mutation operator: uniform mutation.

- Mutation probability: 10%.
- Recombination operator: one point crossover
- Crossover probability: 30%
- Population size: 50
- Parent selection mechanism: Tournament selection size 5
- Survivor selection mechanism: Fitness based selection.
- Fitness Function: Minimizing F(x) value

2. [30 pts] 2nd Meta-Heuristic Algorithm
   - You're going to implement one more meta-heuristic algorithm for the project. You're free to select the algorithm.
   - You may use ready libraries such as mealpy[2].
   - You may implement algorithms such as "Artificial Bee Colony" algorithm, "Particle Swarm Optimization" algorithm, "Bat Algorithm", "Firefly Algorithm", "Cuckoo Search" algorithm, "Tabu Search" etc.
   - Explain why did you select that algorithm in the report file?

3. [20 pts] Use at least one surrogate model and add this model to both of your meta-heuristic implementations. A surrogate model such as a Radial Basis Function (RBF), Gaussian Process (Kriging), or Neural Network, Random Forest will be trained to approximate the fitness function, to reduce the number of exact evaluations. You can utilize ready tools such as Surrogate Modeling Toolbox [3].

Comparison-Report (20 pts)

After implementing GA and one more meta-heuristic algorithm, you need to compare their performances and present the results in your report.

- For 1000 runs what is the fitness value and the execution time achieved by GA and the 2nd algorithm?
- For 1000 runs what is the fitness value and the execution time achieved by GA and the 2nd algorithm with a surrogate model?
- For 5000 runs what is the fitness value and the execution time achieved by GA and the 2nd algorithm?
- For 5000 runs what is the fitness value and the execution time achieved by GA and the 2nd algorithm with a surrogate model?

Submission Details

- ❖ Submit the source code.
- ❖ Submit the report, check the report draft and fill the required parts for your project.
- ❖ This assignment effects overall 50% of your final grade.
- ❖ If you submit your project late, you will lose 5 points for each late days.
- ❖ Source codes and the report must be compressed as a **single zip** file and must be submitted via **ADUZEM**. Don't add the dataset to project folder (its size is huge so it's not possible).
- ❖ Zip file must be named with all group members' student numbers (example→ 2007900011_2007900012.zip).
- ❖ All group members' names must exist in the report file.
- ❖ One of the group members may submit the assignment.
- ❖ In any forms of copying and cheating all parties will get zero grade.

Good Luck!

[1] [GitHub - SaaadRaaa/Truss-Optimization: Analysis and Optimization of Truss Structures using Genetic Algorithms]()

[2] https://mealpy.readthedocs.io/en/latest/pages/models/mealpy.swarm_based.html

[3] [GitHub - SMTorg/smt: Surrogate Modeling Toolbox]()