Course Project 1

The following project is an extended version of the course example on power plant maintenance. In this version, in addition to considering the minimum energy production constraint of the power plants, the maintenance cost for each season is also taken into account as an additional constraint.

1- Review the materials presented in class at the address below and use the information provided there along with the following materials to complete the project.
http://cv.znu.ac.ir/afsharchim/AI/lectures/GA.pdf
2- Enhance your understanding of the **multi-objective optimization technique** by exploring the NSGA-II algorithm and leveraging libraries like DEAP or pymoo.

The project due is **Farvardin 9th, 1404**.

1. Decision Variables

Let $x_{i,j}$ be a binary decision variable where:

- i represents the unit number (1 to 7).
- j represents the interval (1 to 4).

$x_{i,j} = 1$ if maintenance for unit i starts at the beginning of interval j, and $x_{i,j} = 0$ otherwise.

2. Objective Function

The objective is now **multi-objective**:

1. **Maximize the minimum net reserve** across all intervals.
2. **Minimize the total maintenance cost.**

The total maintenance cost is calculated as:

$$\text{Total Maintenance Cost} = \sum_{i=1}^{7} \sum_{j=1}^{4} c_{i,j} \cdot x_{i,j}$$

where $c_{i,j}$ is the cost of maintaining unit i during interval j.

To combine these objectives, we can use a **weighted sum approach**:

$$\text{Objective Function} = w_1 \cdot \min_j(\text{Net Reserve}_j) - w_2 \cdot \text{Total Maintenance Cost}$$

where w_1 and w_2 are weights that balance the importance of maximizing the net reserve and minimizing the maintenance cost. These weights can be adjusted based on the problem's priorities.

3. Constraints

- **Maintenance Duration Constraint**: Each unit must be maintained for the required number of intervals.
  - For units requiring 1 interval:

$$\sum_{j=1}^{4} x_{i,j} = 1 \quad \text{for } i \in \{3, 4, 5, 6, 7\}$$

  - For units requiring 2 intervals:

$$\sum_{j=1}^{3}(x_{i,j}+x_{i,j+1})=1 \quad \text{for } i \in \{1,2\}$$

- **Non-Negative Net Reserve Constraint**: The net reserve must be non-negative in every interval:

$$\text{Net Reserve}_j \geq 0 \quad \text{for all } j \in \{1,2,3,4\}$$

- **Maintenance Cost Constraint**: The total maintenance cost must not exceed a predefined budget B:

$$\sum_{i=1}^{7}\sum_{j=1}^{4} c_{i,j} \cdot x_{i,j} \leq B$$

If no budget is specified, this constraint can be omitted, and the cost can be minimized directly in the objective function.

- **Binary Constraint**: The decision variables $x_{i,j}$ are binary:

$$x_{i,j} \in \{0,1\} \quad \text{for all } i, j$$

4. Genetic Algorithm Implementation

- **Chromosome Representation**: Each chromosome represents a possible maintenance schedule. It is a vector of binary values $x_{i,j}$, where each gene corresponds to a decision variable $x_{i,j}$.
- **Fitness Function**: The fitness function now incorporates both the minimum net reserve and the total maintenance cost. For example:

$$\text{Fitness} = w_1 \cdot \min_j(\text{Net Reserve}_j) - w_2 \cdot \text{Total Maintenance Cost}$$

The goal is to maximize this fitness value.

- **Crossover and Mutation**: Standard genetic operators like crossover and mutation can be applied. Crossover can be performed by swapping parts of the chromosomes, and mutation can be performed by flipping bits in the chromosome.
- **Selection**: Use a selection mechanism (e.g., roulette wheel selection, tournament selection) to select the best chromosomes for the next generation.
- **Stopping Criteria**: The algorithm can stop after a fixed number of generations or when the fitness value converges.

Example of Maintenance Costs

Assume the following maintenance costs $c_{i,j}$ for each unit i and interval j:

Unit i	Interval 1 Cost	Interval 2 Cost	Interval 3 Cost	Interval 4 Cost
1	100	120	110	130
2	90	95	100	105
3	80	85	90	95
4	150	160	155	165
5	70	75	80	85
6	60	65	70	75
7	50	55	60	65

These costs can be used to calculate the total maintenance cost for a given schedule.

Example of Fitness Calculation

For a given chromosome:

1. Calculate the total available capacity for each interval by subtracting the capacities of units under maintenance.
2. Compute the net reserve for each interval and find the minimum net reserve.
3. Calculate the total maintenance cost using the costs $c_{i,j}$.
4. Compute the fitness value using the weighted sum approach:

$$\text{Fitness} = w_1 \cdot \min_j(\text{Net Reserve}_j) - w_2 \cdot \text{Total Maintenance Cost}$$