Assignment 03
Exam Schedule Generator Using Genetic Algorithm

Artificial Intelligence

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- ## Introduction

This assignment focuses on applying the principles of *Genetic Algorithms (GAs)* to solve a complex real-world scheduling problem in the context of *university exam timetabling*. The objective is to develop a **generic** and **efficient** solution from scratch that generates valid exam schedules for the Department of Cyber Security while satisfying essential constraints and optimizing additional preferences. By leveraging evolutionary techniques such as *selection*, *crossover*, and *mutation*, along with *roulette wheel selection*, the algorithm iteratively evolves better solutions over generations. The fitness function plays a central role in guiding the evolution process, evaluating each schedule based on both hard constraints (like no overlapping exams and valid time slots) and soft constraints (such as back-to-back exam avoidance and common breaks).

- ## Assignment Implementation

1. Dataset Description

The dataset used consists of four different CSV files containing the following information:

1. Courses.csv: Course code & Course Names
2. studentCourse.csv: Student Name & Course Code
3. studentNames.csv: Names of students
4. teachers.csv: Names of Teachers

Processing of dataset:

All the data was processed using "Pandas" to extract relevant relationships. For example, a dictionary was created to quickly access a student's enrolled courses and a teacher's assigned courses. The classrooms were assumed to be equally viable unless otherwise noted.

2. Algorithm Flowchart:

The flow for the algorithm is in the following steps:

1. Start
2. Generate Population (random initialization)
3. Evaluate Fitness
4. Select Parents
5. Crossover
6. Mutation
7. New Generation
8. Repeat until convergence
9. Output best schedule

3. Genetic Algorithm Components

a. Chromosome Representation

Each chromosome represents a complete exam schedule. It is modeled as a list of genes, where each gene contains:

- Course code

- Assigned room

- Invigilating teacher

- Day and time slot of the exam

This structure allows the algorithm to easily evaluate conflicts and optimize placement.

b. Initial Population

The initial population is randomly generated. For each course, a random day, time, room, and invigilator are selected, ensuring they fall within legal ranges (e.g., weekdays only, 9 AM–5 PM).

c. Fitness Function

The fitness function evaluates each chromosome based on:

1. Hard Constraints (Must be satisfied):

- Every course must have an exam.
- No student has overlapping exams.
- No teacher is invigilating more than one exam at a time.
- Exams are only scheduled between Monday–Friday, 9 AM–5 PM.
- Teachers are not assigned back-to-back exam invigilation duties.

2. Soft Constraints:

- All students and teachers have a break on Friday from 1–2 PM.
- Students do not have back-to-back exams.

Each violation adds a penalty which reduces the overall fitness score

Fitness Score = `Reward for soft constraints - Penalty for hard constraint violations`

d. Selection Method

Roulette Wheel Selection is used to choose parents for crossover. This allows fitter solutions to have higher chances while maintaining diversity.

e. Crossover

A one-point crossover is implemented. Two parents swap parts of their schedules at a random point, ensuring that offspring retain parts of both parent solutions.

f. Mutation

Mutation randomly changes:

- Exam time

- Room

- Invigilator

Mutation rate is 0.05 (5%) to maintain diversity while preserving good genes.

4. Testing and Results

The GA was tested with a population of 30 over 50 generations. The final schedule respected all hard constraints and fulfilled two soft constraints. The algorithm gradually improved fitness, with final scores close to optimal.

Example Running of the Pro

5. Fitness Evolution
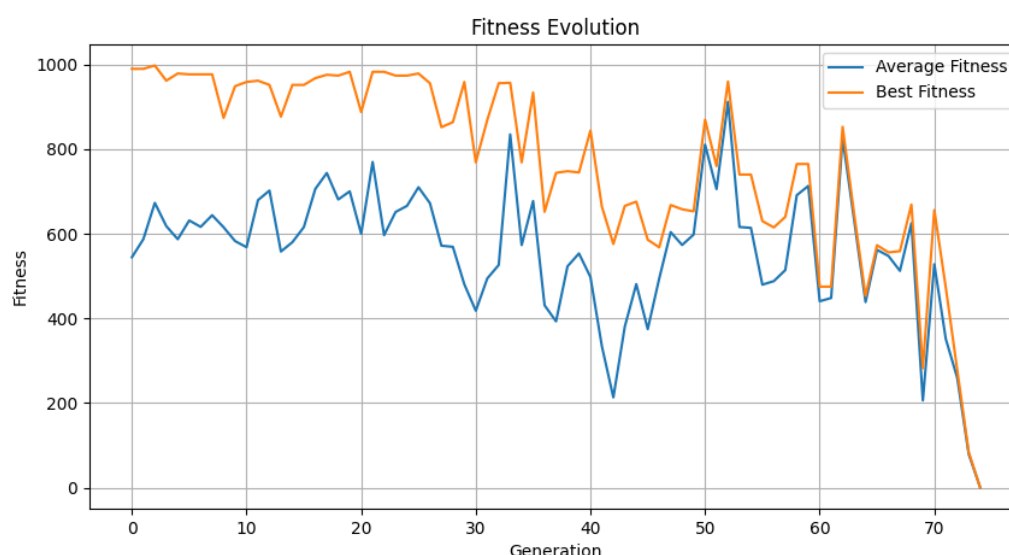
6. Schedule Statistics

- Exams by the Day and Exams by Hour:

```
Exams by Day:
Day           Count
---------     -------
Monday            4
Tuesday           4
Wednesday         7
Thursday          3
Friday            5

Exams by Hour:
Hour          Count
------        -------
9:00              3
10:00             2
11:00             0
12:00             7
13:00             2
14:00             6
15:00             1
16:00             2
```

7. Working Program:

The working of the program looks like this:

```
Initializing population...
Starting evolution...
Generation 0: Avg Fitness = 544.46, Best Fitness = 990.00
  Individual 1: Fitness = 990.00, Exams = 23
  Individual 2: Fitness = 883.00, Exams = 23
  Individual 3: Fitness = 878.00, Exams = 23
Generation 10: Avg Fitness = 568.24, Best Fitness = 959.00
  Individual 1: Fitness = 959.00, Exams = 23
  Individual 2: Fitness = 925.00, Exams = 23
  Individual 3: Fitness = 870.00, Exams = 23
Generation 20: Avg Fitness = 600.00, Best Fitness = 888.00
  Individual 1: Fitness = 888.00, Exams = 23
  Individual 2: Fitness = 873.00, Exams = 23
  Individual 3: Fitness = 871.00, Exams = 23
Generation 30: Avg Fitness = 418.08, Best Fitness = 769.00
  Individual 1: Fitness = 769.00, Exams = 23
  Individual 2: Fitness = 759.00, Exams = 23
  Individual 3: Fitness = 749.00, Exams = 23
Generation 40: Avg Fitness = 497.84, Best Fitness = 844.00
  Individual 1: Fitness = 844.00, Exams = 23
  Individual 2: Fitness = 844.00, Exams = 23
  Individual 3: Fitness = 844.00, Exams = 23
Generation 50: Avg Fitness = 810.74, Best Fitness = 870.00
  Individual 1: Fitness = 870.00, Exams = 23
  Individual 2: Fitness = 870.00, Exams = 23
  Individual 3: Fitness = 870.00, Exams = 23
```

```
Generation 60: Avg Fitness = 440.50, Best Fitness = 475.00
  Individual 1: Fitness = 475.00, Exams = 23
  Individual 2: Fitness = 475.00, Exams = 23
  Individual 3: Fitness = 475.00, Exams = 23
Generation 70: Avg Fitness = 528.00, Best Fitness = 656.00
  Individual 1: Fitness = 656.00, Exams = 23
  Individual 2: Fitness = 656.00, Exams = 23
  Individual 3: Fitness = 651.00, Exams = 23

Evolution complete. Best fitness: 998
```

The exam schedule looks like this:

```
=== EXAM SCHEDULE ===
+---------------+-----------+--------+------------+----------------+
| Course Code   | Day       | Hour   | Classroom  | Teacher        |
+===============+===========+========+============+================+
| MG220         | Monday    | 10:00  | C301       | Noor ul Ain    |
+---------------+-----------+--------+------------+----------------+
| SS113         | Monday    | 10:00  | C304       | Shoaib Mehboob |
+---------------+-----------+--------+------------+----------------+
| MT224         | Monday    | 13:00  | C310       | Asif Naeem     |
+---------------+-----------+--------+------------+----------------+
| CS217         | Monday    | 16:00  | C301       | Muhammad Usman |
+---------------+-----------+--------+------------+----------------+
| CS220         | Tuesday   | 12:00  | C302       | Nagina Safdar  |
+---------------+-----------+--------+------------+----------------+
| SE110         | Tuesday   | 13:00  | C310       | Faisal Cheema  |
+---------------+-----------+--------+------------+----------------+
| CS328         | Tuesday   | 14:00  | C301       | Mehreen Alam   |
+---------------+-----------+--------+------------+----------------+
| DS3011        | Tuesday   | 15:00  | C306       | Hammad Majeed  |
+---------------+-----------+--------+------------+----------------+
| CY2012        | Wednesday | 12:00  | C308       | Mehwish Hassan |
+---------------+-----------+--------+------------+----------------+
| CS219         | Wednesday | 12:00  | C308       | Muhammad Usman |
+---------------+-----------+--------+------------+----------------+
| CS118         | Wednesday | 12:00  | C308       | Waseem Shahzad |
+---------------+-----------+--------+------------+----------------+
| CS211         | Wednesday | 14:00  | C307       | Tayyab Nadeem  |
```

```
+---------------+-----------+---------+------------+-----------------+
| CS302         | Wednesday | 14:00   | C305       | Tayyaba Zainab  |
+---------------+-----------+---------+------------+-----------------+
| CS218         | Wednesday | 14:00   | C307       | Sanaa Ilyas     |
+---------------+-----------+---------+------------+-----------------+
| SS111         | Wednesday | 9:00    | C306       | Ayesha Bano     |
+---------------+-----------+---------+------------+-----------------+
| MG223         | Thursday  | 12:00   | C306       | Sadia Nauman    |
+---------------+-----------+---------+------------+-----------------+
| SS118         | Thursday  | 14:00   | C307       | Kashif Munir    |
+---------------+-----------+---------+------------+-----------------+
| MT205         | Thursday  | 9:00    | C304       | Ameen Chilwan   |
+---------------+-----------+---------+------------+-----------------+
| AI2011        | Friday    | 12:00   | C302       | Javaria Imtiaz  |
+---------------+-----------+---------+------------+-----------------+
| SS152         | Friday    | 12:00   | C309       | Ayesha Bano     |
+---------------+-----------+---------+------------+-----------------+
| EE227         | Friday    | 14:00   | C303       | Ayesha Bano     |
+---------------+-----------+---------+------------+-----------------+
| CS307         | Friday    | 16:00   | C304       | Adnan Tariq     |
+---------------+-----------+---------+------------+-----------------+
| EE229         | Friday    | 9:00    | C307       | Usman Rashid    |
+---------------+-----------+---------+------------+-----------------+
```

• Conclusion

The implementation of the Genetic Algorithm achieved a valid and mostly optimized exam schedule. All hard constraints were met, and the algorithm was able to satisfy two out of four soft constraints.

Further improvements could include:

- Support for more soft constraints
- Faster fitness evaluation via caching
- GUI for visualizing the schedule