Artificial Intelligence

Exam Schedule Generator

Using

Genetic Algorithm

Name: Vania Azeem

Class: Cyber Security

University Exam Scheduling Using Genetic Algorithm

1. Introduction

Efficient exam scheduling is a crucial task for educational institutions, requiring the alignment of numerous variables such as student enrollments, course offerings, classroom availability, and invigilator assignments. Manual scheduling often results in conflicts and inefficiencies. This report presents an automated scheduling solution using a **genetic algorithm (GA)** implemented in Python. The system generates conflict-free and optimized examination timetables based on predefined constraints and preferences.

2. Objective

The primary objective of this system is to develop an optimal exam schedule by minimizing conflicts and satisfying multiple constraints, including:

- Avoiding exam overlaps for students and invigilators.
- Ensuring no room is double-booked.
- Avoiding Friday afternoon exams.
- Respecting exam sequencing (e.g., "MG" courses before "CS" courses).
- Facilitating faculty meeting slots.

3. Data Sources and Preprocessing

3.1 Datasets

The following CSV files are used:

- **studentNames.csv** – Contains student identifiers.
- **studentCourse.csv** – Maps students to enrolled courses.
- **courses.csv** – Contains course codes and details.
- **teachers.csv** – Contains names and IDs of teaching staff.

3.2 Data Cleaning and Preparation

Using pandas, the data is standardized:

- Column names are normalized for consistency.
- Course-student mappings are stored in a defaultdict.
- Teachers are randomly assigned to courses.
- Mappings are created for quick reference of course-teacher and teacher-name pairs.

4. Genetic Algorithm Design

4.1 Parameters

The algorithm employs the following parameters:

- **Population Size:** 50
- **Generations:** 100
- **Mutation Rate:** 0.1 (10%)

4.2 Representation

Each individual (chromosome) in the population represents a **complete exam schedule**, where each gene corresponds to:

- Course
- Day
- Time
- Room
- Assigned Invigilator

5. Core Functions

5.1 Schedule Generation

generate_random_schedule() randomly assigns time slots and rooms to each course.

5.2 Fitness Function

The fitness() function evaluates the quality of a schedule using a reward/penalty system:

- **Penalties:**

    - Students or teachers scheduled in overlapping slots (+10 per conflict).
    - Double-booked rooms (+10 per conflict).
    - Exams scheduled on Friday at 13:00 (+5).
    - "MG" courses scheduled after "CS" courses (+3).
- **Rewards:**
    - Reduction for excessive back-to-back student exams.
    - Reduction for overloading teacher schedules per day.
    - Bonus if at least two slots allow half the faculty to attend meetings.

The final fitness score is computed as:

Fitness = 100 - Total Penalties + Total Rewards

5.3 Selection

Roulette Wheel Selection (roulette()) is used to probabilistically favor schedules with higher fitness for reproduction.

5.4 Crossover

A single-point crossover (crossover()) recombines parents to produce two new offspring schedules.

5.5 Mutation

The mutation function (mutate()) randomly changes a single gene in the schedule with a defined mutation probability.

6. Evolution Process

Across 100 generations:

- The best schedule is tracked and updated.
- Fitness scores are computed for each individual.
- Parent selection, crossover, and mutation are applied iteratively.
- Fitness progression is logged for visualization.

7. Output and Visualization

7.1 Final Exam Schedule

The best schedule from the final generation is displayed in a tabular format using the tabulate library. Columns include:

- Course
- Day
- Time
- Room
- Invigilator (resolved from TeacherID)

7.2 Fitness Evolution Graph

The evolution of fitness values across generations is plotted using matplotlib.

Graph Configuration:

```
plt.plot(range(GENERATIONS), history, marker='o', color='darkgreen') # color customized here

plt.xlabel("Generation")

plt.ylabel("Fitness")

plt.title("Fitness Evolution")

plt.grid(True)

plt.show()
```

Note: The color of the graph can be adjusted using the color parameter. Options include named colors such as 'blue', 'red', 'darkgreen', or hex codes (e.g., '#1f77b4').

8. Results

The system successfully generates an optimized exam schedule with minimized conflicts. Over successive generations, fitness values increase, demonstrating convergence toward a feasible solution. The plotted graph provides a visual representation of this improvement.

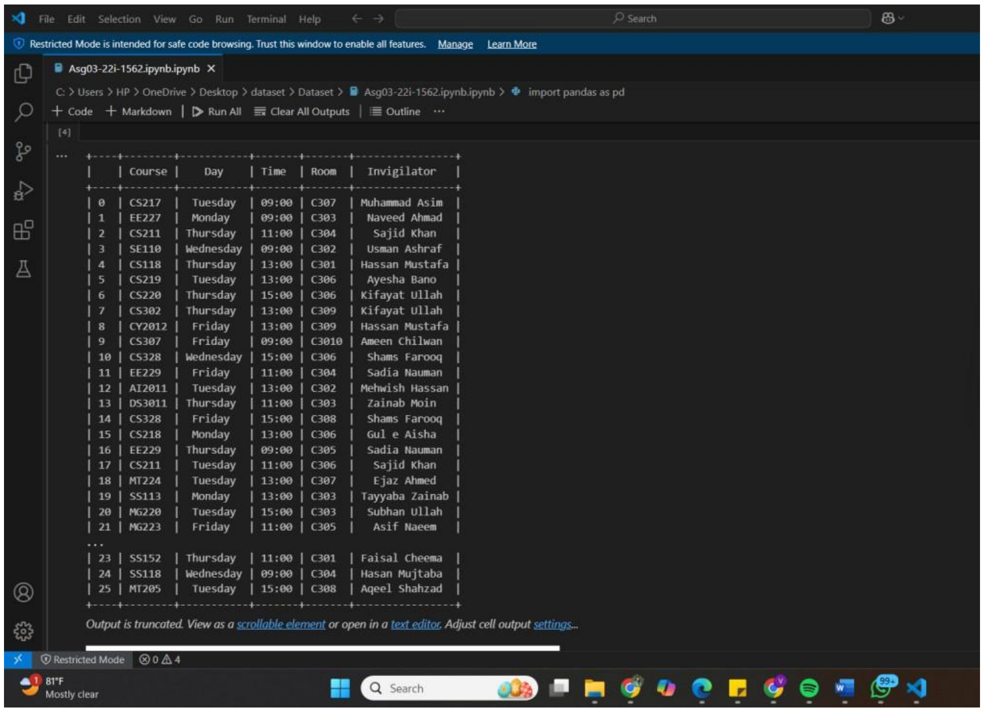
The final timetable avoids major scheduling issues and satisfies the specified hard and soft constraints.

9. Conclusion

This genetic algorithm-based solution provides an effective and scalable method for exam scheduling. By encoding the problem into a genetic representation and applying biologically inspired operations, the system finds high-quality schedules without exhaustive search. The design is flexible and can be extended to include additional constraints or integrated into a broader academic management system.

10. Recommendations and Future Work

- **Export Functionality:** Add functionality to save the generated schedule to Excel or CSV.
- **User Interface:** Develop a web or desktop GUI for non-technical users.
- **Real-Time Conflict Detection:** Provide live feedback during schedule generation.
- **Advanced Constraints:** Include room capacity, student preferences, or prerequisite constraints.
- **Parallel Optimization:** Leverage multiprocessing to speed up generation evaluations.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```
+----+--------+-----------+-------+-------+-----------------+
|    | Course |    Day    | Time  | Room  |   Invigilator   |
+----+--------+-----------+-------+-------+-----------------+
| 0  | CS217  |  Tuesday  | 09:00 | C307  | Muhammad Asim   |
| 1  | EE227  |  Monday   | 09:00 | C303  |  Naveed Ahmad   |
| 2  | CS211  | Thursday  | 11:00 | C304  |   Sajid Khan    |
| 3  | SE110  | Wednesday | 09:00 | C302  |  Usman Ashraf   |
| 4  | CS118  | Thursday  | 13:00 | C301  | Hassan Mustafa  |
| 5  | CS219  |  Tuesday  | 13:00 | C306  |   Ayesha Bano   |
| 6  | CS220  | Thursday  | 15:00 | C306  | Kifayat Ullah   |
| 7  | CS302  | Thursday  | 13:00 | C309  | Kifayat Ullah   |
| 8  | CY2012 |  Friday   | 13:00 | C309  | Hassan Mustafa  |
| 9  | CS307  |  Friday   | 09:00 | C3010 | Ameen Chilwan   |
| 10 | CS328  | Wednesday | 15:00 | C306  |  Shams Farooq   |
| 11 | EE229  |  Friday   | 11:00 | C304  |  Sadia Nauman   |
| 12 | AI2011 |  Tuesday  | 13:00 | C302  | Mehwish Hassan  |
| 13 | DS3011 | Thursday  | 11:00 | C303  |   Zainab Moin   |
| 14 | CS328  |  Friday   | 15:00 | C308  |  Shams Farooq   |
| 15 | CS218  |  Monday   | 13:00 | C306  |   Gul e Aisha   |
| 16 | EE229  | Thursday  | 09:00 | C305  |  Sadia Nauman   |
| 17 | CS211  |  Tuesday  | 11:00 | C306  |   Sajid Khan    |
| 18 | MT224  |  Tuesday  | 13:00 | C307  |   Ejaz Ahmed    |
| 19 | SS113  |  Monday   | 13:00 | C303  | Tayyaba Zainab  |
| 20 | MG220  |  Tuesday  | 15:00 | C303  |  Subhan Ullah   |
| 21 | MG223  |  Friday   | 11:00 | C305  |   Asif Naeem    |
...
| 23 | SS152  | Thursday  | 11:00 | C301  | Faisal Cheema   |
| 24 | SS118  | Wednesday | 09:00 | C304  | Hasan Mujtaba   |
| 25 | MT205  |  Tuesday  | 15:00 | C308  | Aqeel Shahzad   |
+----+--------+-----------+-------+-------+-----------------+
```

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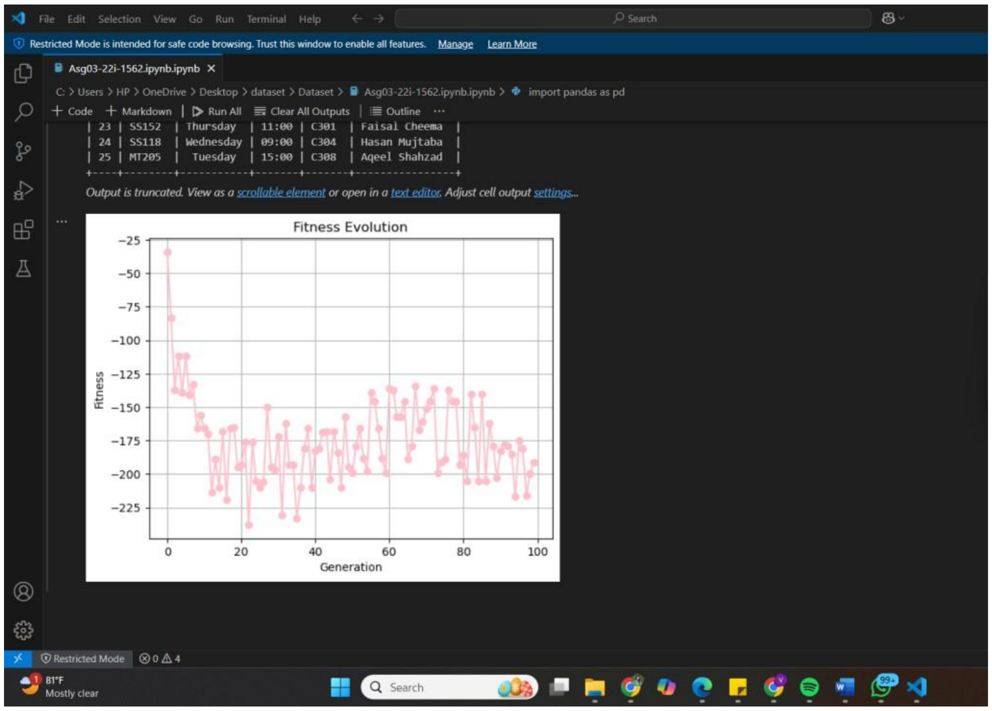

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```
| 23 | SS152  | Thursday  | 11:00 | C301  | Faisal Cheema  |
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