Merci pour le code main.py et les exigences de votre professeur. Voici comment nous allons procéder pour rédiger le rapport au format IEEE en anglais :

**🧩 Structure du rapport IEEE suggérée**

**Title**: *Drone Delivery Route Planning under Dynamic Constraints Using A*, CSP, and Genetic Algorithms\*

**Authors**: [Your Full Name]

**Abstract**  
Briefly summarize the goal of the project, the challenges (e.g., energy limits, no-fly zones), and the solution involving graph-based modeling, A\*, CSP, and GA. (~150 words)

**1. Introduction**

* Problem context: rising demand for efficient autonomous drone delivery.
* Key challenge: dynamically constrained environment.
* Objectives of the project.

**2. Problem Definition**

* Description of the delivery optimization problem.
* Constraints: weight, energy, time windows, and no-fly zones.
* Definitions of drones, deliveries, and no-fly zones with data structure details.

**3. Methodology**

**3.1 Graph Construction**

* Explain how deliveries are modeled as nodes, and paths as edges.
* Mention sparse graph generation and inclusion of edge costs:

Cost(i,j)=Distance×WeightPenalty+PriorityPenalty\text{Cost}(i, j) = \text{Distance} \times \text{WeightPenalty} + \text{PriorityPenalty}

**3.2 A\* Algorithm**

* Describe A\* search logic with the heuristic:

f(n)=g(n)+h(n)f(n) = g(n) + h(n)

* Explain how the heuristic accounts for no-fly zones and energy.

**3.3 CSP for Dynamic Constraints**

* One drone per delivery, avoiding constraint violations.
* Drones must obey no-fly zones and energy limitations.
* CSP used to generate valid assignments before optimization.

**3.4 Genetic Algorithm for Optimization**

* Initial population creation using valid solutions (from CSP).
* Fitness function:

Fitness=(DeliveriesCompleted×W1)−(EnergyUsed×W2)−(ConstraintViolations×W3)\text{Fitness} = (\text{DeliveriesCompleted} \times W\_1) - (\text{EnergyUsed} \times W\_2) - (\text{ConstraintViolations} \times W\_3)

* GA operators: crossover, mutation, and selection.
* Elitism and heap-based prioritization of urgent deliveries.

**4. Experiments and Results**

**4.1 Scenario Setup**

* Scenario 1: 5 drones, 20 deliveries, 2 no-fly zones.
* Graph type used: sparse.
* Parameters: population size, generation count.

**4.2 Evaluation Metrics**

* Delivery completion rate.
* Energy usage.
* Execution time.

**4.3 Performance**

* Include execution time from main.py.
* Use result from best\_individual and total paths found.
* Visualization examples from plot\_combined\_graph\_and\_path.

**5. Discussion**

* Analysis of trade-offs between GA and A\*.
* Dynamic reactivity with no-fly zones.
* Possible limitations: randomness, mutation quality, drone charging (if not implemented fully).

**6. Conclusion and Future Work**

* Summarize the hybrid approach effectiveness.
* Suggestions: integration of real-time changes, reinforcement learning, multi-objective GA.

**7. References**

* Cite sources on A\*, CSP, GA, and drone delivery literature.

**📌 Next Steps**

1. I can now help you **write each section**.
2. Do you want me to start generating the **Abstract + Introduction** based on what you have?

Let me know if you'd prefer to iterate section by section, or if you'd like a full draft of the IEEE-style report right away.