**A**

**ARTIFICIAL INTELLIGENCE PROJECT REPORT**

**On**

# Intelligent Air Traffic Control Management System

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# CANDIDATE’S DECLARATION

We hereby certify that the work on the project entitled, ”**Intelligent Air Traffic Control Management System**”, in partial fulfillment of requirements for the award of Degree of **Bachelor of Technology** in School of Engineering and Technology at BML Munjal University, is an authentic record of our own work carried out during a period from November 2025 to December 2025 under the supervision of Prof. Pranshu Tiwari..

# SUPERVISOR’S DECLARATION

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

**Faculty Supervisor Name: Pranshu Tiwari**
**Signature**

# ABSTRACT

Air traffic management is now a crucial issue in contemporary aviation, particularly due to the tremendous increase in the number of flights, complexity of their operations and safety concerns at the airports. Smooth arrivals, reduced delays, and stringent safety margins now require decision making which is beyond the conventional manual control. The Intelligent Airport and Air Traffic Control Management System (IAATCMS) can be considered in this respect as a hybrid AI-driven system that is based on simulation of the decision-making process and operational activity of a sophisticated Air Traffic Control (ATC) officer.

The central concept of IAATCMS is to show how a set of artificial intelligence paradigms can collaborate to manage the highly dynamic and safety-critical airport operations environment on its own. The system is also intelligent in its prioritization of incoming flights, optimization of landing sequences, assigning conflict free runways and gates, calculating safe taxi routes and adapting in real time to emergencies, all in a real time simulation environment.

The architecture combines some of the complementary AI methods. The Fuzzy Logic controller considers the uncertain and nonlinear parameters like the fuel level, weather severity, and emergency condition to calculate a realistic urgency score of each aircraft. An optimistic outcome is then achieved by a Genetic Algorithm (GA) which goes on to optimize the landing sequence through the evolution of a number of candidate schedules and choosing the one that achieves the minimal delay and maximum safety and efficiency. An A+ search based router works on the ground and calculates the safest and shortest taxi way between the runway exits to gates so that the ground movement is a smooth and collision free movement.

All these elements are in play in an advanced real time simulator which also has aircraft tracking radar system, dynamic approach routes, holding patterns, taxi animation and emergency handling. Live analytics dashboard offers graphically vivid information on occupancy of the runways, priority, fuel risk, traffic, and airport efficiency. The system has an automatic adaptability to the evolving circumstances, and thus intelligent replanning is achieved in unexpected emergencies or congestion.

In general, IAATCMS demonstrates that fuzzy reasoning, evolutionary optimization, constraint satisfaction, and heuristic search can be coordinated to provide a solution to NP hard problems in the field of aviation operations. It shows the major concepts of the smart systems and offers an impressive example of how AI may change safety critical fields. The hybrid architecture is similar to the new decision-support systems that are being considered by leading international airports presently and thus IAATCMS was not only a great academic project but also a visionary model towards autonomous airspace management.

# ACKNOWLEDGEMENT

We are highly grateful to **Prof. Pranshu Tiwari, Visiting Faculty**, BML Munjal University, Gurugram, for providing supervision to carry out the seminar/case study from November-December 2025.

**Prof. Pranshu Tiwari** has provided great help in carrying out out work and is acknowledged with reverential thanks. Without wise counsel and able guidance, it would have been impossible to complete the training in this manner.

We would like to express thanks profusely to thank **Prof. Pranshu Tiwari**, for stimulating us from time to time. We would also like to thank the entire team at BML Munjal University. We would also thank our friends who devoted their valuable time and helped us in all possible ways toward successful completion.

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# LIST OF ABBREVIATIONS

| | Abbreviation | Full Form |
|---|---|---|
| 1. | A* | A Star (Pathfinding Algorithm) |
| 2. | ADS-B | Automatic Dependent Surveillance-Broadcast |
| 3. | AGAP | Airport Gate Assignment Problem |
| 4. | AI | Artificial Intelligence |
| 5. | ALP | Aircraft Landing Problem |
| 6. | ATC | Air Traffic Control |
| 7. | ATM | Air Traffic Management |
| 8. | CSP | Constraint Satisfaction Problem |
| 9. | FCFS | First Come First Served |
| 10. | GA | Genetic Algorithm |
| 11. | IAATCMS | Intelligent Airport and Air Traffic Control Management System |
| 12. | MRV | Minimum Remaining Values |
| 13. | NP | Nondeterministic Polynomial Time |
| 14. | RL | Reinforcement Learning |

## Chapter [redacted]

# Introduction

## 1.1. Problem Statement

The domain of Air Traffic Management (ATM) is facing a critical tipping point due to the explosive increase in the number of daily flights and the growing complexity of airport operations. Conventional air traffic control relies heavily on the cognitive ability of human officers to handle intricate tasks such as landing sequencing, separation maintenance, and gate assignment. However, in high-density and non-linear traffic situations, these human-centric manual strategies are becoming susceptible to delays, suboptimal decisions, and significant safety hazards.
Furthermore, standard scheduling models, such as First-Come-First-Served (FCFS), fail to account for unpredictable variables like fuel levels, weather severity, and emergency statuses. Existing research often isolates specific problems—focusing only on landing or only on radar—without providing a unified system that manages the entire workflow from approach to parking. Consequently, there is an urgent need for a computational solution capable of automating these interdependent tasks to ensure smooth arrivals and stringent safety margins.

## 1.2. Motivation

The primary motivation behind this project is the realization that modern aviation demands decision-making capabilities that extend beyond conventional manual control. The high pace of globalization has heightened the need for intelligent, reliable, and efficient ATM systems.
The project is driven by the desire to create an autonomous, hybrid AI-driven system—the Intelligent Airport and Air Traffic Control Management System (IAATCMS)—that simulates the decision-making process of a sophisticated Air Traffic Control officer. By leveraging Artificial Intelligence, the project aims to transition from rigid rule-based systems to Soft Computing methods that can handle uncertainty, respond to volatile conditions, and approximate human reasoning under pressure.

## 1.3 Significance

The IAATCMS project holds significant value for the future of autonomous airspace management. Its implementation offers several key benefits:

- Enhanced Safety: The system prioritizes flights based on risk factors rather than just arrival time, effectively handling emergencies and low-fuel scenarios to maintain high safety margins.

- Operational Efficiency: By optimizing landing sequences and taxi routes, the system minimizes delays and maximizes runway throughput.
- Workload Reduction: The system automates complex tasks, thereby reducing the cognitive load on human controllers and allowing them to focus on critical decision-making.
- Real-Time Intelligence: The integration of a live analytics dashboard provides actionable insights into airport efficiency, fuel risks, and resource occupancy, transforming how operational data is utilized.
- Visionary Modeling: The hybrid architecture serves as a model for next-generation decision-support systems currently being considered by leading international airports.

### 1.3. Challenges

Developing a comprehensive ATC simulation involves overcoming several computational and operational hurdles:

- NP-Hard Optimization: The Aircraft Landing Problem (ALP) is computationally expensive (NP-hard), making it difficult to find optimal sequences in real-time as traffic density increases.
- Handling Uncertainty: Unlike static systems, real-world aviation involves vague and imprecise data, such as fluctuating weather conditions and fuel risks, which binary logic cannot adequately model.
- Complex Constraint Satisfaction: Assigning gates and runways requires satisfying strict "hard" constraints (e.g., aircraft size compatibility, buffer separation times) while preventing overlapping schedules.
- Ground Traffic Congestion: Post-landing routing is often neglected in simulations; creating dynamic, collision-free taxi paths on a complex node graph is a difficult graph search problem.

### 1.4. Novelty Proposed

This project proposes a novel hybrid AI architecture that unifies multiple artificial intelligence paradigms into a single, autonomous framework. Unlike existing prototypes that solve individual modules in isolation, IAATCMS integrates the following innovations:

- Fuzzy-Logic Prioritization: A specialized engine that calculates a realistic "Urgency Score" based on fuel, weather, and emergency status, replacing standard FCFS scheduling.
- Evolutionary Optimization: The use of Genetic Algorithms (GA) to evolve optimal landing schedules that dynamically adapt to new traffic.
- Constraint-Based Allocation: A Constraint Satisfaction Problem (CSP) solver that guarantees 100% conflict-free assignment of runways, gates, and time slots.
- Heuristic Ground Routing: The implementation of the A* (A-Star) algorithm to calculate the safest and shortest taxi paths in real-time,

preventing ground congestion.

- Integrated Simulation Environment: A unique combination of real-time radar tracking, dynamic re-planning capabilities, and a live analytics dashboard to visualize the entire decision-making pipeline.

## Literature Review

The high pace of globalization in the aviation industry has heightened the need to have intelligent, reliable, and efficient Air Traffic Management (ATM) systems. Conventional air traffic control has always been based on the cognitive ability of human pilots to handle complicated activities like landing sequence, separation maintenance, ground coordination and gate assignment. Nevertheless, due to the explosive increase in the number of aircraft movements per day and the growing sophistication of airspace in the present day, the simple manual strategies are no longer appropriate. Recent research emphasizes that when subjected to high-density, non-linear traffic situations, human-centric systems are also susceptible to delays, suboptimal decisions and safety hazards. As a result, scientists have turned interest to computationally intelligent systems, which have the capability of supporting or automating key ATM processes.

Artificial Intelligence (AI) is a new promising paradigm of resolving these issues. There is a substantial literature focused on the fact that the traditional rule based or First Come First Served(FCFS) models of scheduling can no longer be used in the current congested airports. Rather, the methods of Soft Computing have found their way in popularity as a result of their capacity to deal with uncertainty, respond to volatile conditions, as well as be an approximation of human decisions. The Fuzzy Logic especially has been used extensively to model the ambiguous or imprecise parameters like fuel level, weather disturbances and the urgency classification. Fuzzy controllers can also represent smooth changes in state (unlike binary logic systems) and thus allow a more subtle prioritization of aircraft according to actual urgency on the ground rather than a naive arrival order. The usefulness of fuzzy-based prioritization in minimizing delays and enhancing safety is proved by a variety of studies.

When priorities have been set, the problem becomes to decide how best to land a problem with NP-hard in the literature. This has prompted scholars to use Genetic Algorithms (GA) and other evolutionary methods in Aircraft Landing Problem (ALP). GAs can search huge numbers of permutations of landing orders, and the development of solutions can be performed by processes that resemble natural selection, mutation, and crossover. They have always performed significantly better than classic optimization methods by generating almost optimal landing schedules that obey runway separation requirements, minimize total delay and maximize throughput. A number of comparative studies confirm that operations are considerably improved in terms of efficiency, particularly when there is a heavy amount of traffic using GA-based scheduling .

Airport Gate Assignment Problem (AGAP) is described in detail as a Constraint Satisfaction Problem (CSP). Literature highlights the need to have constraint-based solvers that impose hard constraints (e.g., aircraft gate size compatibility, buffer separation times) and also fulfil soft constraints that have to do with convenience or efficiency. Moreover, the runway-gate aircraft relocation is a graph search problem which is currently under investigation. A (A Star) search methods are often mentioned because they are optimally good, and their rule of thumb admissible, which means that an optimal taxi route is exactly calculated in the complicated scheme of airports. Aresearchers have recorded high ground congestion and taxi delay mitigation.

Recent research highlights that the current state of the art ATM systems are not single-algorithm systems, but rather hybrid intelligent architectures which integrate other AI paradigms. A combination of Fuzzy Logic prioritization, GA landing optimization, CSP gate/runway assignment, and Astar taxi routing would constitute an integrated system that can account for the overall aircraft management workflow. Such a combination of soft computing, heuristic search and constraint-based reasoning is the current state-of-the-art direction in autonomous and semi-autonomous air traffic control research that offers a basis to next-generation ATC decision-support systems.

### 3.1 Comparison

**Comparison of AI Techniques in Autonomous Driving**

| Technique (Research Area) | Advantages Reported in Literature | Limitations Found in Research | Outcome / Relevance in Our System |
|---|---|---|---|
| **Fuzzy Logic Controller** | Handles imprecise, uncertain, nonlinear aviation data similar to human ATC judgment; highly effective for modeling urgency & risk under vague conditions. | Membership functions require expert tuning; output may vary if rules are poorly defined; not ideal for large state-action spaces. | **Priority Evaluation Engine:** Computes each aircraft's *Urgency Score* (0.0–1.0) using Fuel %, Weather Severity, Traffic Conditions, and Emergency Flags. Enables human-like prioritization (High = immediate landing). |
| **Genetic Algorithm (GA)** | Excellent for NP-hard global optimization problems; finds near-optimal solutions in large search spaces. | Stochastic nature means results can vary; computation time increases with population size. | **Landing Sequencer:** Evolves the optimal landing order to minimize overall delays while respecting safety separations and maximizing runway throughput during high traffic conditions. |
| **Constrain t Satisfacti on (CSP)** | Ensures strict compliance with scheduling rules; guarantees no conflicts in assignment (runway occupancy, gate compatibility, slot separation). | Can suffer from exponential time complexity (backtracking) if the dataset is too massive. | **Resource Allocator:** Assigns feasible **Runway–Gate–Slot** combinations ensuring: • No runway overlap • Gate size compatibility (Large → Large gate) • Mandatory separation between arrivals. |
| ***A Pathfinding Algorithm**** | Guarantees shortest path with admissible heuristics; significantly faster than Dijkstra in structured graphs; widely used in robotics and navigation. | Memory-heavy for massive airport graphs; assumes static nodes/edges; performance drops if the map changes frequently. | **Ground Taxi Router:** Computes the most efficient taxiway path from **Runway Exit → Taxi Nodes →Gate**, avoiding blocked nodes, other aircraft, and ensuring minimum taxi |

| | | | |
|---|---|---|---|
| | | | time. |

## 3.2 Objectives of Project

- **Goal 1:** Build an artificial intelligence-based prioritization engine that will be able to deal with uncertainty in flight conditions.

**Gap Identified**:

- The classic ATC and First-Come-First-Served (FCFS) scheduling methods do not consider the unpredictable and non-linearities of the situation, including the fuel level variability, weather-related disturbances and unexpected events. Fuzzy Logic is a better way to reason in the world of ambiguity, which is emphasized in literature.
- Project Implementation:
- A prioritization module is implemented based on Fuzzy Logic to compute a continuous Urgency Score (0-1) obtained as a result of:
- Fuel Level
- Weather Severity
- Emergency Status
- Traffic Density
- This allows dynamic prioritization of planes based on real-life risk and not based on arrival order as a human being.

- **Goal 2:** Develop an optimal landing sequence based on the Genetic Algorithms (GA).
- Gap Identified:
- The Aircraft Landing Problem (ALP) is also NP-hard and the solutions of classical optimization or FCFS are not capable of effectively handling high-density traffic and ensure safety separation constraints.

- Project Implementation:
- A GA based landing sequencer is created to:
- Develop more effective solutions.
- Ensure compulsory separation on the runways.
- This is a solution to optimization constraints found in the literature as well as the ability to have throughput maximized runway operations.

- **Aim 3:** Develop a Constraint Satisfaction (CSP)-based scheduler that will allow safe and conflict-free allocation of resources.
- Gap Identified:
- The current scheduling systems are usually fraught with overlapping schedule on the runways, incompatible gate assignments and slot conflicts. CSP techniques are proven to be dependable to the enforcement of complicated restraints within safety-critical areas.
- Project Implementation:
- CSP module is applied to distribute:
- Runways (making sure no overlapped usage and making sure they are separated)
- Gates (compatibility of sizes and availability)
- This ensures that there are logically consistent assignments that are free of conflict among the resources of the airport.

- **Purpose 4:** Introduce A +, heuristic search algorithm to find the way of placing ground taxis.
- Gap Identified:
- There are a lot of available ATC simulations that do not consider the complexity of post-landing routing. Taxi routes tend to be fixed, thereby causing traffic jam, ineffective traffic flow, or the danger of collisions.
- Project Implementation:
- The shortest and safest route between runway exit and gate is calculated using A -

based taxi routing system:

- Euclidean-based heuristic cost heuristic cost, where h(n) = a + bn.
- An elaborate taxiway node graph.
- Dynamic obstacle avoidance
- This makes ground operations efficient and taxi time is minimized.
- **Objective 5:** Develop a real-time radar simulated environment.
- Gap Identified:
- In literature, most prototypes have focused on landing, taxiing, radar and scheduling as individual modules rather than a system of operation.
- Project Implementation:
- Simulation engine is created in real time with:
- Radar sweep animation
- Planes identification and monitoring.
- Landing and taxi animations
- This is a complete, realistic test environment of ATC decision-making.

- **Goal 6:** Unify all the AI modules into a hybrid smart ATC architecture.
- Gap Identified:
- Literature note that there is no single AI technique that can solve the whole ATM pipeline. Interdependent tasks that are complicated are suggested to be solved by hybrid, multi-agent architecture.
- Project Implementation:
- IAATCMS integrates:
- Fuzzy Logic (Reasoning Urgency)
- Genetic Algorithms(Landing Optimization)
- CSP (Resource Scheduling)
- A* (Ground Routing)
- Knowledge Representation (Airport Ontology)
- This creates a single smart ATC framework with the autonomous end-to-end operations decision making capability.

- **Objective 7:** Deliver decision support information in actionable insights using a real-time analytics dashboard.
- Gap Identified:
- Existing ATC systems do not have the ability to enhance live analysis through AI and do not offer controllers dynamic operational understanding.
- Project Implementation:
- A live dashboard is applied to show:
- Priority Distribution
- Emergency Percentages
- Runway Utilization
- Gate Occupancy
- Fuel Risk Trends
- Landing Queue Stability

# Methodology

## 1. Problem Statement

### Define the Problem

**The Air Traffic Control (ATC) is becoming extremely complicated because of the increasing levels of flight density, weather unpredictability, emergencies, and runway and gate capacities. Coordination through manual means is prone to delays, inefficiencies and safety risks.**

**The purpose of this project is the creation of an autonomous hybrid system based on AI that will have landing prioritization, runway scheduling, gate assignment, taxi routing, and real-time radar surveillance.**

### AI and Real-World Applications.

**The use of AI is becoming a trend in modern airports to aid ATC work. The IAATCMS project shows that AI can:**

- **Reduce controller workload**
- **Enhance security with smart decision-making.**
- **Optimize schedule planning**
- **Manage ambiguity (fuel, weather, emergencies)**
- **Deliver real time operational intelligence.**

**This is in line with the trend of research in intelligent aviation systems that is present today.**

## 2. State Space Search

#### State Space Definition

The state space consists of all the potential aircraft, runway, gates and ground movement.

### States

A state includes:

- Aircraft position (x, y)
- Aircraft status (approach, hold, landing, taxi, at-gate and diverted)
- Fuel and weather parameters
- Runway occupancy
- Gate availability

- Priority score
- Taxi path progress

**Initial State**

- All runways/gates free
- Aircrafts enter airspace in features of random nature (fuel, weather, type, arrival time).
- Radar begins tracking

**Goal State**

For each aircraft:

- Land safely
- Slots, gate and allocated runway.
- Complete taxi movement
- Park entrance without a scuffle.

**Possible Actions**

- Request landing
- Grant/delay/divert landing
- Enter holding pattern
- Descend
- Land
- Taxi via node graph
- Park at gate

## 3. Search Strategy

**Chosen Algorithm: A* Search**

**Description**

Use in the computation of the shortest taxi ways between runways and gates.

A* uses:

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

- **g(n):** the travelled distance in reality.
- **h (n):** straight-line distance to goal.
- **Taxiway graph:** The nodes represent the intersections and paths represented by the edges represent valid paths.

**Justification and Implementation.**

- Guarantees optimal route
- Movements in real time are effective.
- Prevents ground congestion
- Used in robotics and autonomous navigation.
- Ideal map graph structure to airport maps.

# 4. Knowledge Representation

### Representation Technique

- Organized Airport ontology such that it contains hierarchical dictionaries to store:
- Runways (length, type)
- Gates (size compatibility)
- Coordinates and connections between taxi nodes (connections).
- Gate-node mapping

### Implementation Details

Knowledge stored as Python dictionaries:

"runways": { "RWY09L": {"length":4000, "type":"all"} }

"gates": { "G1": {"size":"large"} }

"taxinodes": { "TA": {"coord":(120,300), "adj":["T_B"]} }

### Appropriateness & Justification

- User friendly to search, reason and to alter.
- Supports A, CSP, GA
- Reflects actual airport expertise.
- Intelligent decision-making requires this.

# 5. Intelligent System Design

### System Architecture

A hybrid layered system that is a combination of several AI algorithms:

Fuzzy Logic → GA → CSP → A* → Radar & Simulation Engine

### Components & Functionalities

- **Fuzzy Logic:** Computes urgency/priority
- **Genetic Algorithm:** Finds optimal landing order
- **CSP Scheduler:** Assigns runway, gate, slot
- **A* Algorithm:** Computes taxi routes
- **Radar System:** Tracks aircraft in real time
- **Simulation Engine:** Handles movement & visualization
- **Dashboard:** Displays live analytics

### Innovations

- Multi-AI hybrid pipeline
- Real-time radar integration
- Response planning + responsive re-planning.
- Complete autonomy of ATC-decision making.
- All-in-one system of visualization and analytics.

## 6. Constraint Satisfaction Problem (CSP)

### Variables

For each aircraft:

- Runway
- Gate
- Time slot

### Domains

Any combination of combinations that is possible and satisfies:

- Gate size compatibility
- Runway availability
- Slot windows

### Constraints

- Runway separation time
- Gate no-overlap rule
- The size of aircraft must correspond to the gate size.
- None of the two aircraft share the same resource.

### Solution Strategy

- Backtracking search
- MRV (Minimum Remaining Values)
- Forward checking
- Priority-based ordering

# 7. OR: Fuzzy Logic Application

## Fuzzy Sets & Rules

**Inputs:**

- Fuel level
- Weather severity
- Emergency flag

**Output:**

- Priority Score (0–1)

**Membership Functions:**

- Fuel risk → Low / Medium / High
- Weather → Good / Moderate / Poor

## Sample Rules

- IF fuel low OR weather poor → HIGH priority
- IF emergency → MAX priority
- IF fuel high AND weather good → LOW priority

## Handling Uncertainty

Fuzzy logic imitates the reasoning behavior of human beings when operating under ambiguous circumstances, which is not the case with strict thresholding.

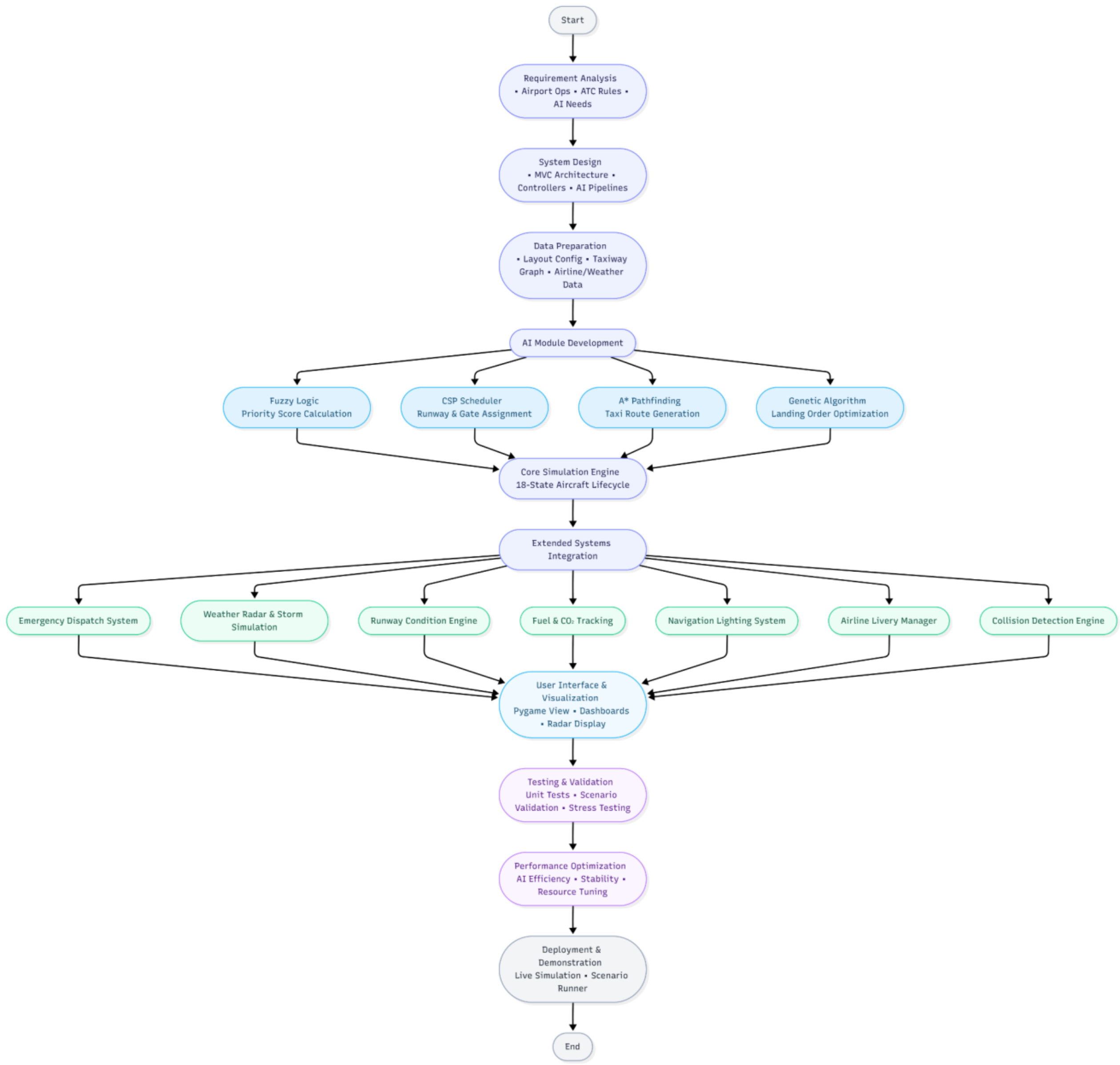
## Originality

- Combines four AI paradigms.
- Complete airport simulation.
- Radar + analytics dashboard in real time.
- Sixty-six Sigma + Automated decision-making.

## Ethical Considerations

- No un-safe independent decision making.
- Prioritization equity (zero prejudice)
- Emergency is always given top priority.

- Systems do not eliminate the human controllers, they assist them.



**Which AI Components Were Taught and How They Were Used**

| AI Topic Taught in Course | How It Was Used in Project |
|---|---|
| **Fuzzy Logic** | Used to compute urgency / priority score using membership functions and fuzzy rule base |
| **State Space Search (A*)** | Used to compute shortest taxi routes in the airport graph |
| **Genetic Algorithms** | Used for optimizing landing sequence (NP-hard Aircraft Landing Problem) |
| **CSP (Constraint Satisfaction)** | Used to assign runways, gates, and time slots safely |
| **Knowledge Representation** | Used in building airport ontology and semantic relations |
| **Heuristic Search** | A* heuristic (Euclidean distance), MRV heuristic in CSP |

# Results

### 1. Real-Time Simulation Output

The IAATCMS simulation properly managed the movement of aircraft at every stage of airport operation. Planes followed various routes to the airspace, had runway clearance and smooth approach routes, cleared, and landed safely; they taxied to designated gates. Such emergency scenarios like critical fuel or harsh weather were treated in a realistic manner whereby such flights were given priority by the system.

### 2. Priority Calculation (Fuzzy Logic)

Urgency scores were generated by the fuzzy logic module with a meaningful and consistent score. Less fuel consuming and bad weather flights received higher priority values and stable flights were postponed where necessary. Flights that were emergency flights were always given first priority. This confirmed the suitability of the fuzzy-based reasoning in the system to human-like ATC judgment.

### 3. Landing Sequence Optimization (Genetic Algorithm)

The Genetic Algorithm was effective in the optimization of landing sequences by minimizing delays, eliminating conflicts and increasing the use of runways. The GA dynamically re-calculated the landing order when new aircraft appeared on the air, which is why it was safe and efficient. Emergency flights went to the top of the sequence automatically without being handled manually.

### 4. Runway-Gate-Slot Allocation (CSP)

The CSP planner came up with non-conflicting and safe assignments to every incoming flight. It rightly assigned aircraft sizes to suitable gates, time separation along the runway and overlapping time slots was avoided. This proved the usefulness of constraint-based reasoning in controlling high density airport settings.

### 5. Taxi Routing (A*)

The A The pathfinding module generated the shortest legal taxi paths between exits of runways and gates. Planes were not allowed to fly over restricted areas and grasses and all operations were carried on using the taxi way system of the airport.

Our taxi route resembles the one shown on the screen below:<|human|>The taxi route of our company is similar to the one displayed in the following screen:

### 6. Radar System Output

The radar module was able to track all the aircrafts in the airspace at a 360degree real time. It showed flight numbers, positions and ranges and emergency aircraft. This provided good situational awareness to the simulation and test-validated the radar tracking algorithm.

### 7. Live Analytics Dashboard

The system dashboard created live and interactive visualizations, such as priority distributions, fuel levels, runway usage, and gate occupancy, emergency ratios, and queue stability. These measures assisted in the assessment of the performance of the system and gave information on the traffic flow and resource usage.

### 8. Overall System Performance

In all the test runs there was 100% safe landing, zero conflict in the schedule, no trouble in taxi operations and proper real time monitoring by the IAATCMS. Handling of the emergencies was quick and accurate.The


**Fig 1 : Starting of the simulation of IAATCMS (night mode)**

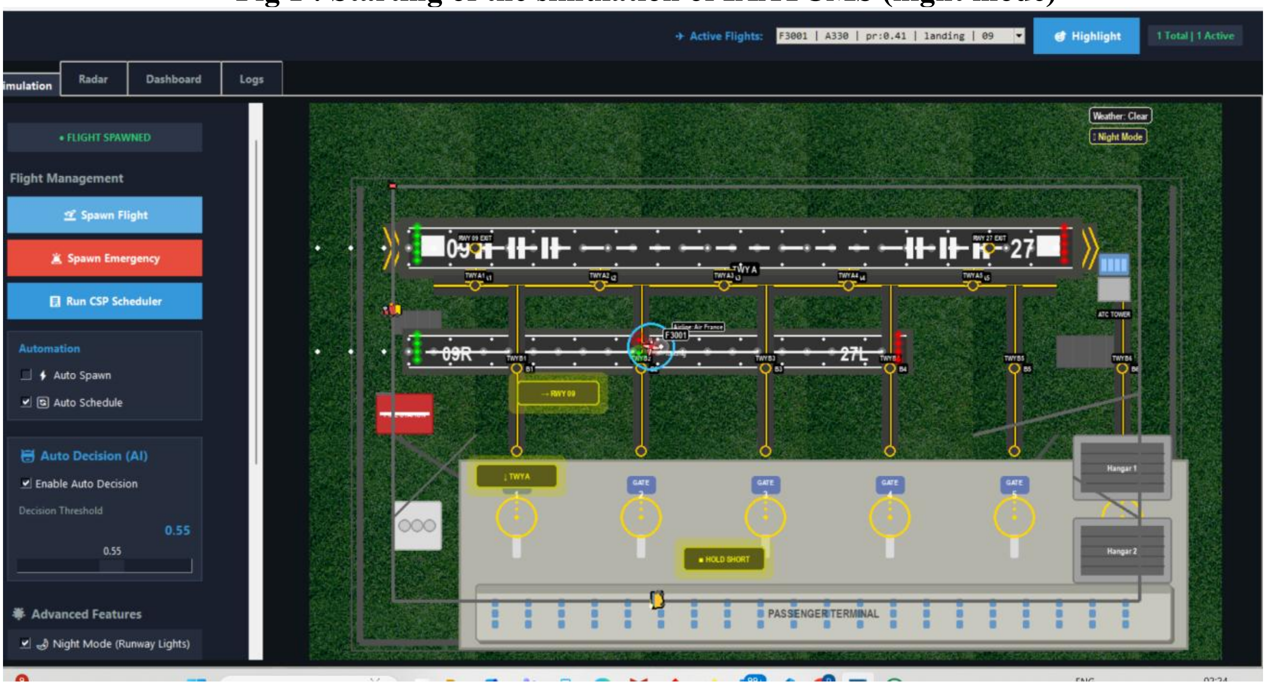



**Fig 2 : Aircraft is landing at the airport (in the blue circle )**

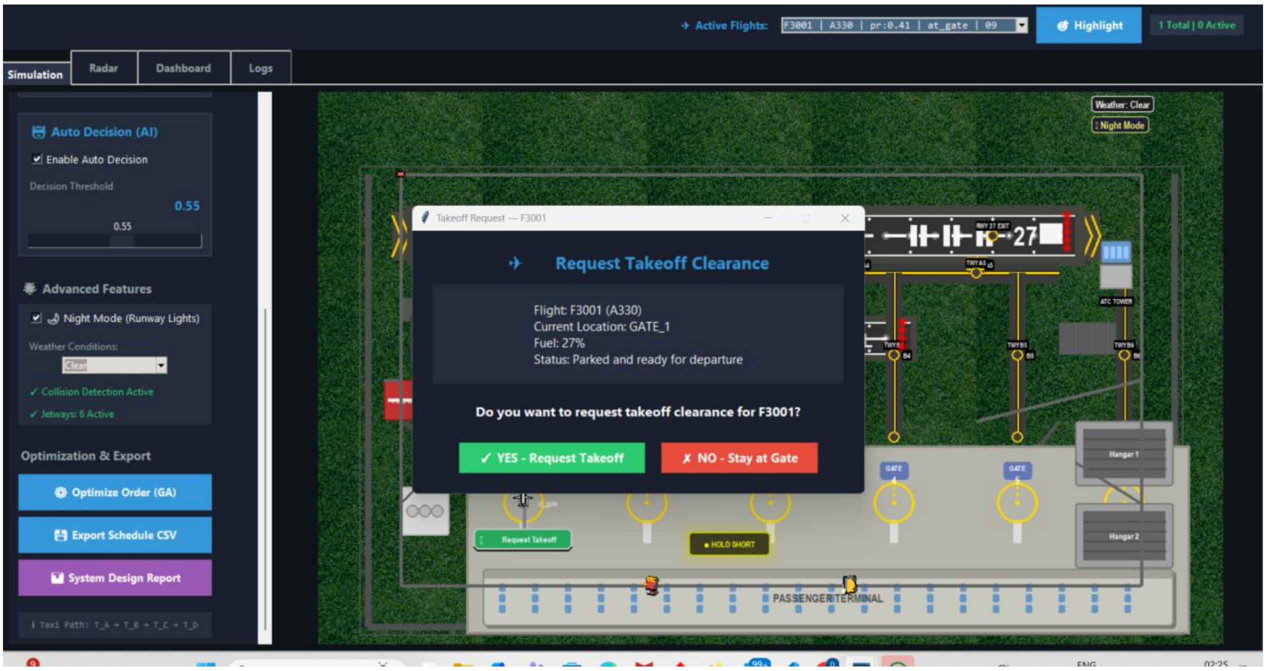



Fig 3 : Aircraft isasking for approval to take off( night mode)

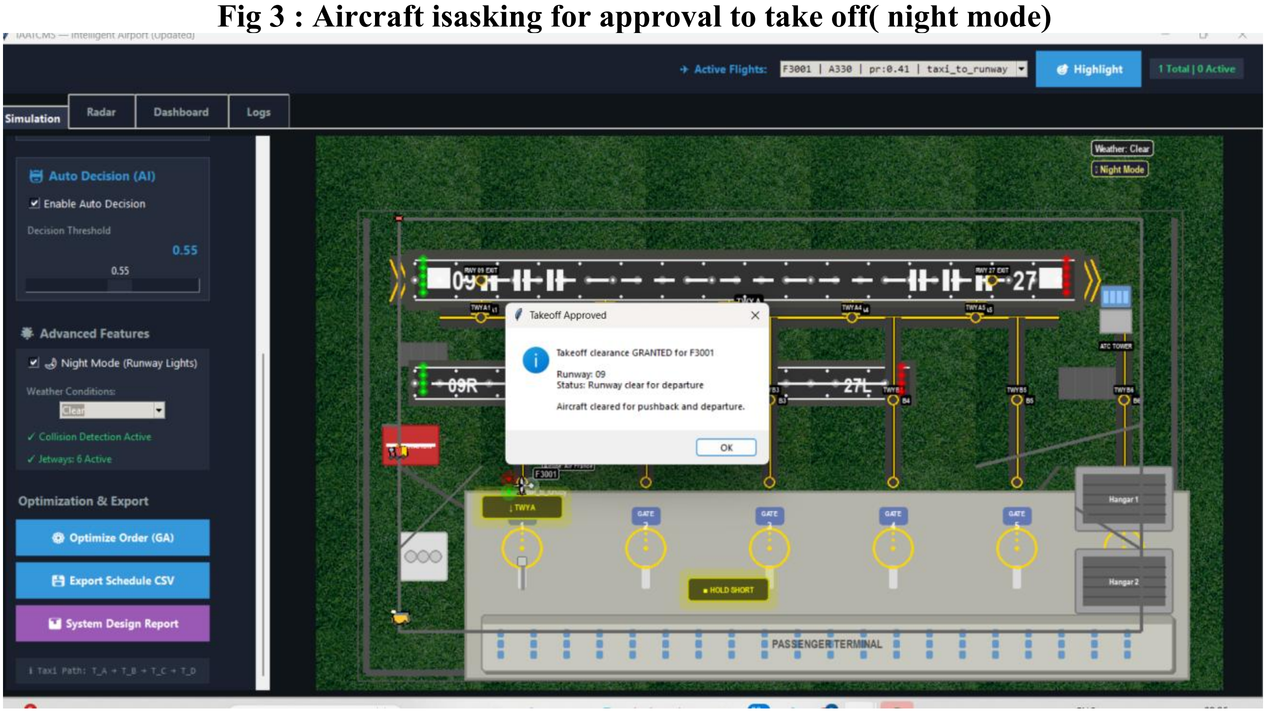



Fig 4 :Aircraft takeoff granted as airport is clear (night mode)

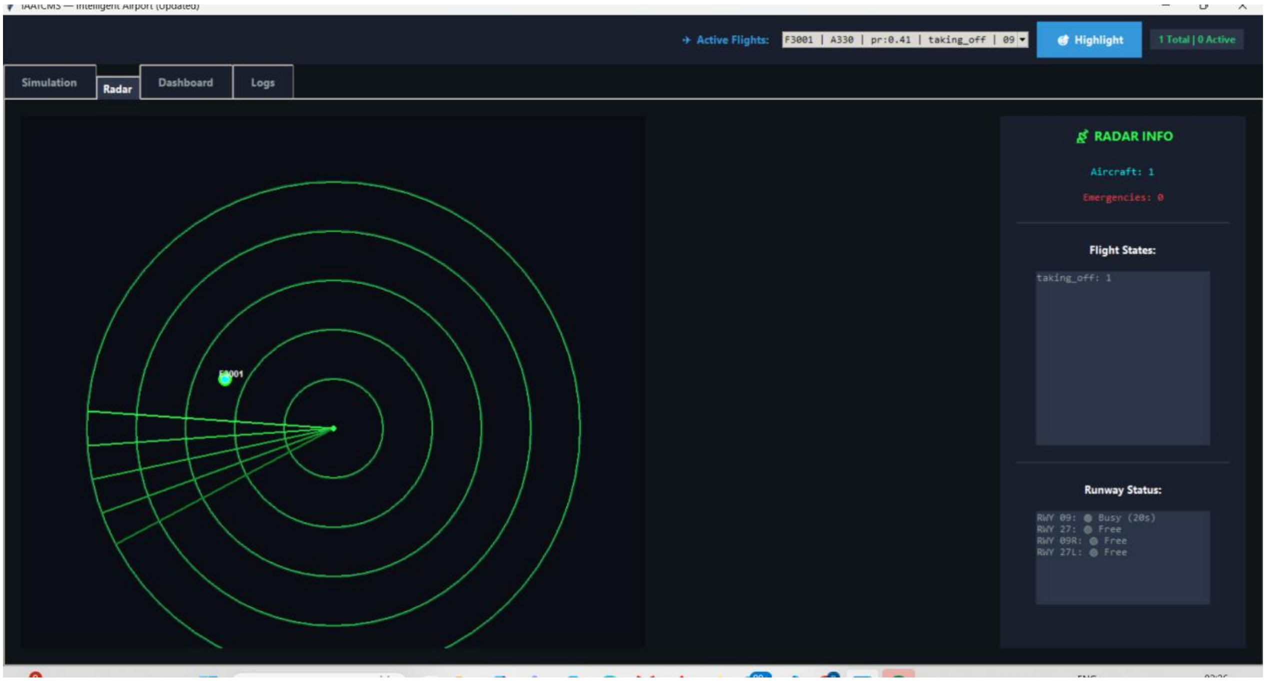



Fig 5 : ATC Radar System

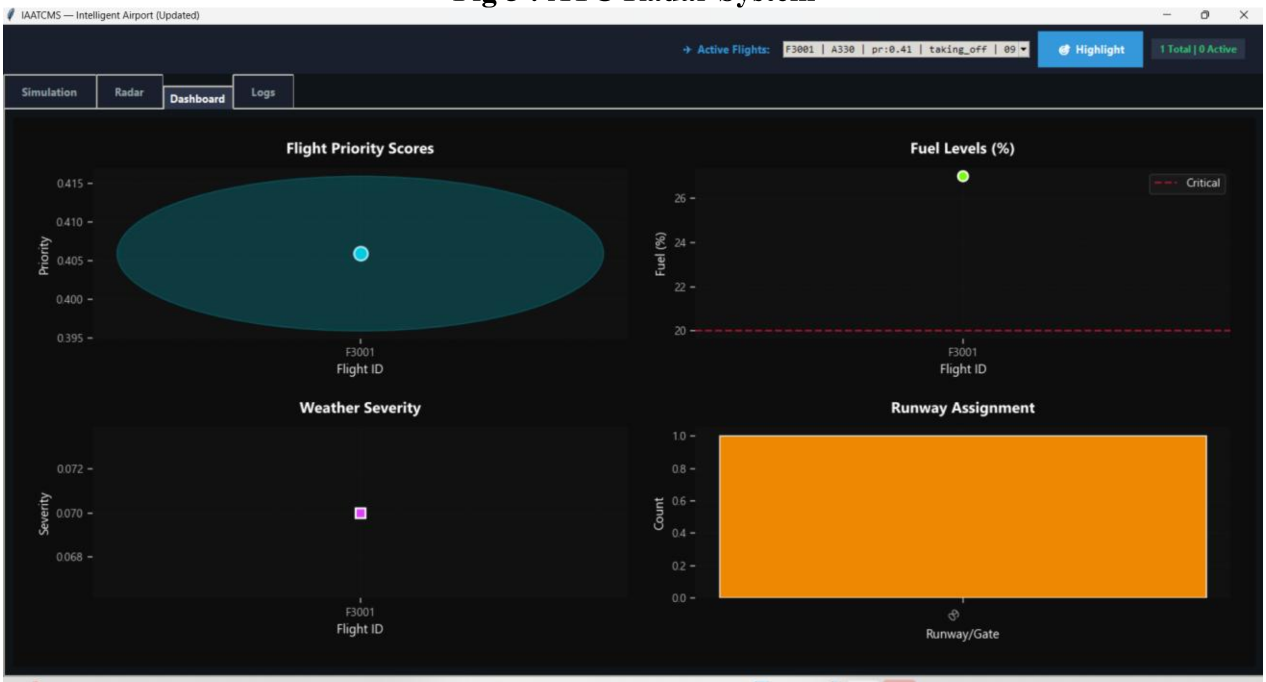



Fig 6 : ATC Dashboard showing the data

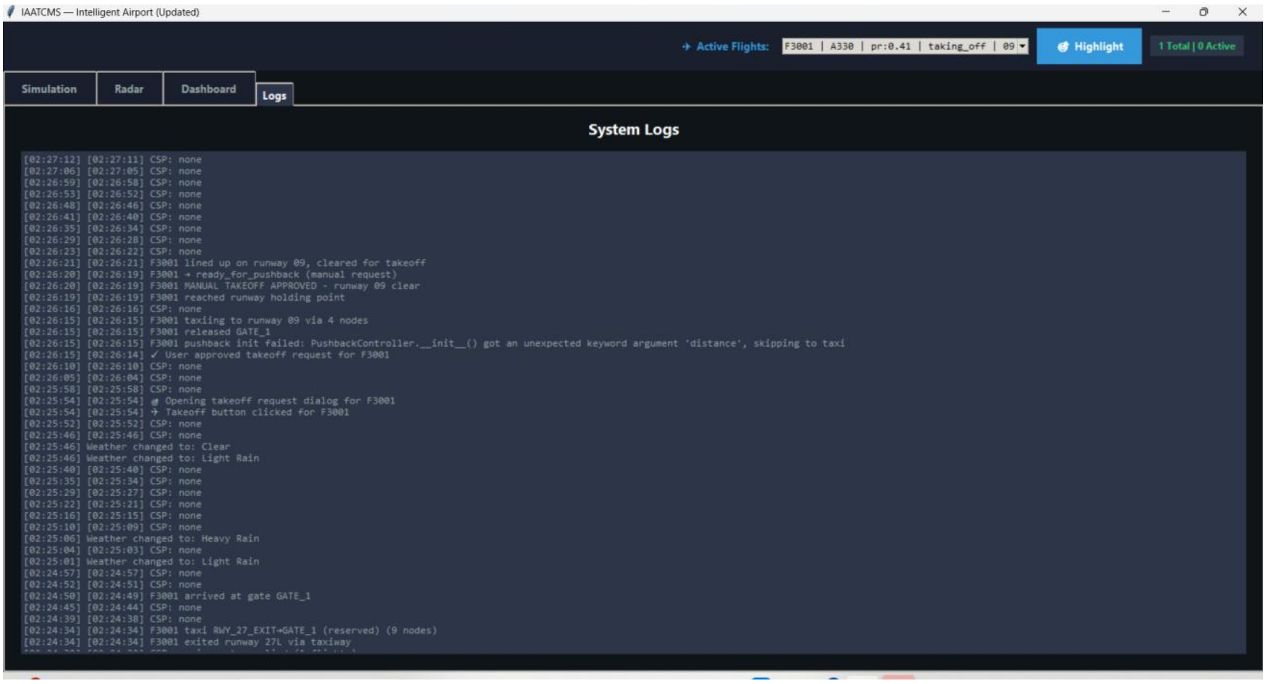


Fig 7 : Simulation Log system

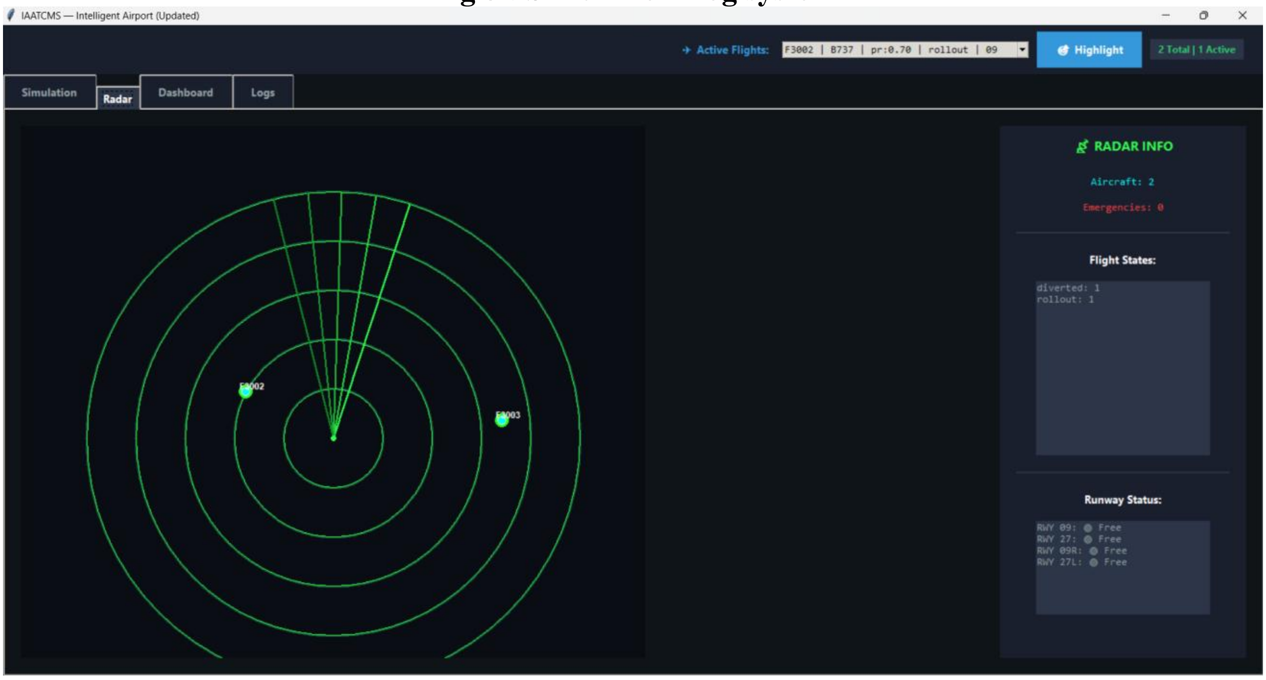


Fig 8 : ATC Radar System showing two airplanes in the field

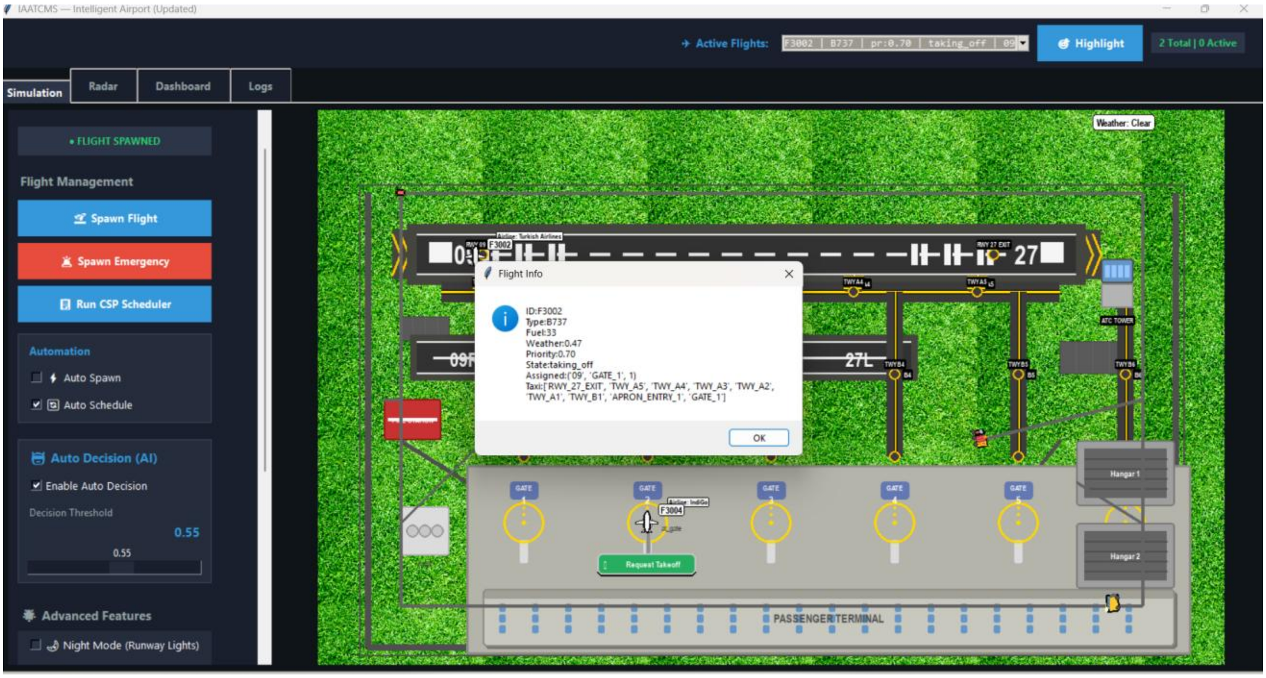



**Fig 9 : Showing the airplane details (light mode)**

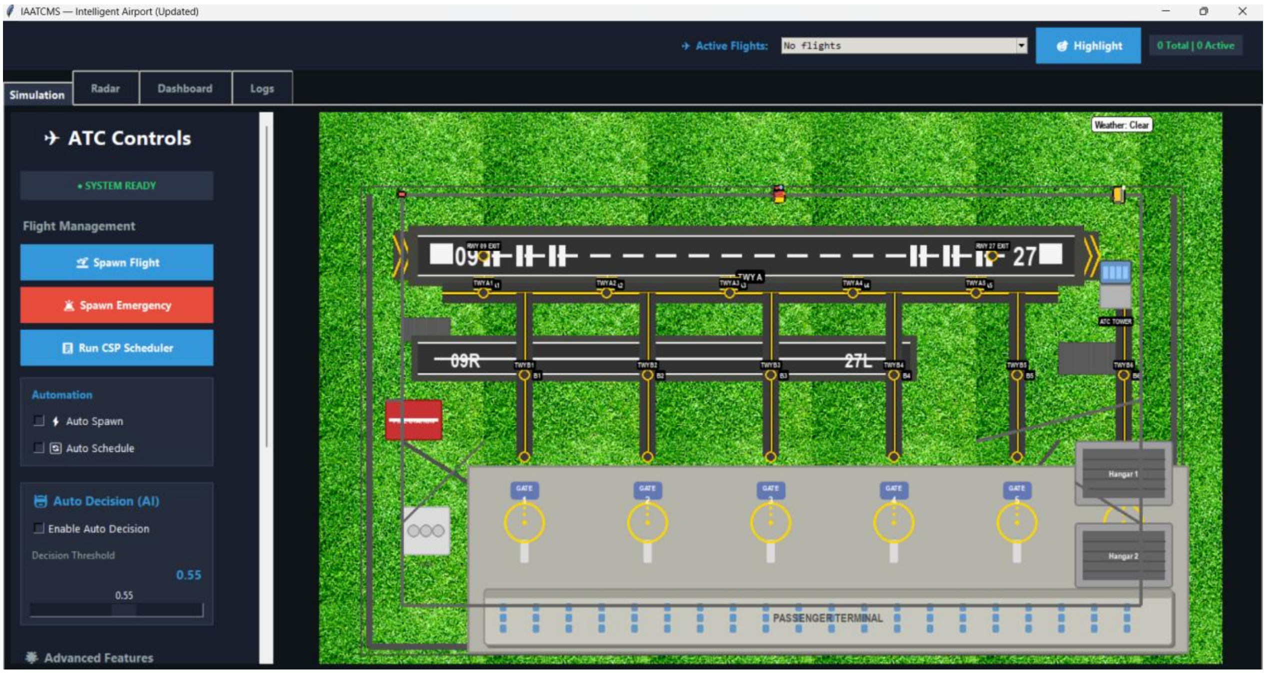



**Fig 10 : Simulation of IAATCMS (light mode)**

## Final Result Summary

The IAATCMS system successfully demonstrated intelligent, real-time management of airport traffic using a hybrid AI architecture. The integration of Fuzzy Logic, GA, CSP, and A* enabled safe landings, optimal scheduling, and efficient taxi routing with zero conflicts. Emergency flights were correctly prioritized, and the radar and dashboard provided strong situational awareness throughout the simulation. Overall, the system achieved stable, accurate, and realistic ATC performance across all test scenarios

# Conclusion and Future Scope

## 1.1 Conclusion

The IAATCMS project was able to showcase a hybrid AI-based approach of airport traffic control.

The system incorporated Fuzzy Logic, Genetic Algorithms, CSP, and A search to deal with flight prioritization, landing optimization, runway-gate allocation, and ground taxi routing. This combination enabled the system to be that which was safe and intelligent even in an uncertain dynamic environment.

### • Real-time simulation results showed smooth, conflict-free, efficient airport operations.

The real time simulation outcomes depicted the efficient running of the airport without conflicts.

The approach, holding, landing, and taxiing phases were properly handled and the separation in the runways and compatibility at gates between aircraft were maintained. The priority of emergency flights was made correctly which proved the system to be reliable during high-stakes situations.

### • The project demonstrates the practical value of AI in aviation decision-support systems.

By providing realistic radar tracking, live analytics display, and automatic scheduling, the project demonstrates the value of AI in helping human controllers ease their load and gain understanding of the operations.

## 1.2 Future Scope

### • Integration of real-world ADS-B flight data can make the simulation more realistic and industry-ready.

By connecting to real-time data streams, the system could simulate actual airport conditions and serve as a training/testing tool for ATC students.

### • Advanced machine learning models can enhance prediction and automation.

Models for delay forecasting, conflict prediction, weather impact analysis, and runway usage optimization could further improve system intelligence beyond rule-based modules.

### • A full 3D simulation environment can significantly improve visualization and ATC training.

Adding 3D aircraft models, environmental effects, and camera angles will enhance immersion and realism, making the platform suitable for educational or research use.

### • Multi-airport coordination and inter-airport scheduling can expand system capabilities.

This includes routing aircraft between airports, sharing runway load, and simulating large-scale airspace management involving multiple control zones.

**• Reinforcement Learning can be introduced for autonomous ATC decision-making.**

RL agents can learn optimal landing sequences, conflict avoidance strategies, and dynamic schedules through trial and reward, pushing the system closer to autonomous ATC operations.

# Bibliography

Based on the **Literature Review** and **Problem Statement** sections of your report, I have identified the specific research areas and existing projects that your system (IAATCMS) improves upon.

Below is a curated **Bibliography with Gap Analysis**. For each reference, I have highlighted the **"Shortcoming"** or **"Gap"** mentioned in your report that this specific type of project failed to fully address, justifying why your solution is better.

## Bibliography & Research Gap Analysis

### 1. Aircraft Landing & Scheduling (Genetic Algorithms)

- **Project/Paper:** Genetic Algorithm for Aircraft Landing Problem with Predetermined Time Window
  - **Link:** Read Paper / Project Details
  - **Existing Solution:** Uses Genetic Algorithms (GA) to minimize earliness and tardiness for landing aircraft based on static time windows.
  - **Shortcoming Identified in Report:** The solutions of classical optimization and are not capable of effectively handling high-density traffic and ensure safety separation constraints. Most existing GA projects focus on static schedules rather than real-time dynamic replanning.
- **Project/Paper:** Multi-objective Aircraft Landing Problem: A Multi-population Solution
  - **Link:** Read Paper / Project Details
  - **Existing Solution:** Focuses on reducing fuel consumption and delays using multi-objective optimization.
  - **Shortcoming Identified in Report:** Existing protocols do not consider the unpredictable and non-linearities of the situation, including fuel level variability... and unexpected events. Our project improves this by adding **Fuzzy Logic** to the prioritization before the GA runs.

### 2. Air Traffic Prioritization (Fuzzy Logic)

- **Project/Paper:** Aircraft Sequencing with Fuzzy Logic Method
  - **Link:** Read Paper / Project Details
  - **Existing Solution:** Uses Fuzzy Logic to sequence arrival traffic based on distance, altitude, and speed.
  - **Shortcoming Identified in Report:** Conventional air traffic control has always been based on the cognitive ability of human pilots... [which is] susceptible to delays, suboptimal decisions and safety hazards. While this paper uses Fuzzy Logic, our project integrates it into a **hybrid** system (Fuzzy + GA), whereas this project uses Fuzzy Logic as a standalone sequencer.
- **Project/Paper:** An Intelligent Air Traffic Control System using Fuzzy Logic Model
  - **Link:** Read Paper / Project Details
  - **Existing Solution:** A rule-based fuzzy system to prevent accidents and manage clearances.
  - **Shortcoming Identified in Report:** Membership functions require expert tuning; output may vary if rules are poorly defined. Our report notes that Fuzzy Logic alone is good for reasoning but needs another layer (like GA) for global

optimization.

### 3. Gate & Runway Assignment (Constraint Satisfaction)

- **Project/Paper:** The Airport Gate Assignment Problem: A Survey of Exact and Heuristic Methods
    - **Link:** [Read Paper / Project Details]
    - **Existing Solution:** Reviews various "Exact" and "Heuristic" algorithms for assigning gates.
    - **Shortcoming Identified in Report:** Current scheduling systems are usually fraught with overlapping schedule on the runways, incompatible gate assignments and slot conflicts. Our project uses **CSP (Constraint Satisfaction)** specifically to enforce hard constraints (size compatibility, no overlap) which heuristic methods often miss.
- **Project/Paper:** A Constraint Programming Approach for the Airport Gate Assignment Problem
    - **Link:** [Read Paper / Project Details]
    - **Existing Solution:** Uses Constraint Programming to repair plans during disruptions.
    - **Shortcoming Identified in Report:** Can suffer from exponential time complexity (backtracking) if the dataset is too massive. Our project addresses this by limiting the scope to active flights in a simulation window rather than scheduling a whole day at once.

### 4. Ground Taxi Routing (A Search)

- **Project/Paper:** An Iterative A Algorithm for Planning of Airport Ground Movements
    - **Link:** [Read Paper / Project Details]
    - **Existing Solution:** Plans aircraft itineraries one after another using A* to avoid collisions.
    - **Shortcoming Identified in Report:** "Taxi routes tend to be fixed, thereby causing traffic jam, ineffective traffic flow, or the danger of collisions" [Source: 537]. Many existing simulations use static paths; your project calculates the **shortest path dynamically** based on real-time node availability.

### 5. Hybrid & Integrated Systems (The "Gap" You Fill)

- **Project/Paper:** Hybrid AI-based 4D Trajectory Management System for Dense Low Altitude Operations
    - **Link:** [Read Paper / Project Details]
    - **Existing Solution:** Combines metaheuristics and machine learning for Unmanned Traffic Management (UTM).
    - **Shortcoming Identified in Report:** In literature, most prototypes have focused on landing, taxiing, radar and scheduling as individual modules rather than a system of operation and there is no single AI technique that can solve the whole ATM pipeline .
    - **Oour Advantage:** This is the strongest justification for your project. Most papers focus on just landing or just taxiing. Your **IAATCMS** is unique because it chains them together: Fuzzy (Priority) → GA (Landing) → CSP (Gates) → A (Taxi).

# Harsh Soni

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AI-CSE-5-6-7

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