AAE1001 - Introduction to Artificial Intelligence and Data Analytics in Aerospace and Aviation Engineering

Week 9-13: Group Project - Design of Path Planning Algorithm for Aircraft Operation

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Ground Rules

For students

- Try to speak as much English as possible.
- Participate the class activates assigned.

For teaching staffs

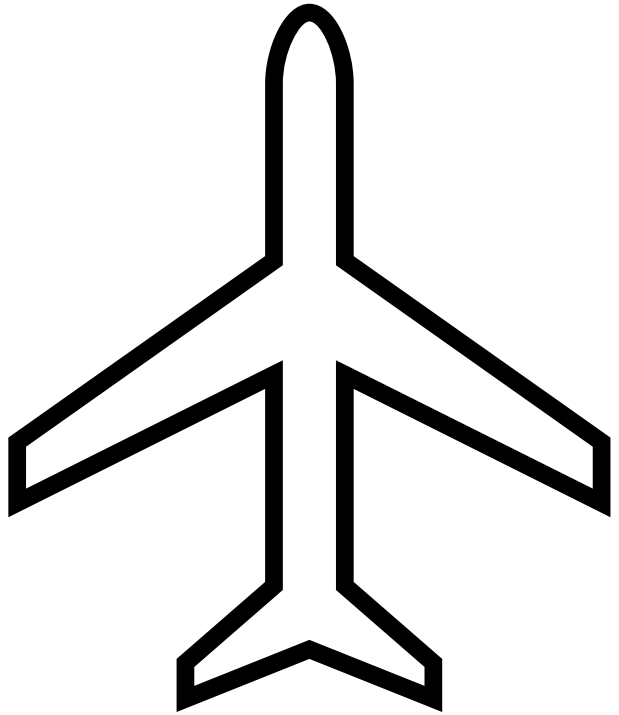
- Reply your email with 3 working day.
- Open to any question regards to the subject

For us!

- Keep an open mind—enter the classroom dialogue with the expectation of learning something new. Look forward to learning about–and being challenged by–ideas, questions, and points of view that are different than your own.
- Arrive on time to the class and finish the class on time

Week 9 Content

1. Introduction to Path Planning
2. Introduction to GitHub (Background)
3. Introduction to GitHub Operations
4. Software Installation and setup Guide

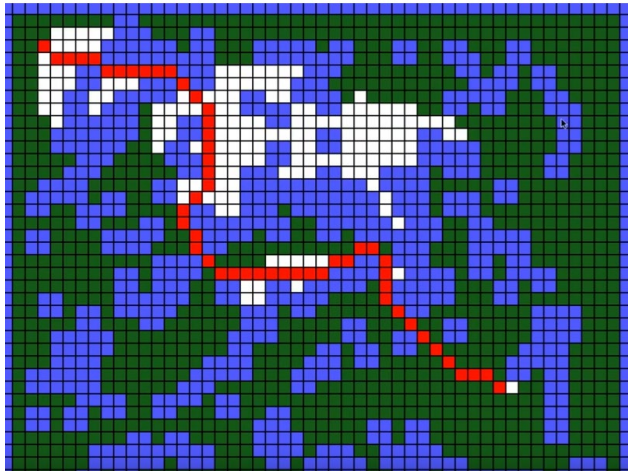


Introduction to Path Planning

What is Path Planning?

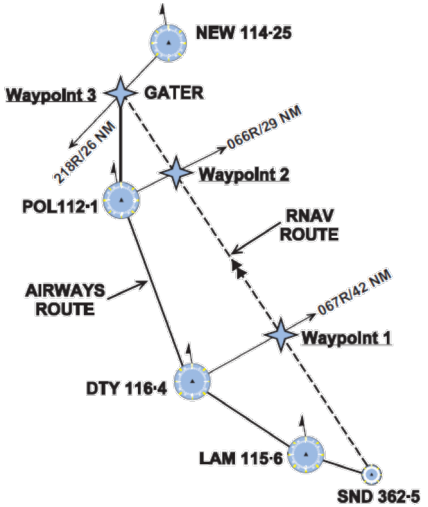
How to go from A to B considering factors!

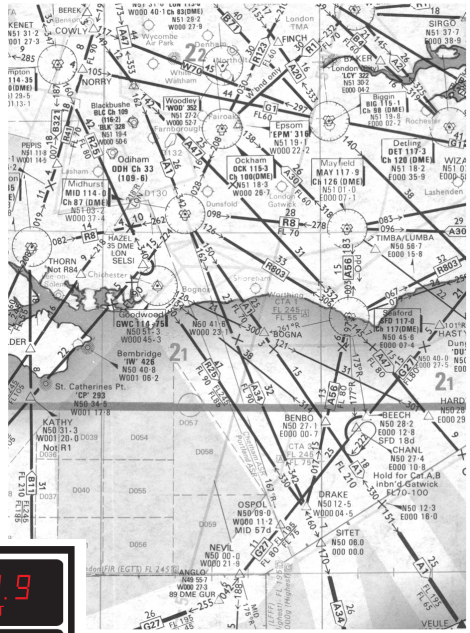
- **Path planning** (also known as the **navigation problem**) is computational problem to find a sequence of valid configurations that moves the object from the source to destination. The term is used in **aviation**, **robotics** and **computer games**.

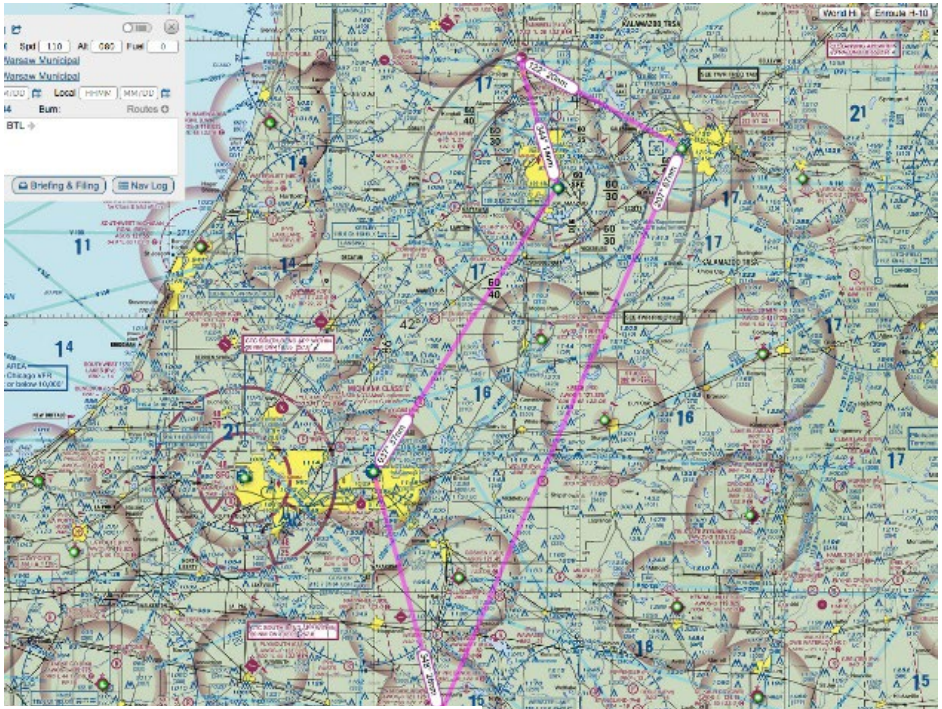


How is Path Planning important to Aviation Engineering?

- Private pilots do the path plan before the flight to make sure the navigation aid is available



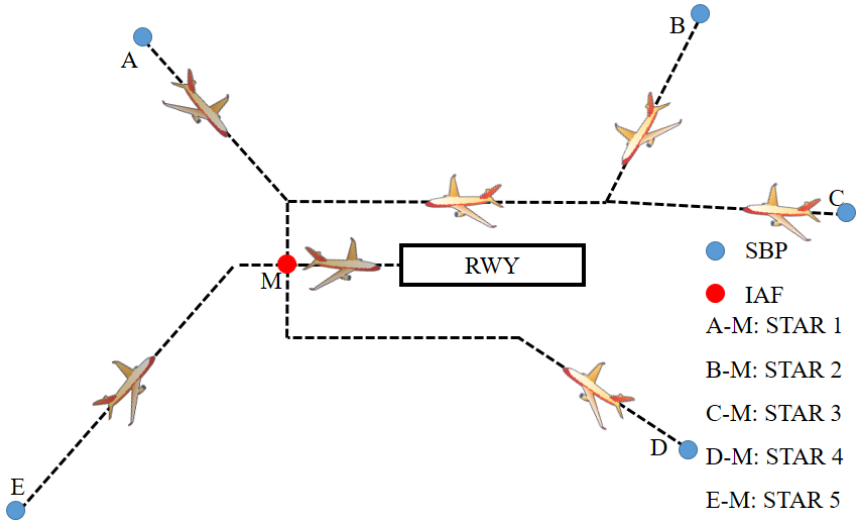


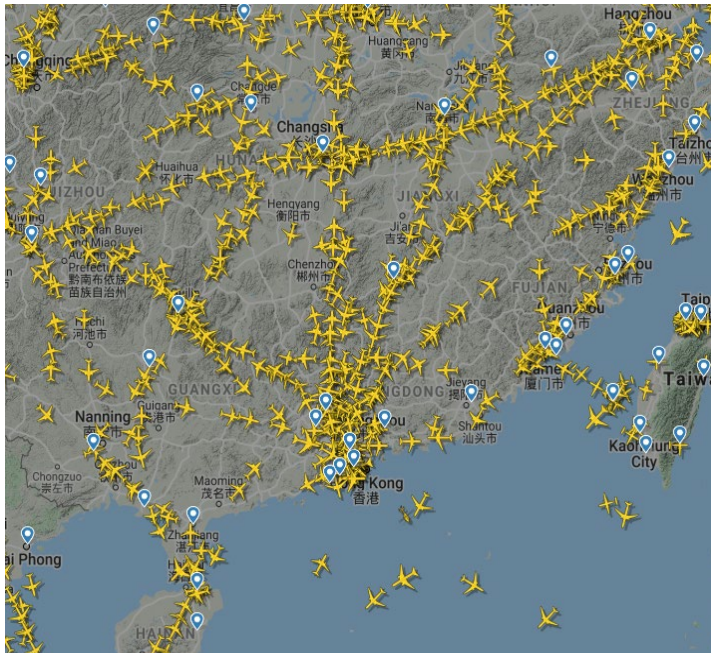


Objective: Safe and Best Sight Seeing

How is Path Planning important to Aviation Engineering?

- For ATC near airports, collaborative path planning is required to make the best use of the crowded airspace





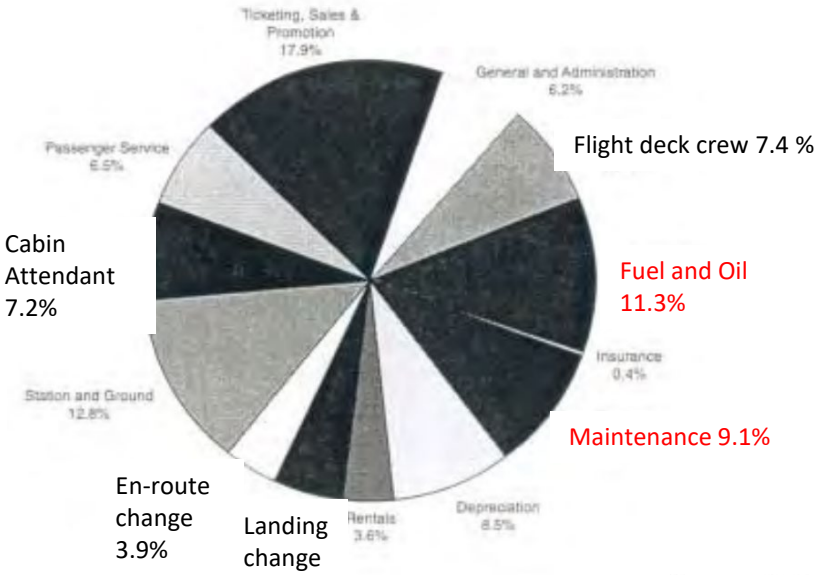
Objective: Safe and least delay

How is Path Planning important to Aviation Engineering?

- Commercial pilot follow the path that plan based on different cost index designed by airlines.

Objective: Safe and Minimum Cost

Figure 2. Distribution of operating costs



Source : IATA

https://ansperformance.eu/library/airbus-cost-index.pdf

2.1 Trip cost

Without having to resort to complicated mathematics we can readily appreciate that the total cost of a specific trip is the sum of fixed and variable costs :

$$C = C_F \times \Delta F + C_T \times \Delta T + C_c$$

with C_F = cost of fuel per kg
C_T = time-related cost per minute of flight
C_c = fixed costs independent of time
ΔF = trip fuel
ΔT = trip time

In order to minimize C or the total trip cost we therefore need to minimize the variable cost :

$$C_F \times \Delta F + C_T \times \Delta T$$

Cost-Index Published by Aircraft Manufacturer

AIRBUS

3.1 A300/A310 Family

Considering, with good approximation, that the following range of time-related costs cover the maintenance cost difference between A300 and A310 as well as the cabin crew contingent (plus or minus two) difference, the following cost brackets result :

	6 < Hourly maintenance cost	< 12 (US$/min)
+	7 < Crew cost	< 14 (US$/min)
	13 < Time-related cost	< 26 (US$/min)

NB : Crew composition = 2 cockpit crews + 8 (± 2) cabin crews.

In turn, the following cost index tables reflect these cost ranges for the A300 and for the A310.

Table 1. A300/A310 cost index

(kg/min)
(Honeywell FMS)

TIME COST (US$/min) / FUEL COST (US$/USG)	LOW < 15	MEDIUM 15 < to < 20	HIGH > 20
LOW < 0.7	65	85	100
MEDIUM 0.7 < < 0.9	50	65	80
HIGH > 0.9	40	55	65

https://ansperformance.eu/library/airbus-cost-index.pdf

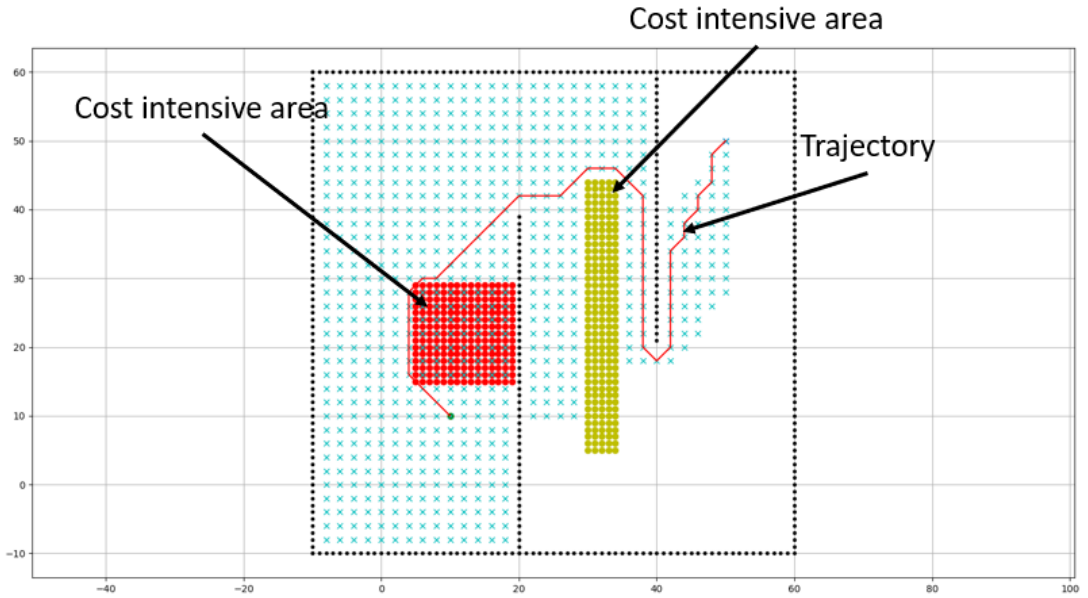
Path Planning

- Optimization Problem:
- To optimize a path that fulfilling all the constrains and by a set of certain criteria.
- Goal of this project, ***to select the best aircraft models with an optimized route that minimized the cost of the aircraft operation under given scenario.***
- ***Design the cost of the aircraft operation***
- ***Design an aircraft model (virtually) with different cost coefficients to fly safe and cheapest.***
- ***Design the path planning algorithm considering 3D, 2D + time, scenarios.***

Expected Outcome:
Every Group have different scenarios

We are airline. We wish to find a route with minimized cost.

What tasks we do?



Aircraft Operation in Flight Control System

Path Planning

Desired Waypoints, Destination and More

Database

Desired Speed, Height and Heading

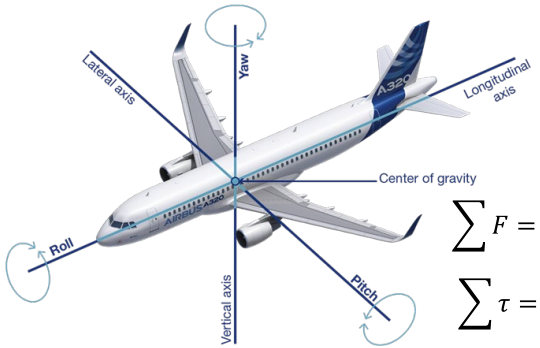
Desired Pitch, Yaw and Roll Angles

Change of Elevator, Rudder and Ailerons Positions

Change of Pitch, Yaw and Roll Angles

Airline Plan → Pilot → FMS → Autopilot → FBW → Flight Mechanics → Integration → Position, Velocity and Rotation of the Aircraft

Gyroscopes



$$\sum F = \frac{d(mv)}{dt}$$

$$\sum \tau = \frac{d(I\omega)}{dt}$$

Climb:		
Thrust	>	Drag
Lift	>	Weight

Cruise:		
Thrust	=	Drag
Lift	=	Weight

Descent:		
Thrust	<	Drag
Lift	<	Weight

Air Data Sensors/Computer

Magnetometer/ AHRS/IRS/GPS

GPS/VOR/DME

VHF/HF by ATC ADS-B/TCAS

How is the Path Planning Project related to the AE programme study?

- Mathematics & Physics
- Computer Science
- Aeronautical and Aviation

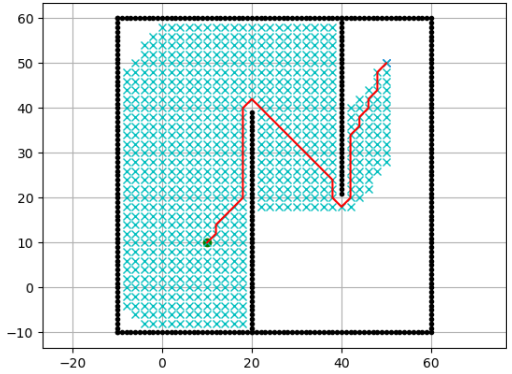
- The path should be planned considering the **practical limitation (aviation system)** of the aircraft

Year 1 (30 + 4 training credits)	
Semester 1 (15 + 2 training credits)	**Semester 2 (15 + 2 training credits)**
AAE1001 Introduction to Artificial Intelligence and Data Analytics in Aerospace and Aviation Engineering (GUR-AIDA) (*2 credits*)	AAE2003 Introduction to Aircraft Systems
AAE1002 Innovation and Entrepreneurship in Green Aviation and Space Economy (GUR-IE) (*1 credit*)	AMA1120 Basic Mathematics II
AAE2004 Introduction to Aviation System and Air Transport Regulation	AP10006 Physics II
AMA1110 Basic Mathematics I	APSS1L01 Tomorrow's Leaders
AP10005 Physics I	CAR I ^
LCR I English Language Subject	
Healthy Lifestyle (non-credit bearing) ^	
AAE2101 / IC2105 Engineering Communication and Fundamentals (4 training credits); ***or*** AAE2102 / IC2133 Aircraft Manufacturing and Maintenance Fundamentals (4 training credits)	
Year 2 (33 + 3 training credits)	
Semester 1 (15 + 3 training credits)	**Semester 2 (18 credits)**
AAE3103 / IC381 Appreciation of Aircraft Manufacturing Processes (3 training credits)	AAE2005 Electrics and Electronic for Aeronautical Engineering
AMA2111 Mathematics I	AMA2112 Mathematics II
ENG2001 Fundamentals of Materials Science and Engineering	CAR II^
ENG2002 Computer Programming	ENG2003 Information Technology
LCR II English Language Subject	LCR III Chinese Language Subject
ME23001 Engineering Mechanics	Service Learning ^
Year 3 (30 + 3 training credits)	
Semester 1 (15 + 1.5 training credits)	**Semester 2 (15 + 1.5 training credits)**
AAE3002 Aircraft Structures and Materials	AAE3001 Fundamentals of Aerodynamics
AAE3004 Dynamical Systems and Control	AAE3003 Aircraft Propulsion Systems
AAE3008 Fundamental Thermal-fluid Science	AAE4006 Flight Mechanics and Control Systems
CAR III ^	ENG3004 Society and the Engineer
Elective Subject (1)	Elective Subject (2)
AAE3104 / IC388 Aircraft Manufacturing and Maintenance Practice (3 training credits)	

What you are expected to learn?

Academic level of algorithm designs

- Design of a path planning algorithm and aircraft model cost function
  - 2D path planning for simplicity



Make use of the **open-resource** to work on coding-project **remotely**.

- Programming and coding
  - Python
- Online coding collaboration
  - GitHub

python™

GitHub

AtsushiSakai / PythonRobotics

Assessments

- (25%) Demonstration and Presentation
- (25%) Report & reflective essay – one report per group, with individual reflective essay
- (10%) Performance/participation in in-class activities (Confidential peer evaluation)

In this project, students will be acted as

- Technical Lead/Members (MUST be the one who is interested at coding)
  - Develop the math behind the compulsory tasks.
  - Write the codes (Compulsory Tasks 1, 2 and 3)
  - Write the codes (Additional Tasks)

- Project Lead/Members (manage the project report and video presentation [slide])
  - Study the “numbers” related to aviation context.
  - Prepare report using GitHub Readme format.
  - Prepare PowerPoint slide and record the presentation video.

Deadline to submit the work

- Codes uploads to GitHub project created yourself
- Project report written in GitHub readme format.
- Peer review assessment
- Video presentation (20-25 minutes).
  - Everyone has to present about 3 minutes.
  - Must have a slide
- DEADLINE 23:50pm on 3 Dec (Sun).

Project GitHub Homepage

https://github.com/IPNL-POLYU/PolyU_AAE1001_Github_Project