# AAE2004 Introduction to Aviation Systems
# AAE
# Design of Path Planning Algorithm for Aircraft Operation

## Week 3: Introduction to Path Planning, Python and GitHub

Dr Li-Ta Hsu and Dr Weisong Wen

Assisted by

Man Hei CHENG (Melvin), Miss Hiu Yi HO (Queenie), Miss Yan Tung LEUNG (Nikki)

# Lecturer's Information

- **Instructor**: Dr Li-Ta HSU
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- Office Hour: by appointment

- **Expertise:** GPS navigation, Autonomous driving, Pedestrian localization using Smartphone, Sensor Integration

# Li-Ta HSU

1985.08 – Born in a fish farmer family in Tainan, Taiwan

2003.06 – Graduated from Kang Ming Senior High School, Taiwan

2007.06 – Bachelor of NCKU Department of Aeronautics and Astronautics (DAA), Taiwan

2010.09 – Ph.D. Candidate of NCKU DAA, Taiwan

2012.02 – Visiting Researcher in University College London, UK

2012.06 – Part-time Consultant for Spirent, UK

2013.07 – Visiting Researcher in Tokyo Marine University, Japan

2013.12 – Ph.D. of NCKU DAA, Taiwan

2014.04 – Postdoctoral Researcher in the University of Tokyo , Japan

2017.05 – Assistant Professor in AAE of PolyU, Hong Kong

2021.07 – Associate Professor in AAE of PolyU, Hong Kong

# Ground Rules

## For students

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

## For teaching staffs

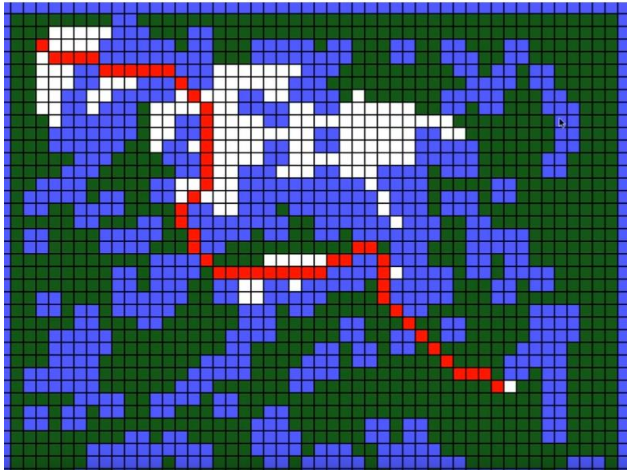
- Reply your email with 3 working day.
- Open to any question regards to the subject

## 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

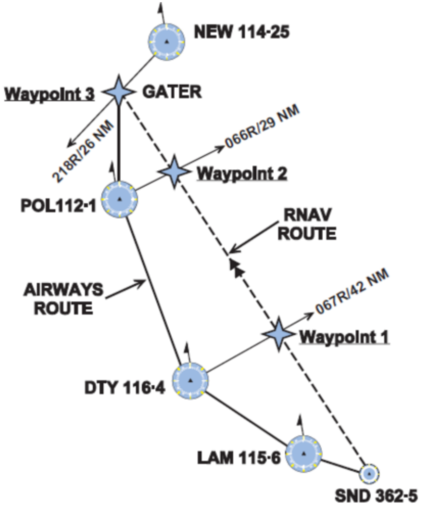
# What is Path Planning? How to go from A to B considering factors!

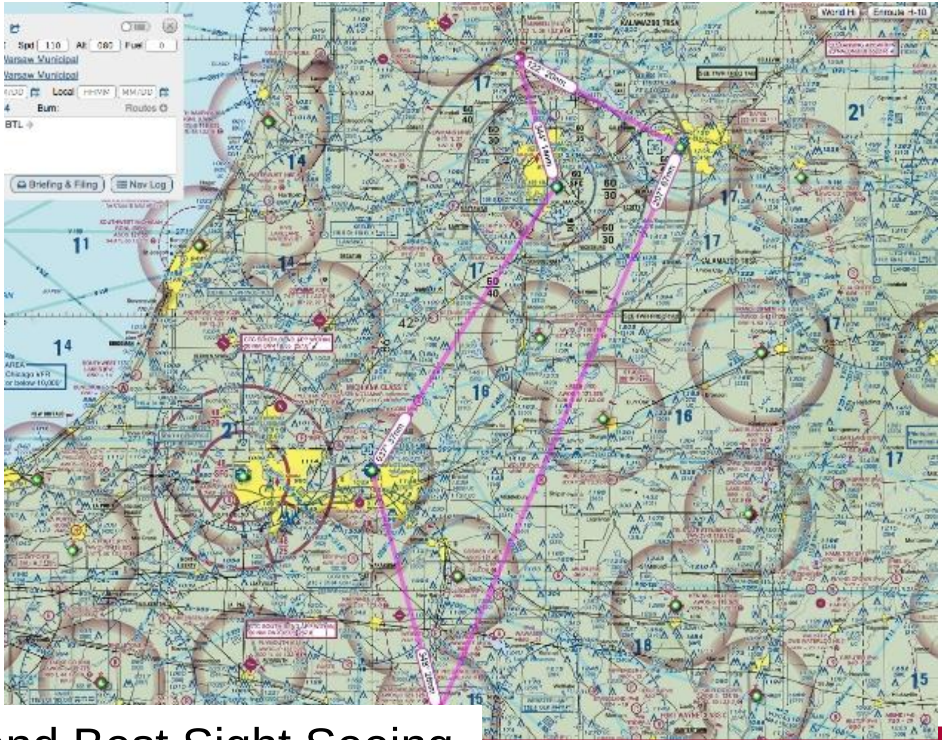
- **Path planning** (also known as the **navigation problem**) is computational problem to find a sequence of valid configurations that moves the object from the source to destination. The term is used in **aviation**, **robotics** and **computer games**.



# 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

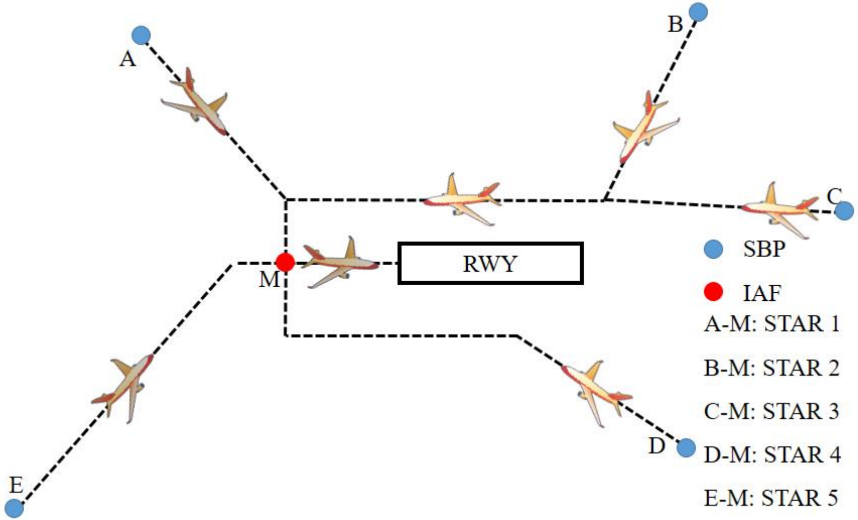


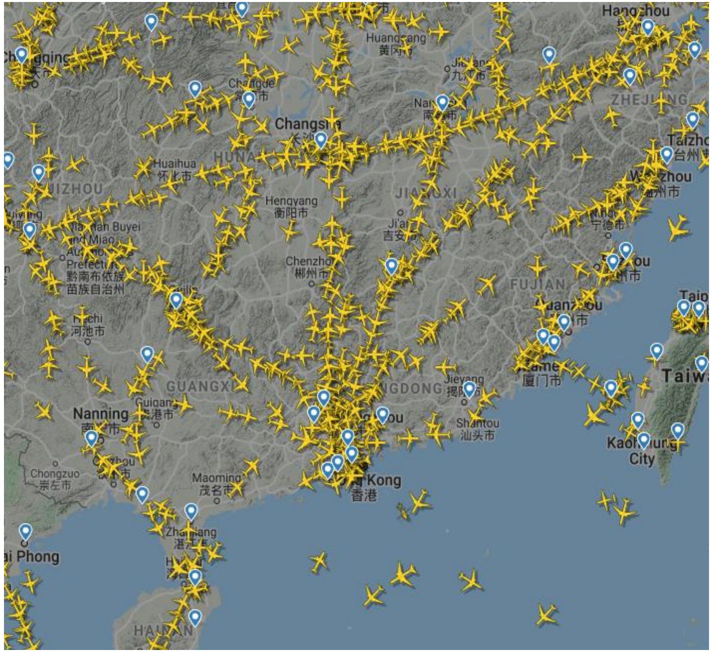




Objective: Safe and Best Sight Seeing

# 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



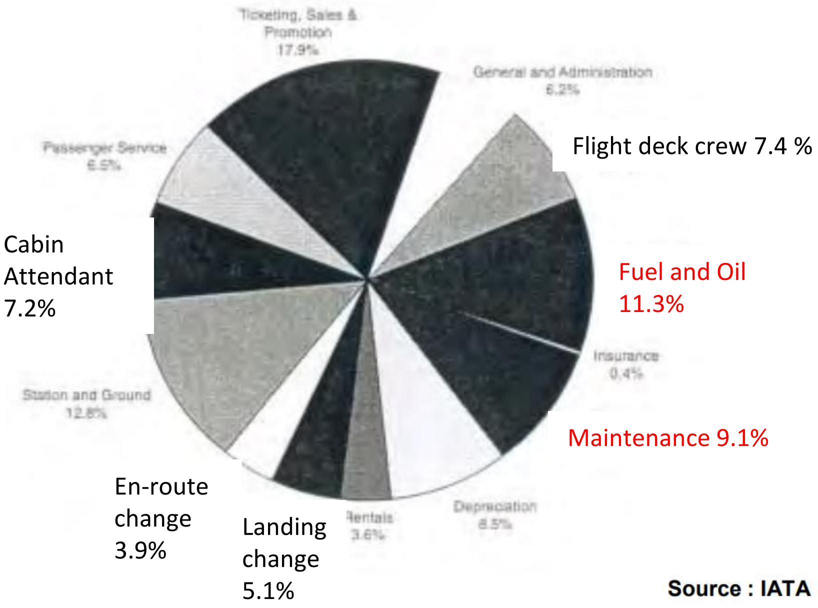

Objective: Safe and least delay

# 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**

**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 :

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

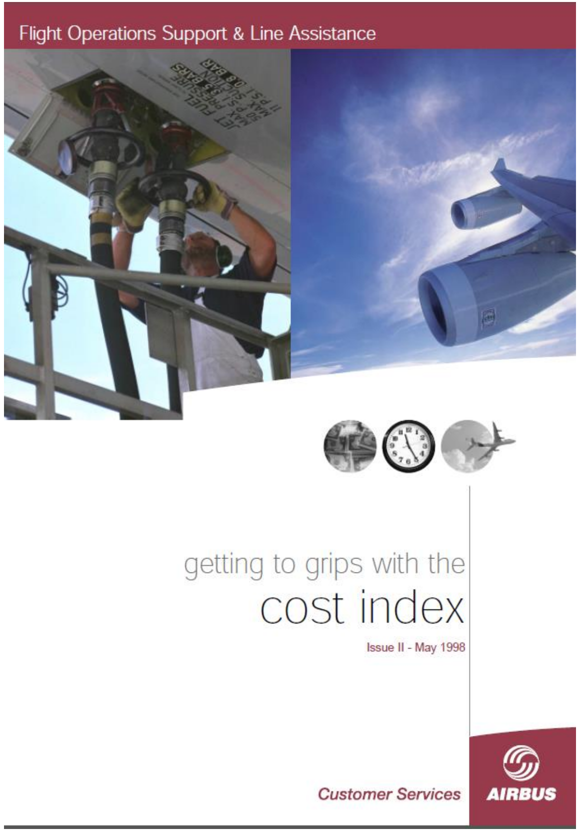
with $C_F$ = cost of fuel per kg
$C_T$ = time-related cost per minute of flight
$C_c$ = fixed costs independent of time
$\Delta F$ = trip fuel
$\Delta T$ = trip time

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

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

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

# 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

# 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

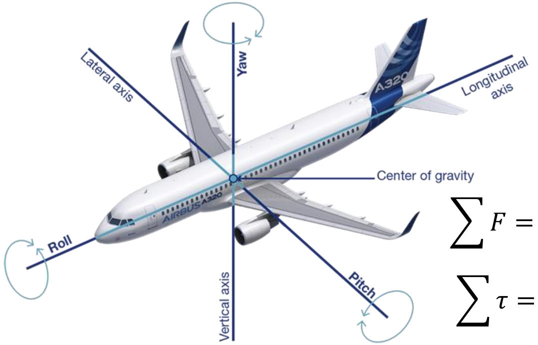
Gyroscopes

Air Data Sensors/Computer

Magnetometer/ AHRS/IRS/GPS

GPS/VOR/DME

VHF/HF by ATC ADS-B/TCAS




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

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

| Climb: | | | Cruise: | | | Descent: | | |
|---|---|---|---|---|---|---|---|---|
| Thrust | > | Drag | Thrust | = | Drag | Thrust | < | Drag |
| Lift | > | Weight | Lift | = | Weight | Lift | < | Weight |

Interdisciplinary Division of Aeronautical and Aviation Engineering
航空工程跨領域學部

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

# How is the Freshman Project related to the AE programme study?

- Mathematics & Physics
- Computer Science
- Aeronautical and Aviation

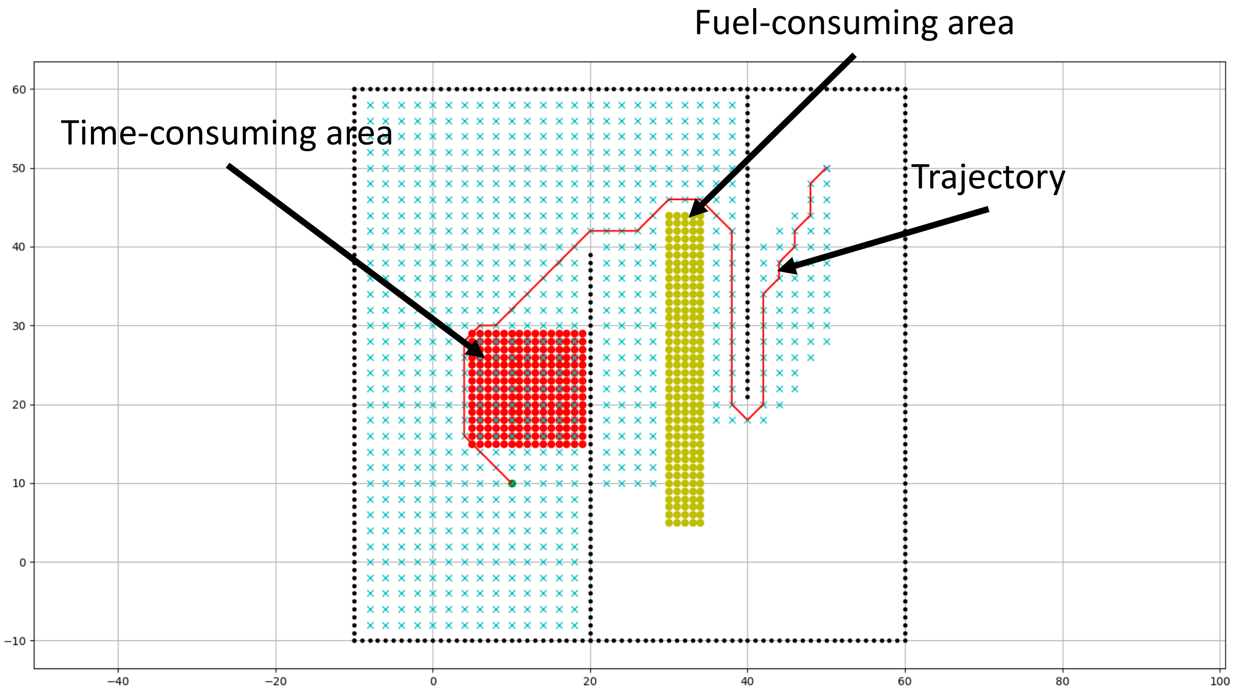
- The plan should be planned considering the physical limitation (dynamics) of the aircraft

| | | | |
|---|---|---|---|
| **Year 1 (33 + 4 training credits)** | | | |
| **Semester 1 (15 + 2 training credits)** | | **Semester 2 (18 +2 training credits)** | |
| AAE2001 | Introduction to Aircraft and Aviation Systems | AMA1120 | Basic Mathematics II |
| AMA1110 | Basic Mathematics I | AP10006 | Physics II |
| AP10005 | Physics I | APSS1L01 | Tomorrow's Leaders |
| ENG1003 | Freshman Seminar for Engineering | ENG2003 | Information Technology |
| LCR I (English) | | LCR II (English) | |
| | | CAR I ^ | |
| Healthy Lifestyle (non-credit bearing) ^ | | | |
| IC2105 Engineering Communication and Fundamentals (4 training credits) ***or*** IC2133 Aircraft Manufacturing and Maintenance Fundamentals (4 training credits) | | | |
| **Year 2 (30 + 3 training credits)** | | | |
| **Semester 1 (15 credits)** | | **Semester 2 (15 + 3 training credits)** | |
| AMA2111 | Mathematics I | AMA2112 | Mathematics II |
| ENG2001 | Fundamentals of Materials Science and Engineering / Biology / Chemistry | EE2902S | Fundamentals of Electrical and Electronic Engineering |
| ENG2002 | Computer Programming | ME33001 | Mechanics of Materials |
| ME23001 | Engineering Mechanics | LCR III (Chinese) | |
| CAR II^ | | CAR III^ | |
| IC381 | Appreciation of Aircraft Manufacturing Processes (3 training credits) | | |
| Year 3 (32 + 3 training credits) | | | |
| Semester 1 (17 + 1.5 training credits) | | **Semester 2 (15 + 1.5 training credits)** | |
| AAE3001 | Fundamentals of Aerodynamics | AAE3003 | Aircraft Propulsion Systems |
| AAE3002 | Aircraft Structures and Materials | AAE4006 | Flight Mechanics and Control Syste |
| AAE3004 | Dynamical Systems and Control | AAE4301 | Avionics Systems |
| ELC3531 | Professional Communication In English For Engineering Students *(2 credits)* | AF3625 | Engineering Economics |
| CAR IV ^ | | ISE3009 | Aviation Safety and Reliability |
| Service Learning ^ | | | |
| IC388 Aircraft Manufacturing and Maintenance practice (3 training credits) | | | |

# 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.***

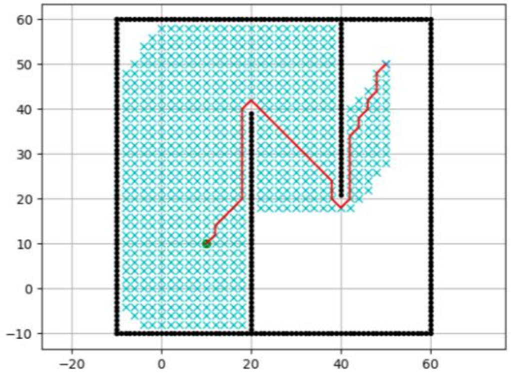
# Expected Outcome.
# Every Group have different scenarios



# Model of Aircraft to select

| Aircraft Model | $C_F$ | $\Delta F$ | $C_T$ | $\Delta T$ | $C_c$ | $\Delta F_a$ | $\Delta T_a$ |
|---|---|---|---|---|---|---|---|
| PolyU-A380 | 1 | 1 | 2 | 5 | 10 | 0.2 | 0.2 |
| PolyU-A381 | 1 | 1.5 | 3 | 5 | 10 | 0.3 | 0.4 |
| PolyU-A382 | 1 | 2.0 | 4 | 5 | 10 | 0.4 | 0.5 |
| PolyU-A383 | 1 | 2.5 | 5 | 5 | 10 | 0.5 | 0.1 |
| AAE-Group 1 | ? | ? | ? | ? | ? | ? | ? |
| AAE-Group 2 | ? | ? | ? | ? | ? | ? | ? |
| AAE-Group 3 | ? | ? | ? | ? | ? | ? | ? |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

# 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

AtsushiSakai / **PythonRobotics**

# In this project, students will be acted as

1. Group leader or members to collaborate on an online project,
2. R&D engineers to design and develop path-planning algorithm,
3. Project manager to present the designed code and prepare report.

# Assessments

- (30%) Demonstration and Presentation
- (40%) Report & reflective essay – one report per group, with individual reflective essay
- (20%) Log sheet – one per student after the first week
- (10%) Performance/participation in in-class activities (Confidential peer evaluation)