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

Week 3: Introduction to Path Planning, Python and GitHub

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Assisted by

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

Lecturer's Information

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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

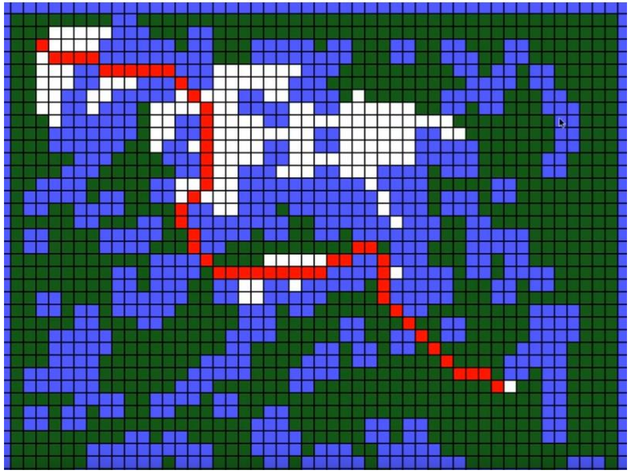
- Reply your email with 3 working day.
- Open to any question regards to the subject

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

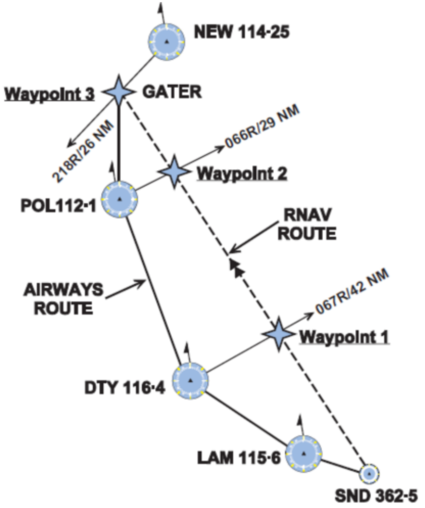
What is Path Planning? How to go from A to B considering factors!

- **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?

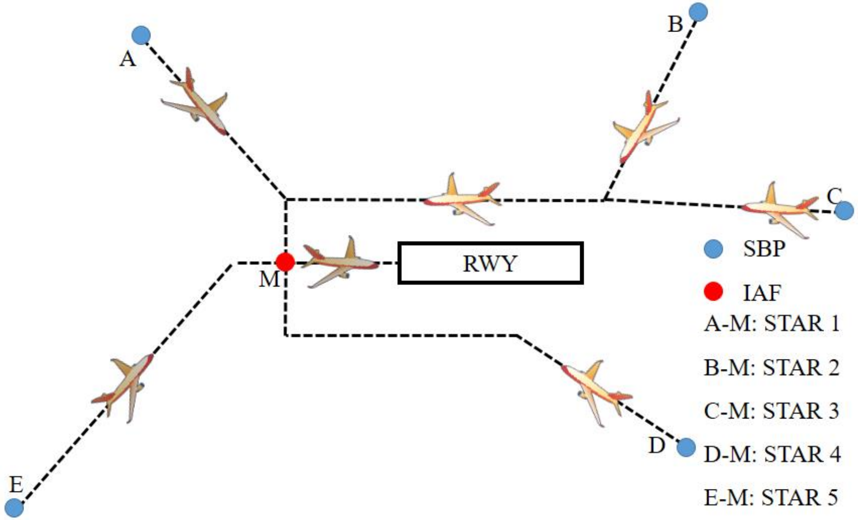
- Private pilots do the path plan before the flight to make sure the navigation aid is available

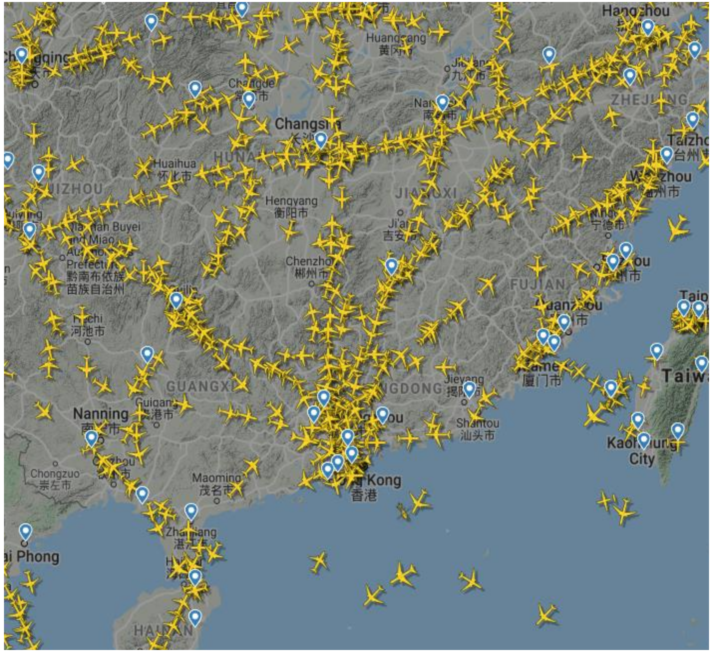


Objective: Safe and Best Sight Seeing

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





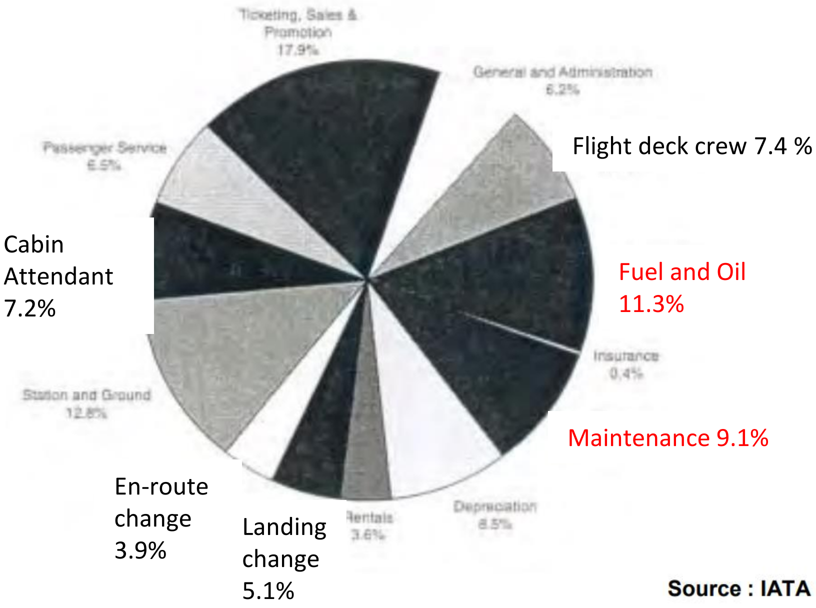
Objective: Safe and least delay

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 :

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

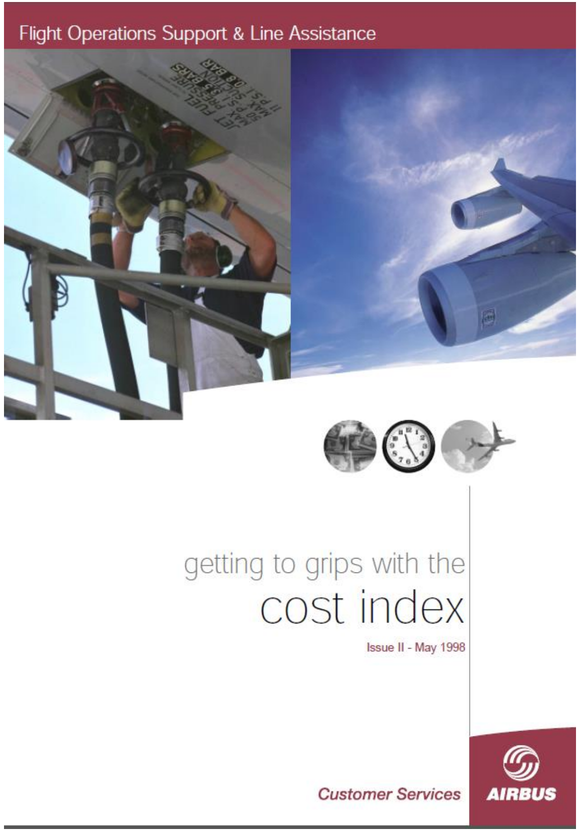
with
C_F = cost of fuel per kg
C_T = time-related cost per minute of flight
C_c = fixed costs independent of time
ΔF = trip fuel
ΔT = trip time

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

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

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.

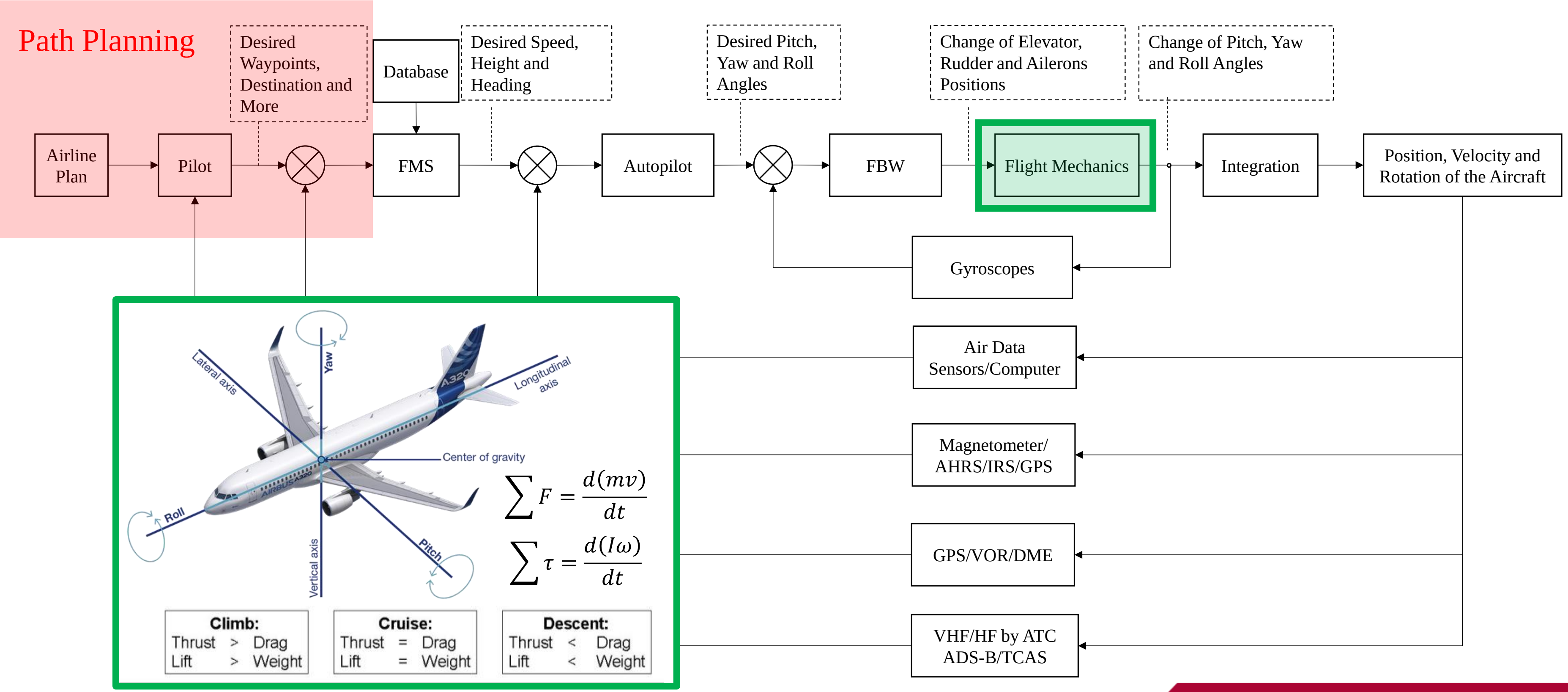
Table 1. A300/A310 cost index

(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



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

- Mathematics & Physics
- Computer Science
- Aeronautical and Aviation

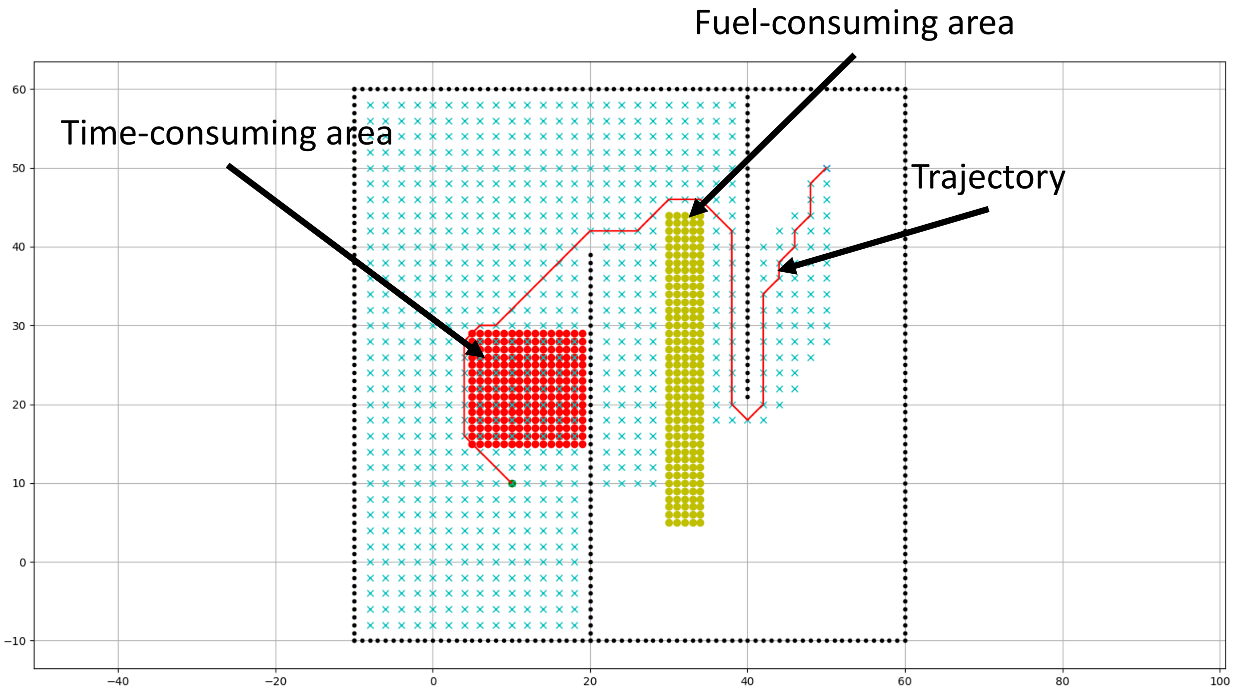
- The plan should be planned considering the physical limitation (dynamics) of the aircraft

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



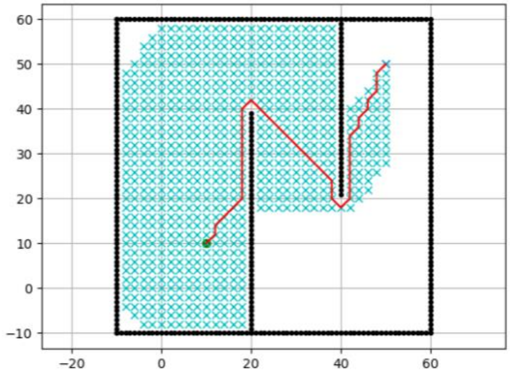
Model of Aircraft to select

Aircraft Model	C_F	ΔF	C_T	ΔT	C_c	ΔF_a	ΔT_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)