ENG1003 Freshman Seminar for Engineering
AAE
Design of Path Planning Algorithm for Aircraft Operation

Week 6: Project Goals (design & learning)
Compulsory Tasks

Dr Li-Ta Hsu and Dr Weisong Wen

Assisted by

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

Tasks of this Freshman Project – Path Planning

1. Find the suitable aircraft models that achieve the minimum cost for the challenge assigned to your group. (Satisfactory)
2. Design a new cost area that can reduce the cost of the route. (Excellence)
3. Design a new aircraft model within the constrains to achieve minimum cost for your group challenge.
4. Additional Tasks (see different slide)

The assessment of path planning part is based on the completion and the performance of 1, 2, 3 (compulsory) and 4 (additional), based on your codes, answers on your report and presentation

The Aircraft Models

- There are many types of aircrafts nowadays!
- Airbus, Boeing, Bombardier and more!
- Each aircraft has different properties
  - Capacity (Passenger and cargo)
  - **COST!**
- Costs of operating an aircraft might include:
  - **Crew cost**
  - **Fuel cost**
  - **Other operational costs**
  - **To keep it simple, costs can be calculated by:**

$$\mathrm{C} = C_F \cdot \Delta F + C_T \cdot \Delta T + C_c$$

With

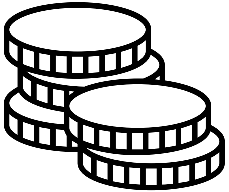
- C_F=cost of fuel per kg
- C_T=time related cost per minute of flight
- C_c=fixed cost independent of time
- C_T=time related cost per minute of flight
- ΔF=trip fuel
- ΔT=trip time
- C = total trip cost

Find the Aircraft Model that achieve minimum cost for each scenario for the challenge assigned to your group.

Task 1

Task 1

- You will be given 3 scenarios, each with different requirements to complete a functioning flight route
- Your task is to find out a shortest route from the departure point to the arrival point, then find out which type of aircraft to use for each scenario to achieve MINIMUM COST while fulfilling the passenger needs
- 3 main factors affecting the total cost:
    1. Shortest distance between your departure and arrival point
    2. Cost intensive area that the flight path might pass through
    3. Aircraft Fuel and Time costs
- Check out the example to understand this task better!



Task 1

- Restrictions and rules:
  - Only consider cruise time
  - Increase flight time by 20% and 40% respectively for cost intensive area 1 and 2 (What originally takes 1 minute to travel will take more time to travel!)
  - Only consider one type of aircraft per scenario
  - Time cost stays the same regardless of any vacancy in an aircraft
  - Only consider the 3 provided aircraft types
  - Each group must use their own obstacle set
  - Assume all aircrafts take 1 minute to travel one unit in the path planning algorithm (More cost for diagonal movements!)
  - **You must calculate the distance of the fastest path by using and modifying the program**
  - You may do the calculations using manually, but doing the calculation using programming will grant you bonus marks!

- Numbers

	A321neo	A330-900neo	A350-900
Fuel Consumption rate (kg/min)	54	84	90
Passenger Capacity	200	300	350
Time cost (Low) ($/min)	10	15	20
Time cost (Medium) ($/min)	15	21	27
Time cost (High) ($/min)	20	27	34
Fixed Cost (C_c) ($)	1800	2000	2500
Source: https://www.airlines-inform.com/			

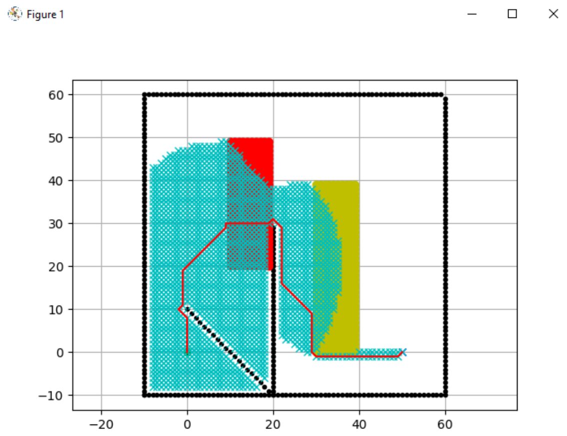
$$C = C_F \cdot \Delta F + C_T \cdot \Delta T + C_c$$

With

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

Task 1 Example (Step-by-step)

- Example Scenario:
  1. 2000 Passengers need to travel this week from the start to the destination
  2. 10 flights maximum for one week
  3. Time cost = low and Fuel cost = 0.8 $/kg
- First step: Find the shortest path for your obstacle set
  1. Set up your obstacles and cost intensive areas using the path planning programme
  2. Modify the program so it will calculate the unit travelled, hence cost via the shortest path (Remember the modifier for cost intensive areas!)
  3. In this example, the shortest path is assumed to be 100 units. After accounting for the cost intensive areas, the time required is 120 minutes



What the working program should look like

Task 1 Example (Step-by-step)

- Second step: Consider the Cost Factors

1. Since we can only operate 10 flights max, the viable options are ten A321 flights, seven A330 flights or six A350 flights to fulfil the 2000 passenger demand
2. We can now calculate the total cost using numbers we have and the cost equation:
   A321: (0.8$/kg x 120min x 54 kg/min + 10 $/min x 120 min + 1800) x 10 flights = $81840
   A330: (0.8$/kg x 120min x 84 kg/min + 15 $/min x 120 min + 2000) x 7 flights = $83048
   A350: (0.8$/kg x 120min x 90 kg/min + 20 $/min x 120 min + 2600) x 6 flights = $81240
3. As the total cost of operating A350 is the lowest, the answer for this example is 6 flights of A350!

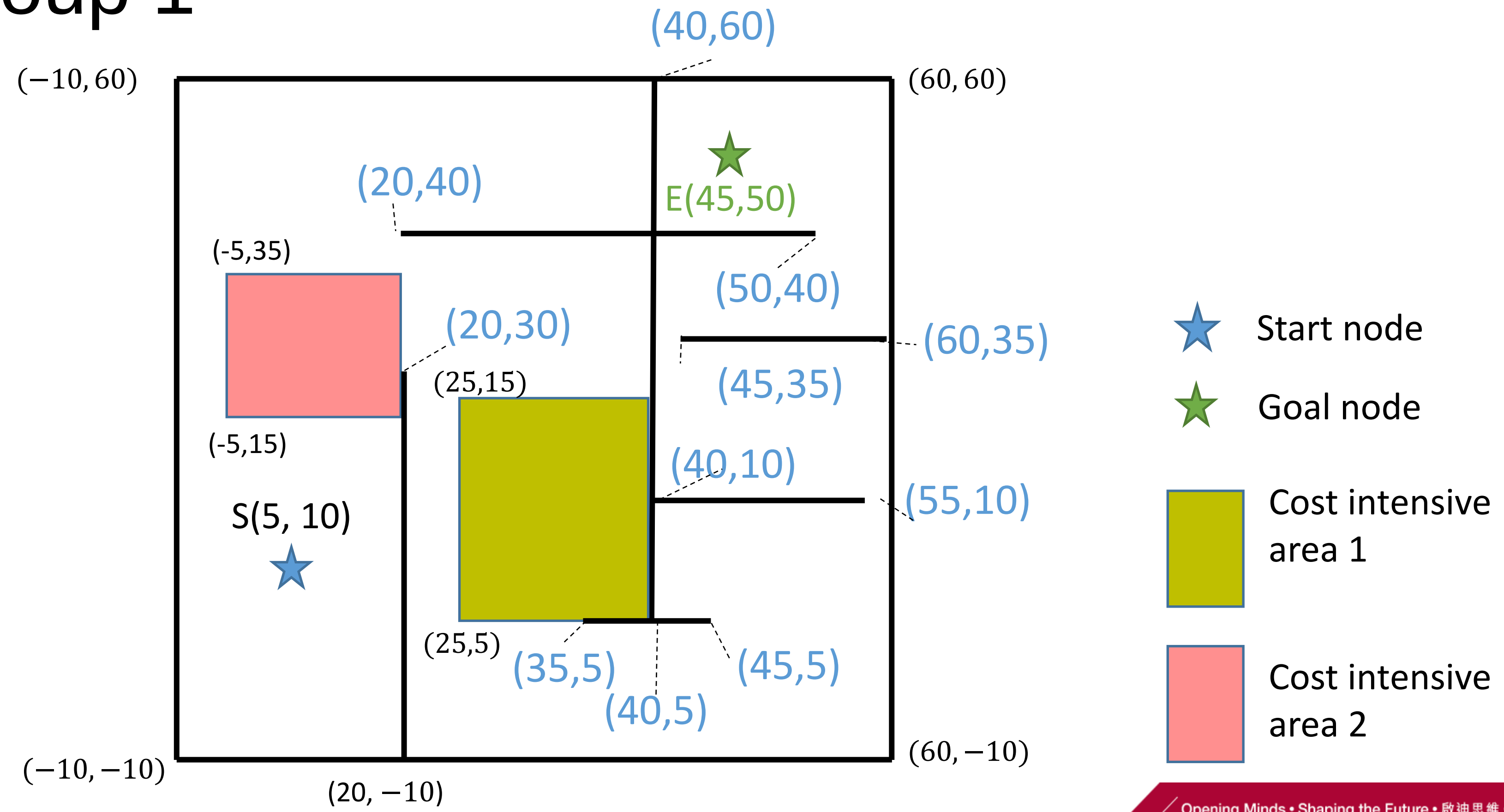
	A321neo	A330-900neo	A350-900
Fuel Consumption rate (kg/min)	54	84	90
Passenger Capacity	200	300	350
Time cost (Low) ($/min)	10	15	20
Time cost (Medium) ($/min)	15	21	27
Time cost (High) ($/min)	20	27	34
Fixed Cost (C_c) ($)	1800	2000	2500
Source: https://www.airlines-inform.com/			

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

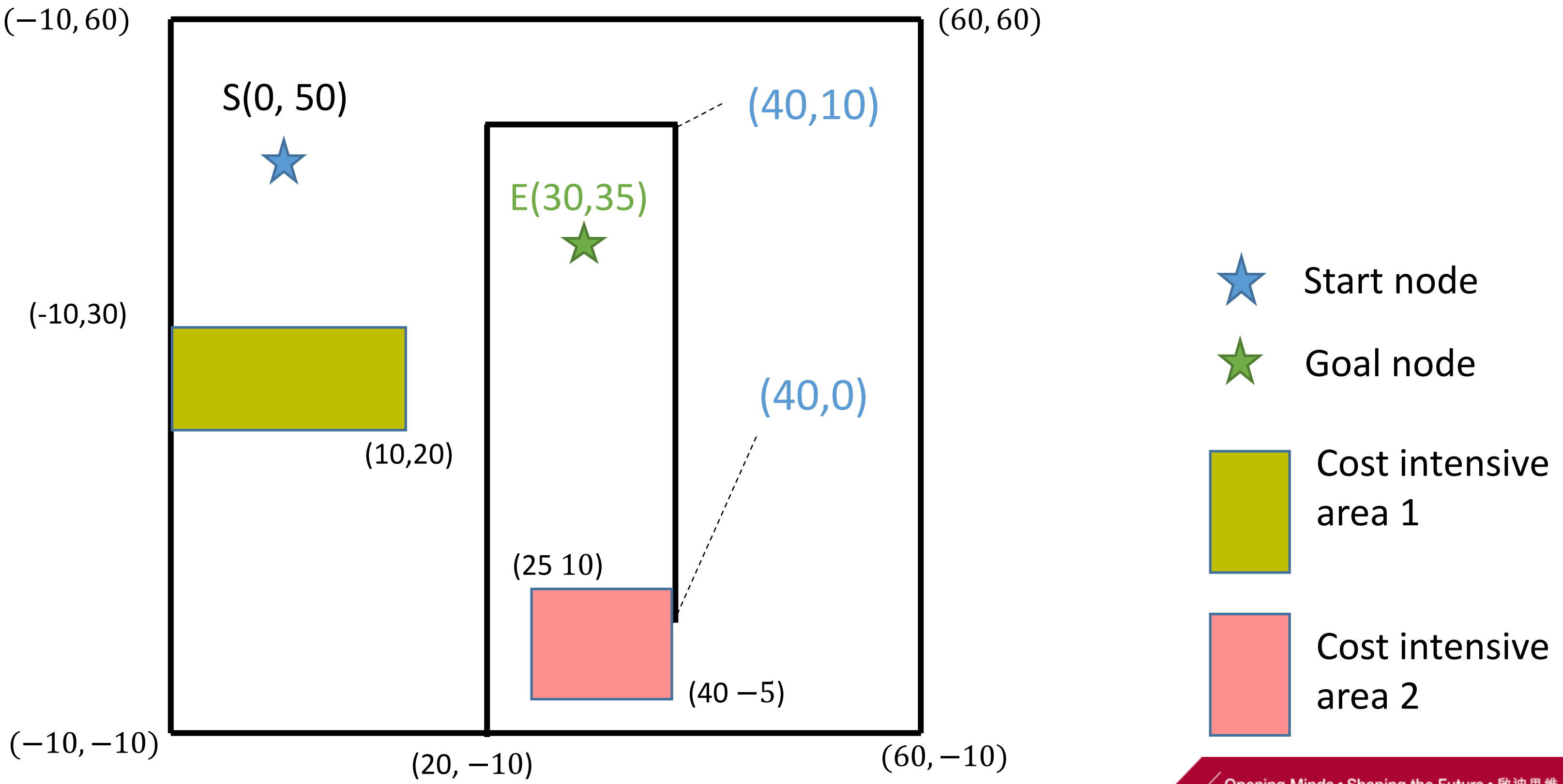
With

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

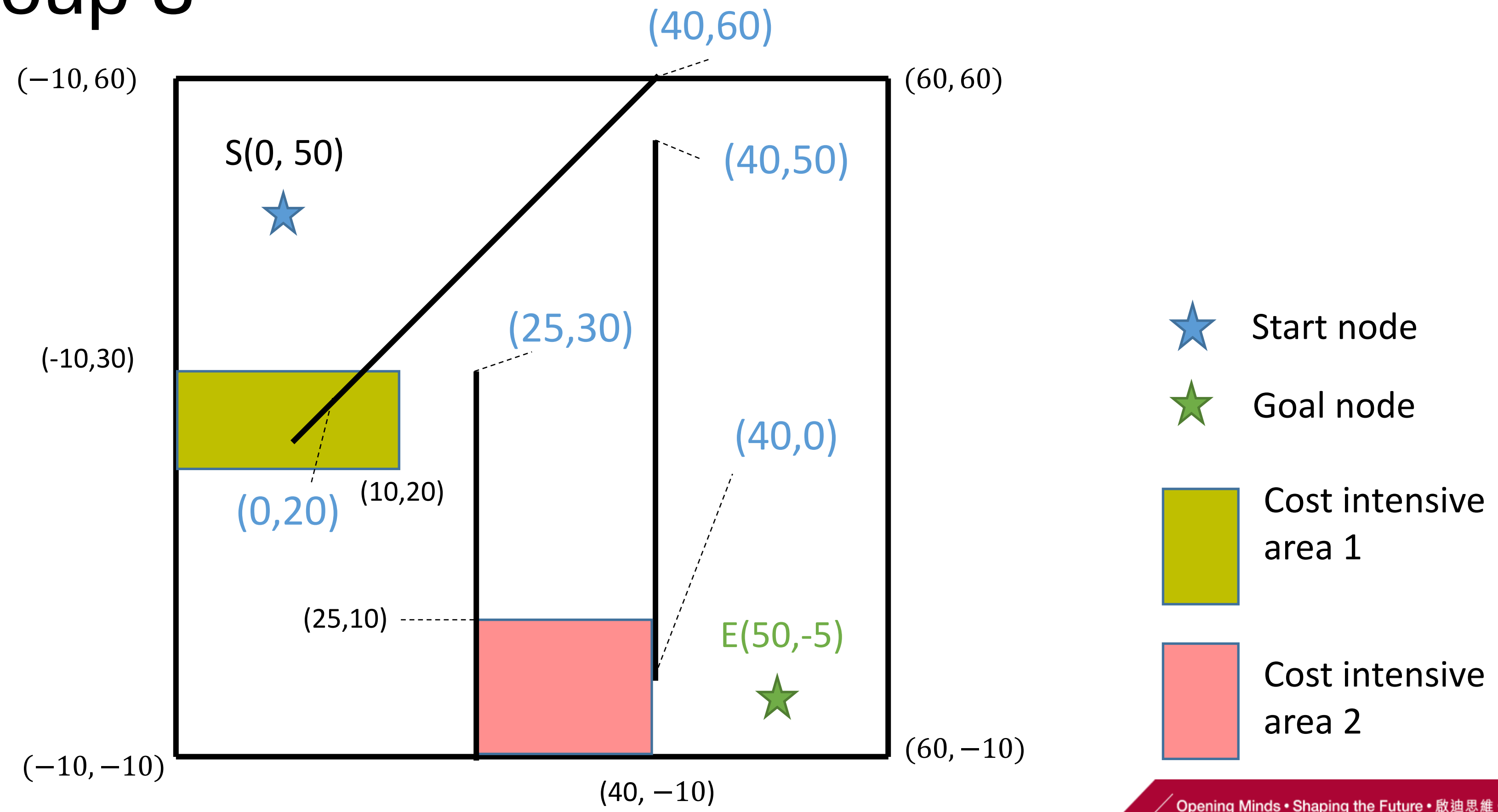
Group 1


(40,60)
(−10, 60)
(60, 60)
(20,40)
E(45,50)
(-5,35)
(50,40)
(20,30)
(60,35)
(25,15)
(45,35)
(-5,15)
(40,10)
(55,10)
S(5, 10)
(25,5)
(35,5)
(45,5)
(40,5)
(60, −10)
(−10, −10)
(20, −10)
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

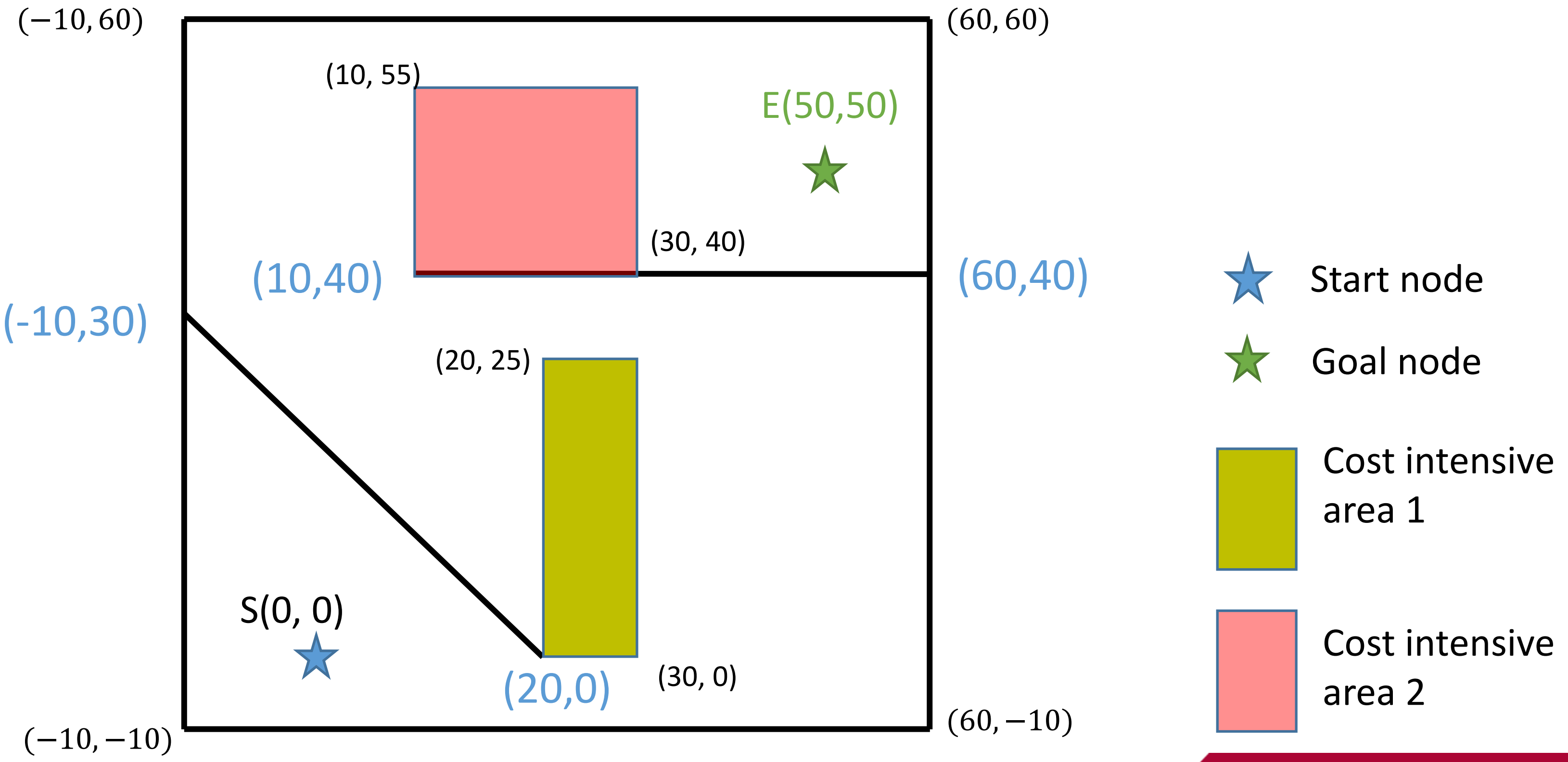
Group 2


(−10, 60)
(60, 60)
S(0, 50)
(40,10)
E(30,35)
(-10,30)
(10,20)
(40,0)
(25 10)
(40 −5)
(−10, −10)
(20, −10)
(60, −10)
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

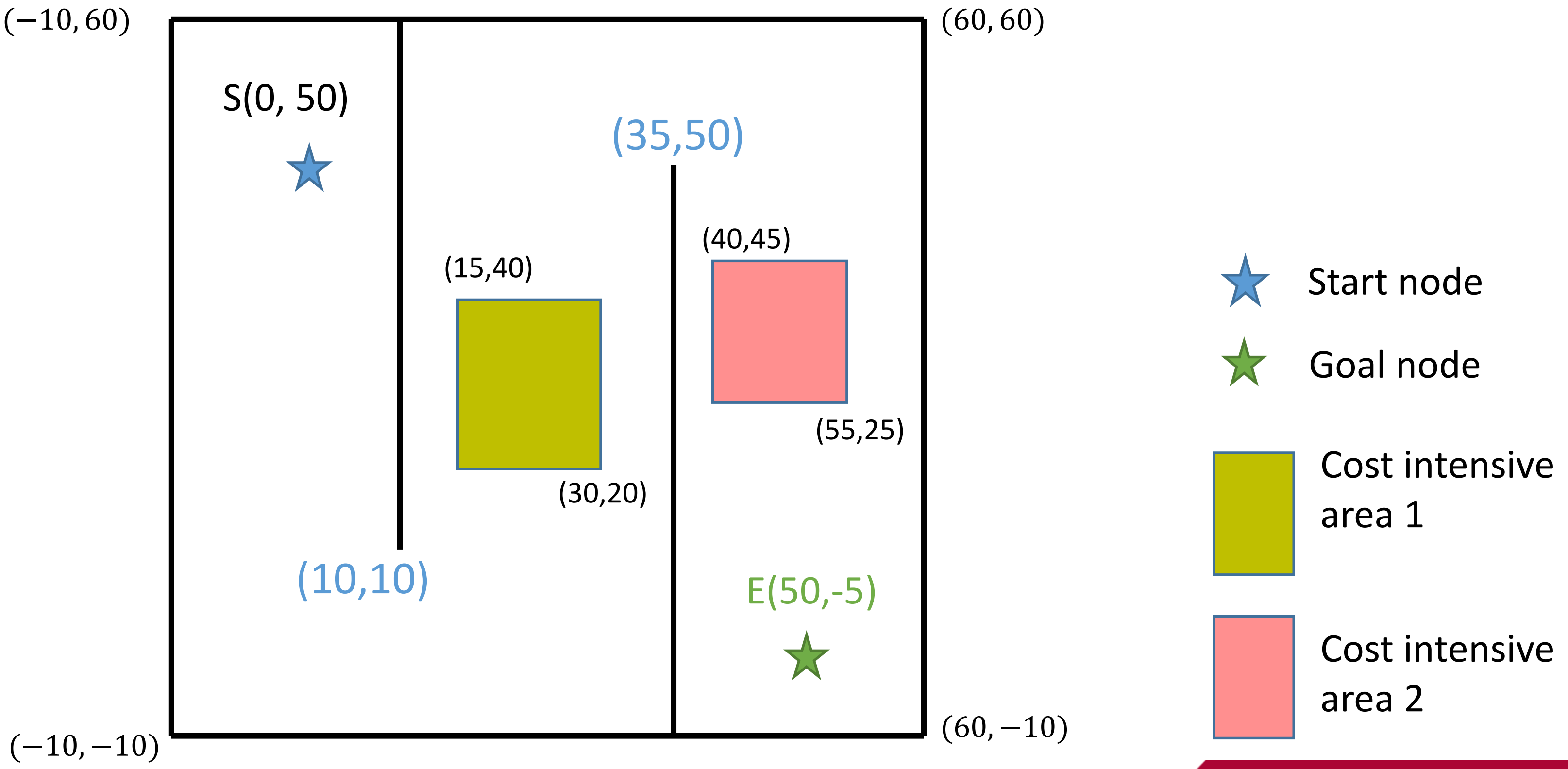
Group 3


(40,60)
(−10, 60)
(60, 60)
S(0, 50)
(40,50)
(25,30)
(-10,30)
(40,0)
(0,20)
(10,20)
(25,10)
E(50,-5)
(−10, −10)
(60, −10)
(40, −10)
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

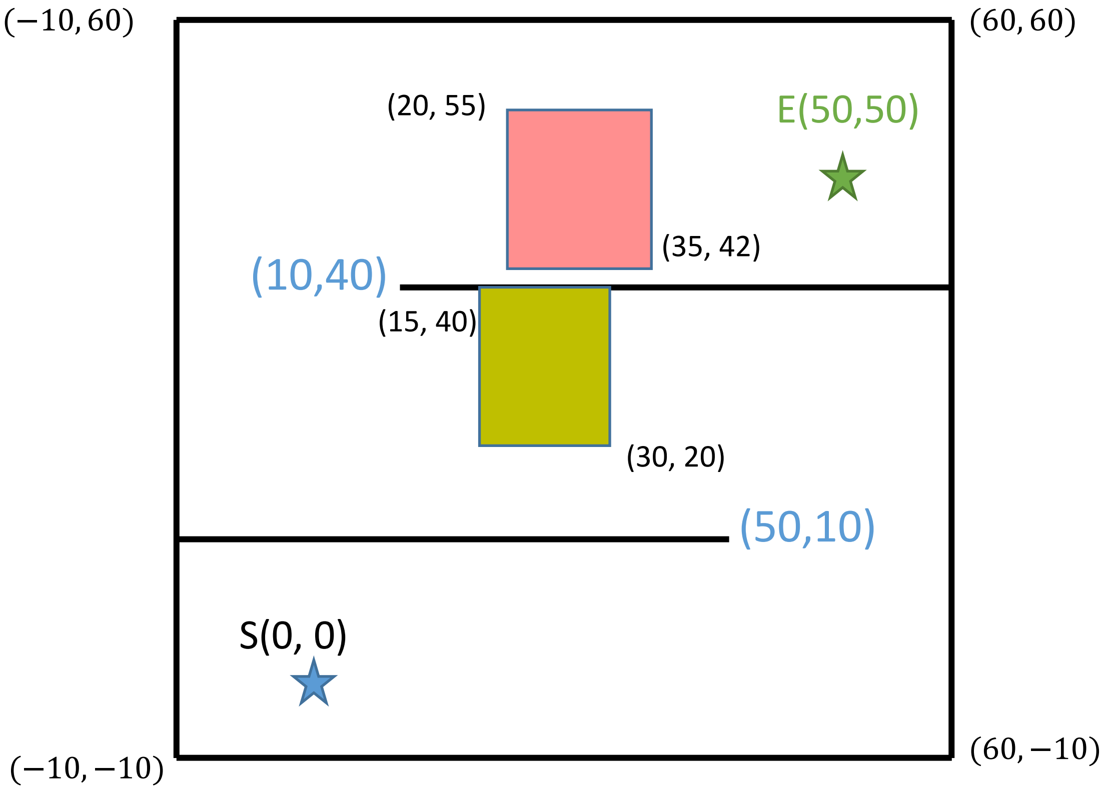
Group 4


(−10, 60)
(60, 60)
(10, 55)
E(50,50)
(30, 40)
(10,40)
(60,40)
(-10,30)
(20, 25)
S(0, 0)
(20,0)
(30, 0)
(−10, −10)
(60, −10)
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

Group 5


$(-10, 60)$
$(60, 60)$
S(0, 50)
(35,50)
(40,45)
(15,40)
(55,25)
(30,20)
(10,10)
E(50,-5)
$(-10, -10)$
$(60, -10)$
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

Group 6



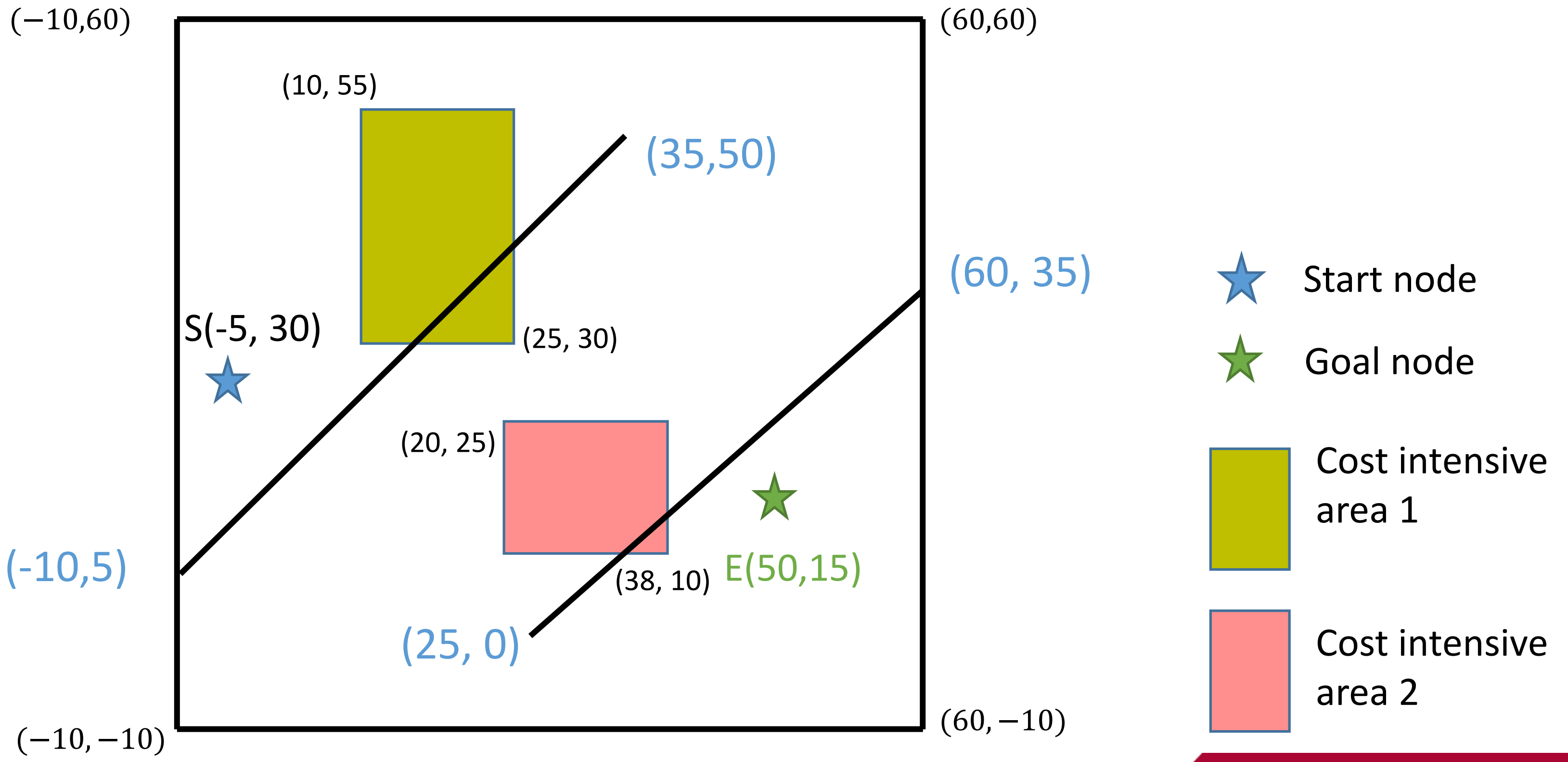
Start node

Goal node

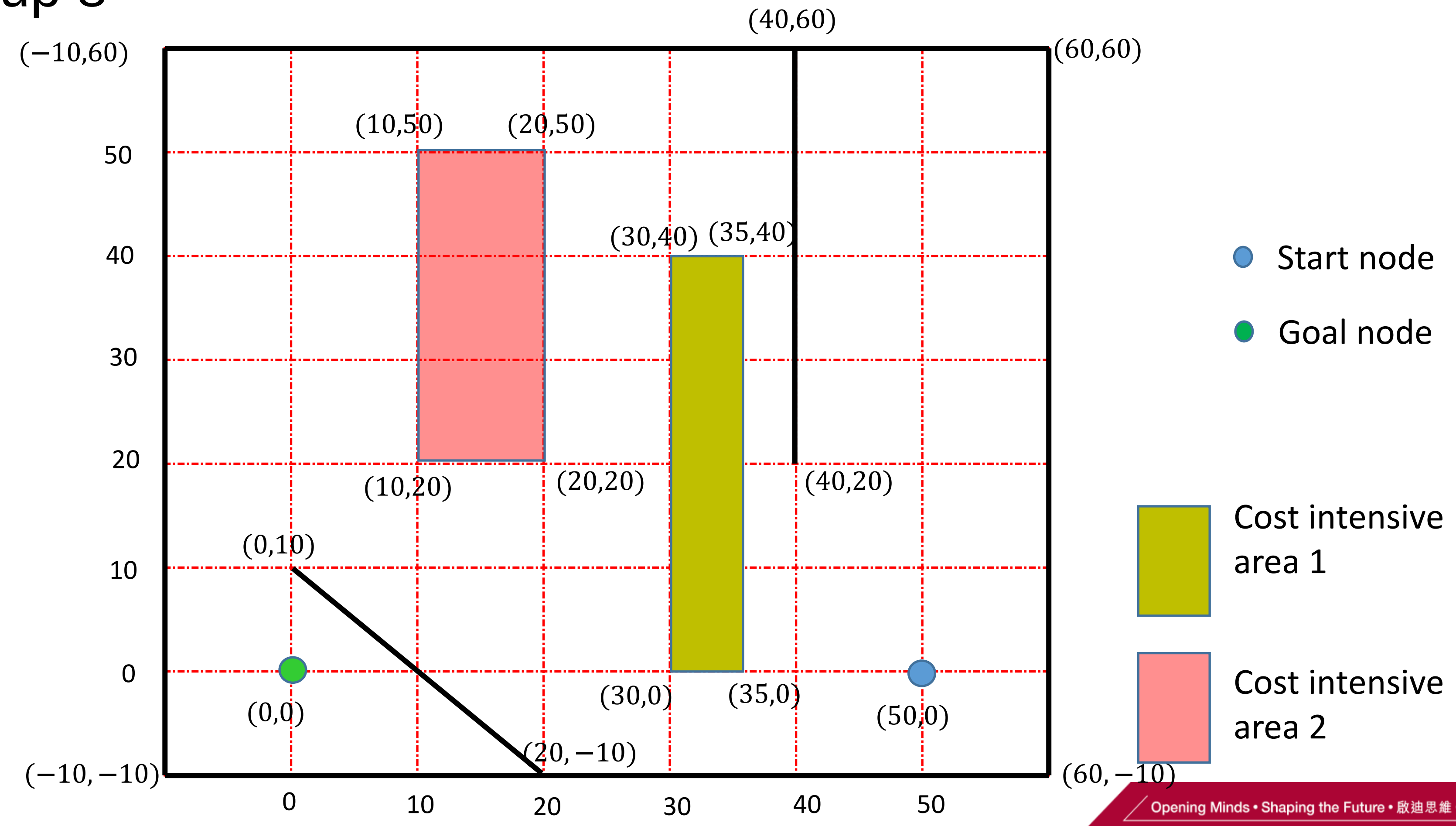
Cost intensive area 1

Cost intensive area 2

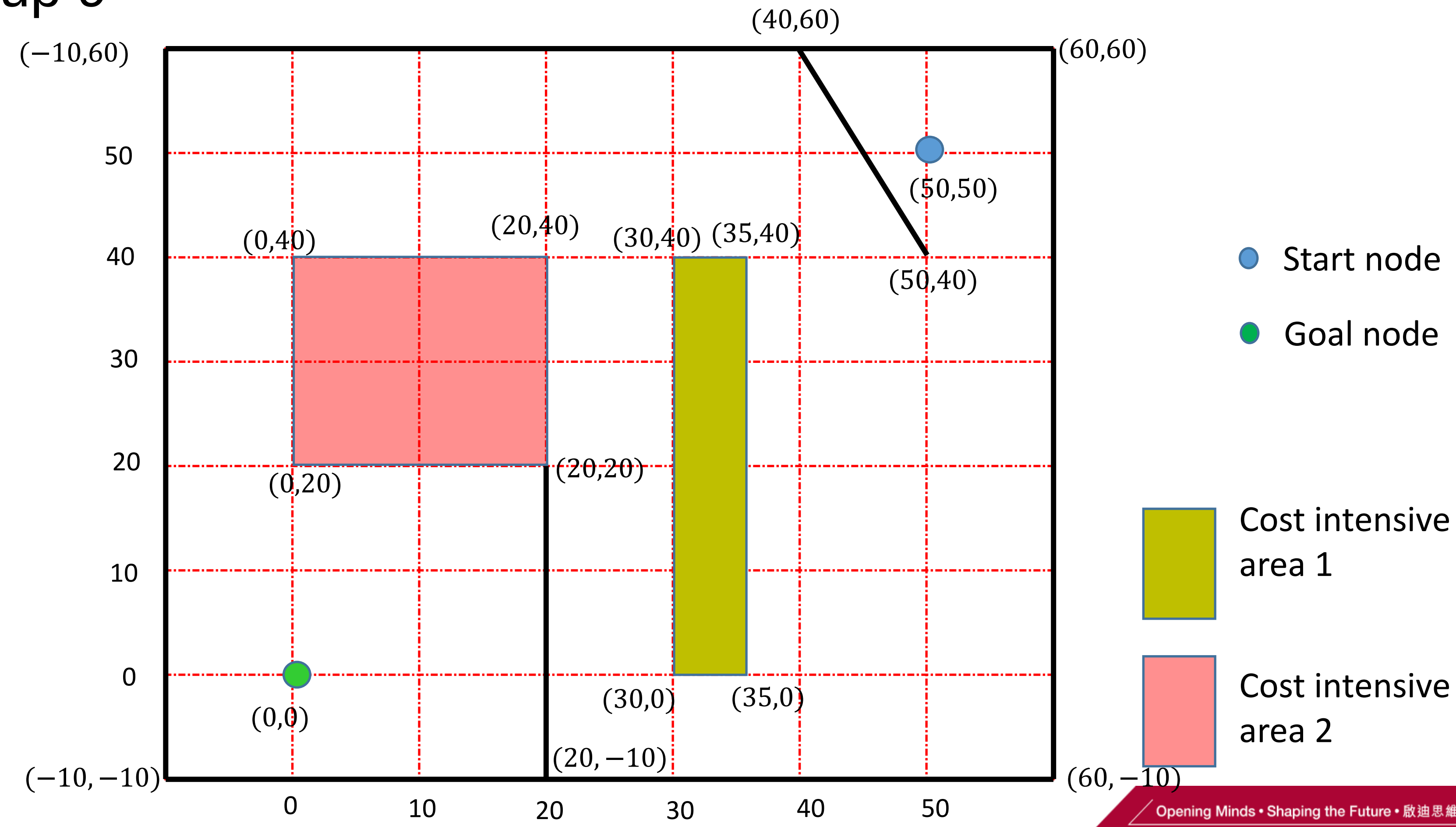
Group 7


$(-10,60)$
$(60,60)$
(10, 55)
(35,50)
(60, 35)
S(-5, 30)
(25, 30)
(20, 25)
(-10,5)
(38, 10)
E(50,15)
(25, 0)
$(-10,-10)$
$(60,-10)$
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

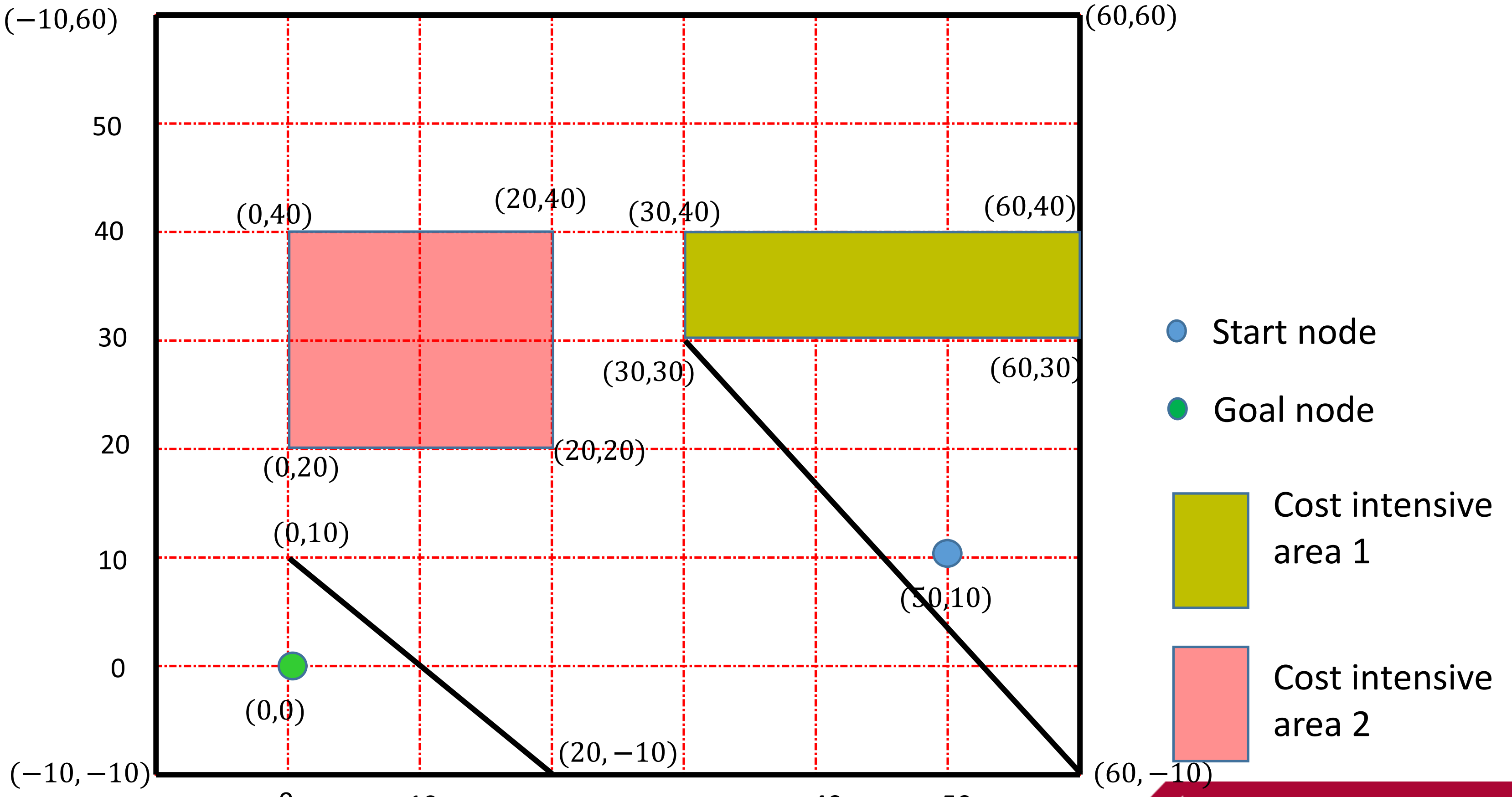
Group 8


(−10,60)
(40,60)
(60,60)
(10,50)
(20,50)
50
(30,40)
(35,40)
40
30
20
(10,20)
(20,20)
(40,20)
(0,10)
10
0
(0,0)
(30,0)
(35,0)
(50,0)
(20, −10)
(−10, −10)
(60, −10)
0
10
20
30
40
50
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

Group 9


(40,60)
(−10,60)
(60,60)
50
(50,50)
(20,40)
(0,40)
(30,40)
(35,40)
40
(50,40)
30
20
(20,20)
(0,20)
10
0
(0,0)
(30,0)
(35,0)
(20, −10)
(−10, −10)
(60, −10)
0
10
20
30
40
50
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

Group 10


(−10,60)
(60,60)
50
40
30
20
10
0
(0,40)
(20,40)
(30,40)
(60,40)
(30,30)
(60,30)
(0,20)
(20,20)
(0,10)
(50,10)
(0,0)
(20, −10)
(−10, −10)
(60, −10)
0
10
20
30
40
50
Start node
Goal node
Cost intensive area 1
Cost intensive area 2

Task 1 Scenarios

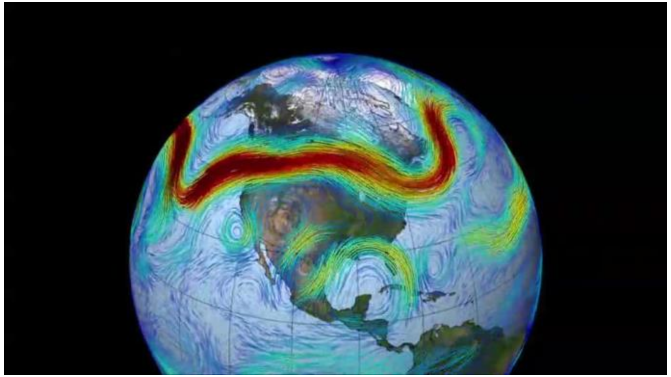
1. Scenario 1
   1. 3000 Passengers need to travel this week from the start to the destination
   2. 12 flights maximum for one week
   3. Time cost = medium and Fuel cost = 0.76 $/kg
2. Scenario 2
   1. 1250 Passengers need to travel within this month from the start to the destination
   2. 5 flights maximum for one week
   3. Time cost = high and Fuel cost = 0.88 $/kg
3. Scenario 3
   1. 2500 Passengers need to travel within this week from the start to the destination
   2. 25 flights maximum for one week
   3. Time cost = low and Fuel cost = 0.95 $/kg

Design a new cost area that can reduce the cost of the route.

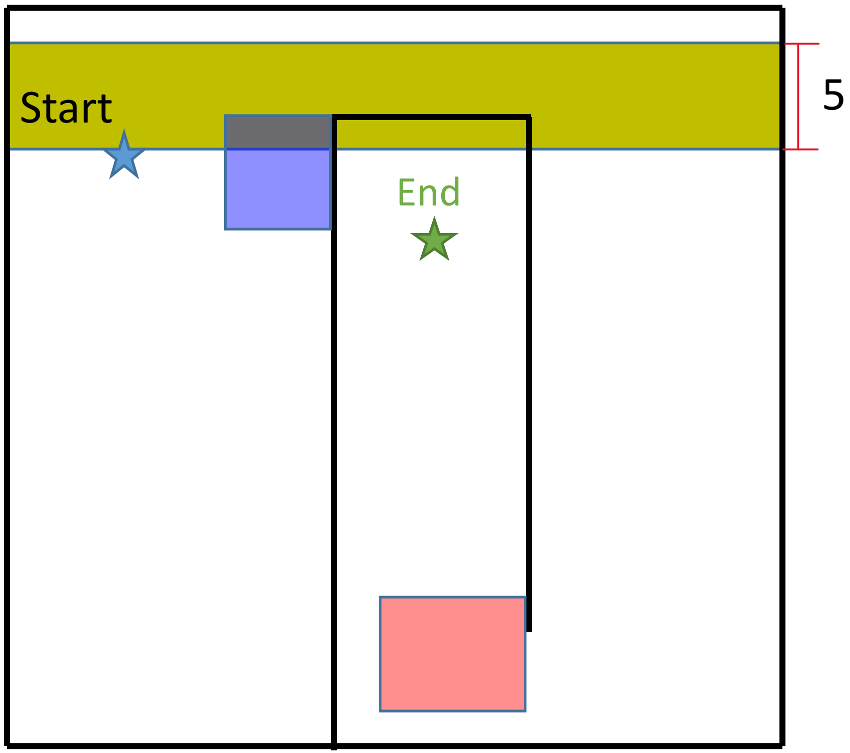
Task 2

Task 2

- There are certain areas where aircrafts could consume relatively less fuel (Jet stream)
- On the other hand, there are cost intensive areas (like the ones you create in task 1)
- Recreate a jet stream that could benefit your flight route the most



Jet stream example (you decide the location)



- Use Scenario 1 of task 1 as the background
- Find the best place to set your minus-cost-area (jet stream) in your group challenge.
- Cost along the jet stream is reduced by 5% *[https://www.theengineer.co.uk/jet-stream-commercial-airlines-reading-university-emissions/]*
- The area of the jet stream must span across the map laterally and span **5** units vertically (Yellow area)
- Again, using the program to do the calculation would grant you more bonus marks!

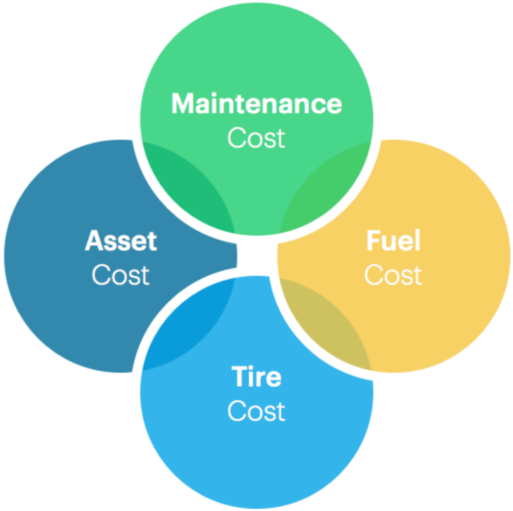
Design a new Aircraft Model that achieve minimum cost for the challenge assigned to your group

(Path planning programme not necessary in this task)

Task 3

Designing an Aircraft

- In real life, aircrafts are designed based on industry needs:
- A380 for large global transport hubs
- Design a new aircraft by finding out its parameters based on the restrictions



Task 3

- Rules and Restrictions:
  - Design a new aircraft to best fit the Scenario 1 in task 1
  - Consider only cruise time of the flight
  - Also design the passenger capacity of the aircraft, for each 50 passenger (min 100 to max 450) increase time cost by 2 (Base C_T = 12)
  - The base design is a twin-engine aircraft, if capacity >= 300, you must switch to a 4-engine aircraft
  - C_c= 2000 for twin-engine aircrafts, 2500 for 4-engine aircrafts
  - Each engine consumes fuel at 20kg/min
  - Follow the following equations and materials on the next slides to design your aircraft:

- Task 3 requires:
  - A name for your aircraft
  - Passenger capacity
  - Engine count
  - Detailed calculation of all operating costs (Follow the equation)
  - Bonus: Carefully study the rules and restrictions, try and explain the reason / evidence behind them (Open ended)

$$\mathrm{C} = C_F \cdot \Delta F + C_T \cdot \Delta T + C_c$$

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

Fuel Cost *https://www.iata.org/en/publications/economics/fuel-monitor/*

Fuel Price Analysis

The jet fuel price ended last week up 5.7% at $111.7/bbl:

4 February 2022	Share in World Index	cts/gal	$/bbl	$/mt	Index Value 2000 = 100	vs. 1 week ago	vs. 1 month ago	vs.1 yr ago
Jet Fuel Price	100%	266.02	111.73	882.30	305.42	5.7%	14.7%	73.7%
Asia & Oceania	22%	251.62	105.68	834.89	301.96	3.5%	14.8%	67.2%
Europe & CIS	28%	266.20	111.80	882.13	301.23	4.8%	14.2%	75.2%
Middle East & Africa	7%	254.67	106.96	844.55	319.42	4.0%	15.4%	71.5%
North America	39%	275.14	115.56	912.90	307.21	7.7%	14.7%	76.4%
Latin & Central America	4%	274.91	115.46	912.17	319.85	7.2%	16.3%	75.5%