Merging Flow and Optimizing Aircraft Scheduling in TMA based on GA

*Akinori Murata, **Daniel Delahaye and* Keiki Takadama

*The University of Electro-Communications
**Ecole Nationale de l'Aviation Civile

Background

Air traffic demand is increasing

Airport is one of bottlenecks of air traffic

Air traffic controller have high cognitive load

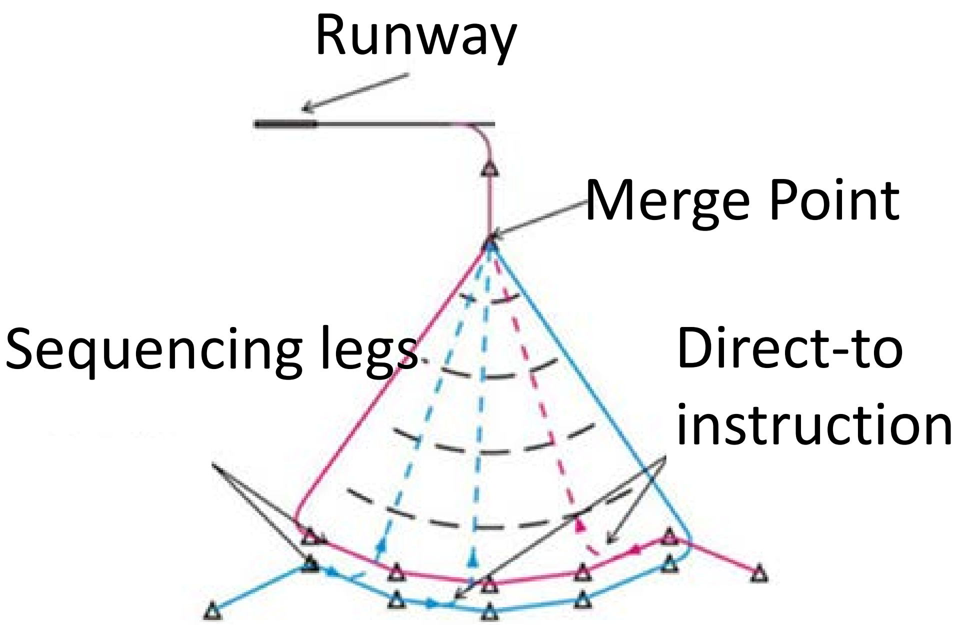
⬇

In Terminal Maneuvering Area (TMA),

- A lot of conflicts occurs in a high possibility

Route topology

Point Merge topology [Boursier 2008]



[Good]

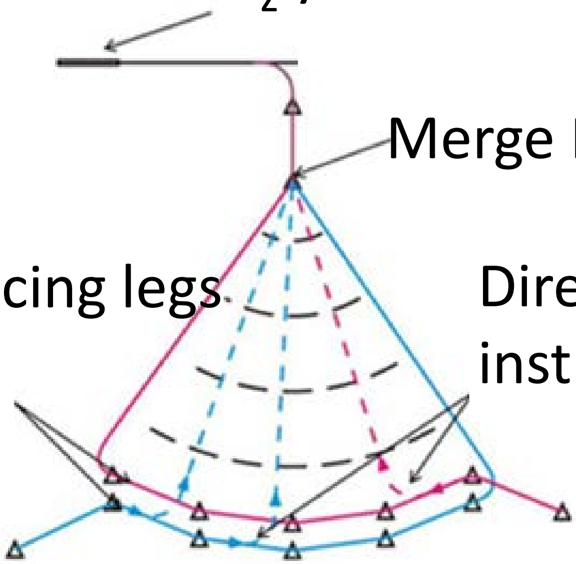
- Easy to understand for controllers

[Bad]

- Occupying a large space

Route topology

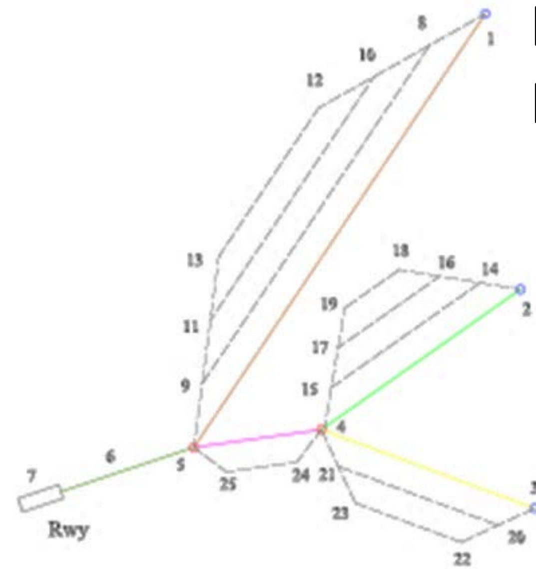
Point Merge topology [Boursier 2008]



[Good]
- Easy to understand for controllers

[Bad]
- Occupying much space

Sub-route topology [Zuniga 2011]



[Good]
- Easy to design the topology

[Bad]
- No order change of aircraft

Objective: effectiveness of sub-route topology in complex env. and order change of aircraft

Conventional method [Zuniga 2011]

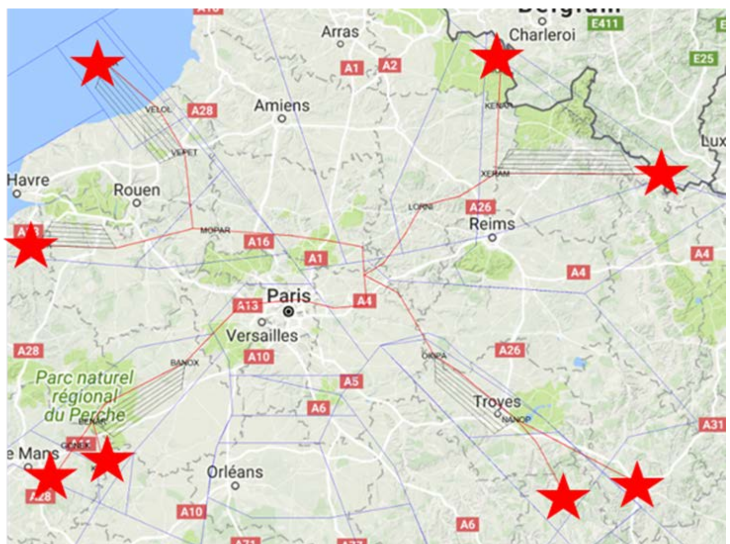
optimization

GA Genetic Algorithm

Finding aircraft speed and sub-route

Repeating

simulation

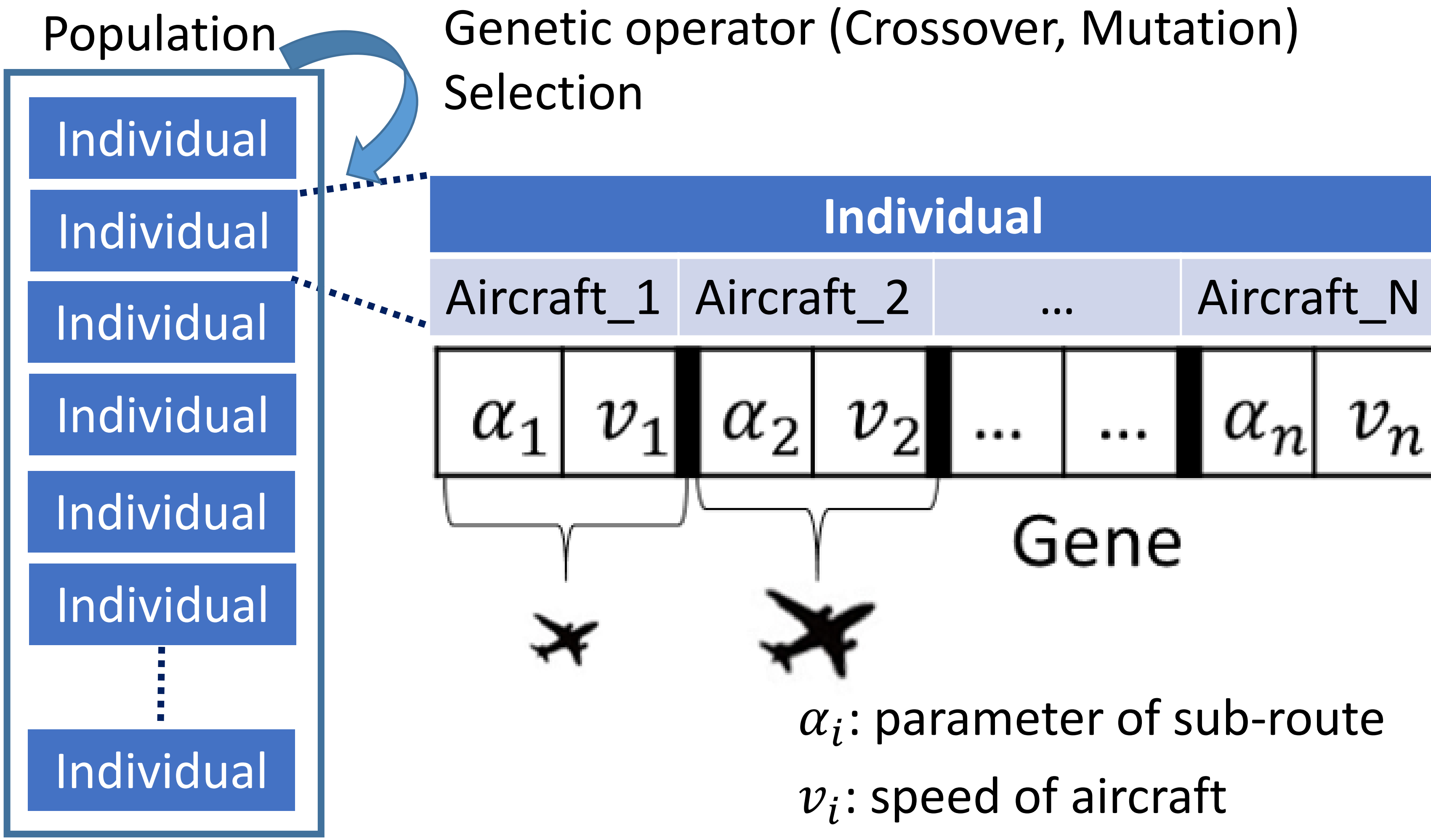


Evaluation (total conflict)

Fitness(total delay)

Conventional method: optimization phase

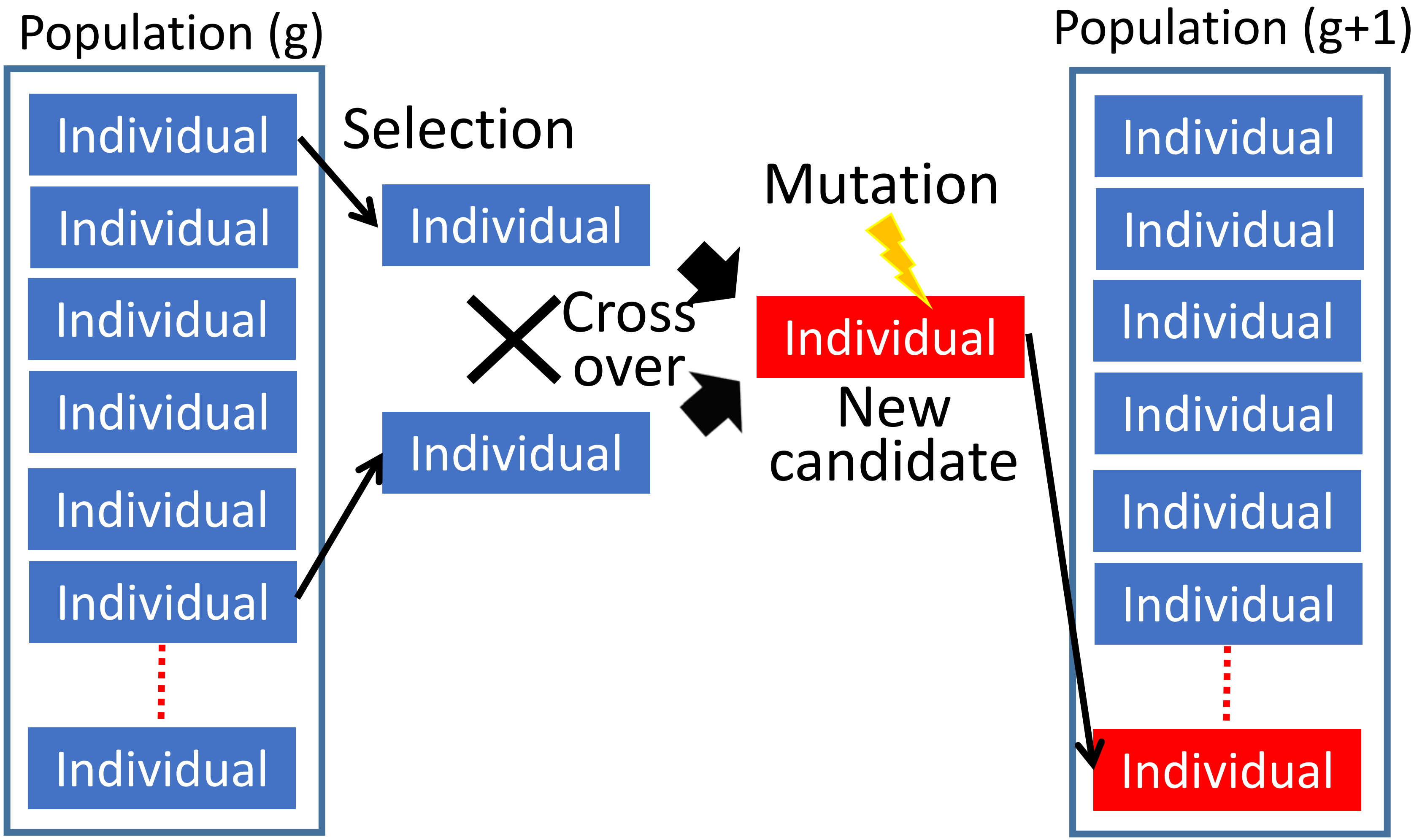
Genetic Algorithm



α_i: parameter of sub-route

v_i: speed of aircraft

Conventional method: optimization phase



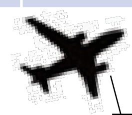
Conventional method: Optimization phase

Individual design
Population

- Individual
- Individual
- Individual
- Individual
- Individual
- Individual
- ⋮
- Individual

Some candidates including aircraft parameters

Individual			
Aircraft_1	Aircraft_2	…	Aircraft_N



(1)Data of aircraft
- Size_(H,M,S)
- Initial Speed
- Time at entry point

(2)Target of GA
- Sub-route parameter (0-1)
- Regulated speed

(3)Evaluation of aircraft
- Total conflicts
- Schedule delay

Conventional method : Simulation phase

optimization

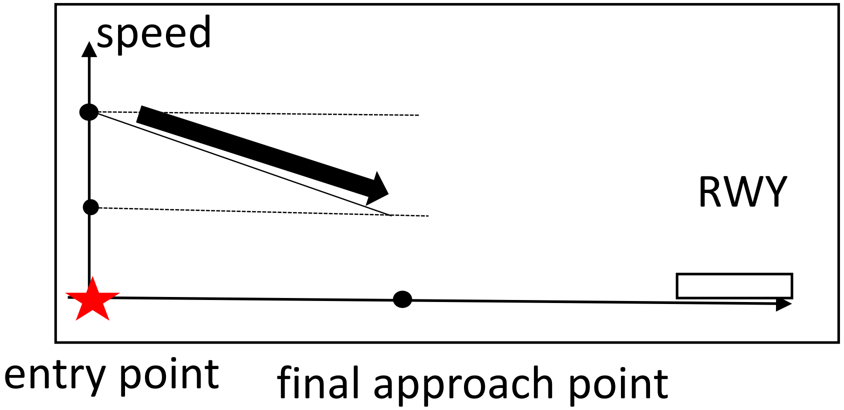
α_4	v_4	α_3	v_3	α_2	v_2	α_1	v_1

Input

simulation

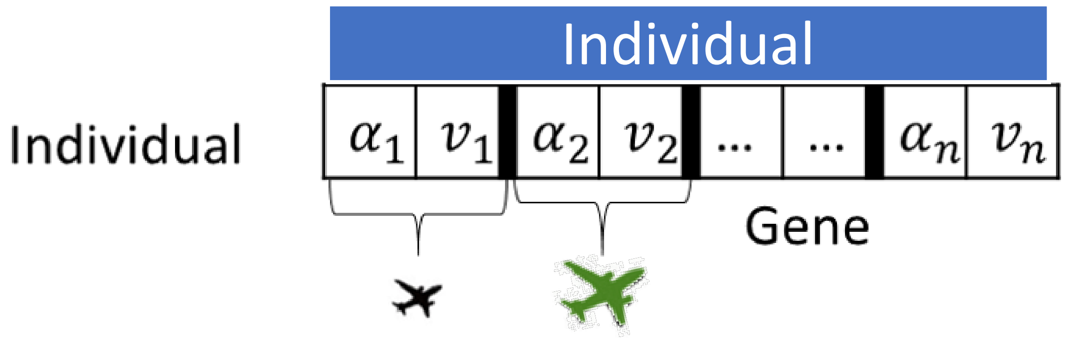
Calculating delay and the total conflicts

Decreasing aircraft speed



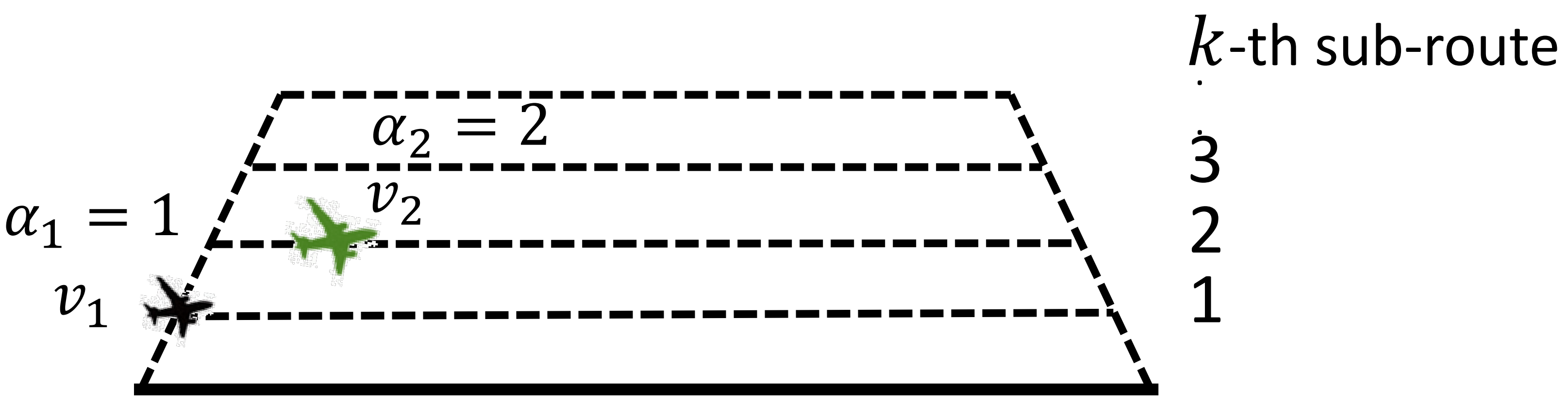
$$Fitness = \sum_{i=1}^{N} (t_i - ETA_i)$$

Conventional method: Sub-route design



α_i: parameter of sub-route

v_i: speed of aircraft

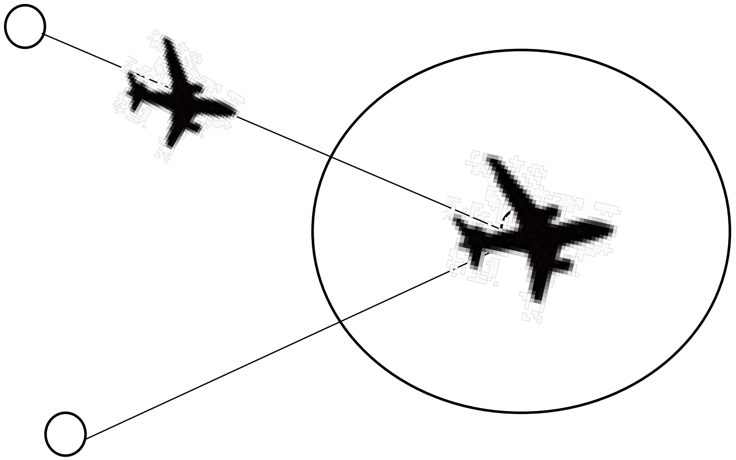


Aircraft fly along a dotted line

Conventional method: Conflict detection

Conventional method

Checking node and link



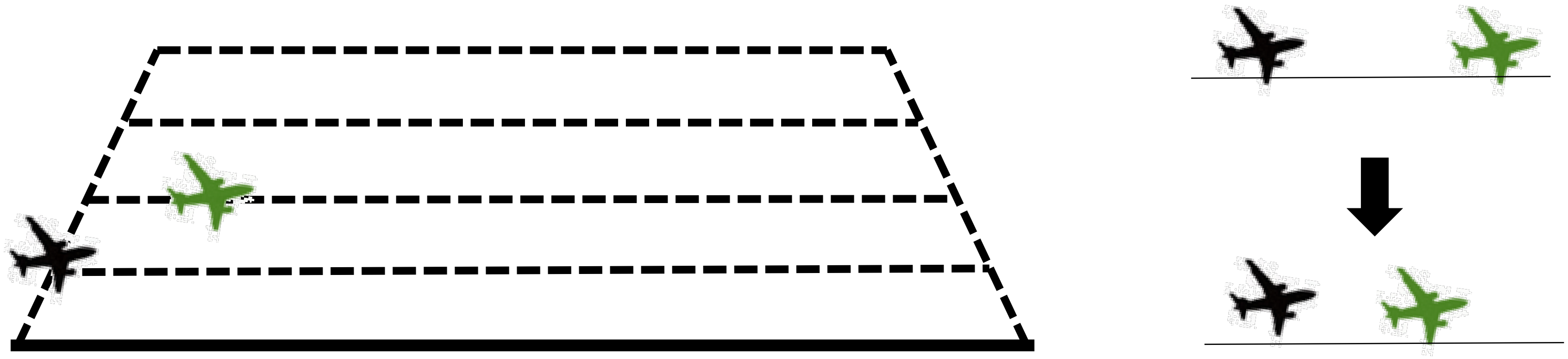
Node= waypoint

Link = route

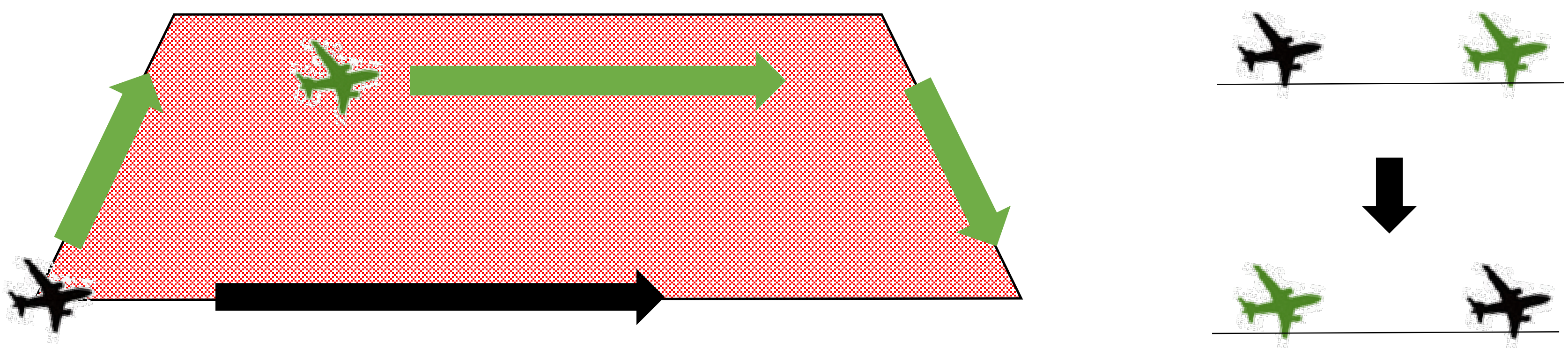
Conventional method cannot position shift from same entry point

Proposed method: Sub-route design

Limited to shift the position for landing sequence



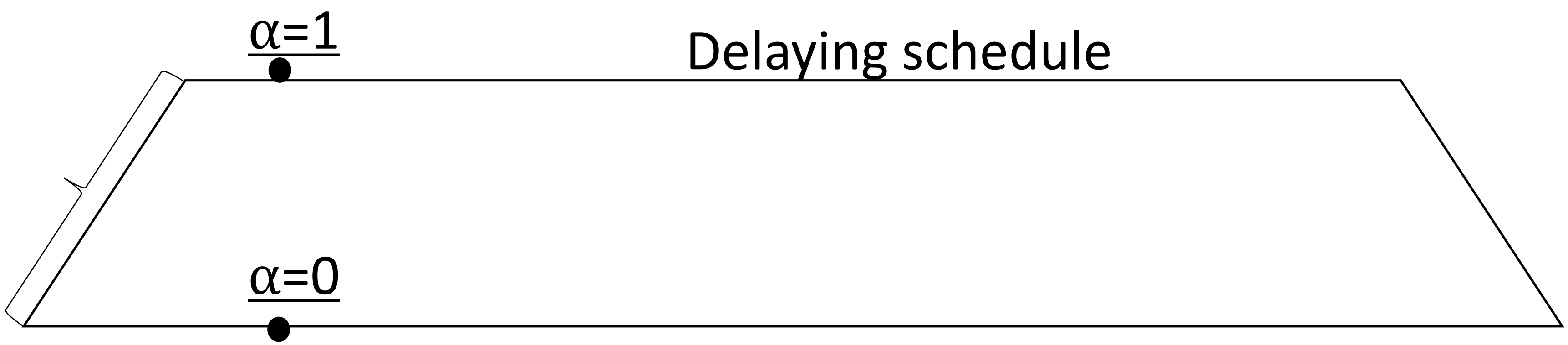
Only fixed candidates of sub-route



More flexible to fly

Proposed method: sub-route selection

Parameter α [$0 \leq \alpha \leq 1$])



Parameter α: continuous value

- Sub-route makes the schedule more flexible

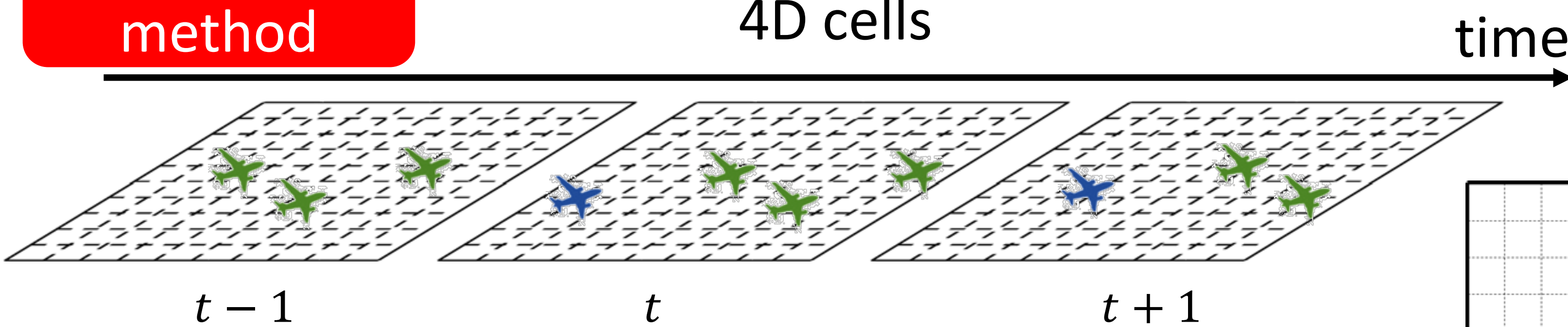
Proposed method: Conflict detection

Conventional method

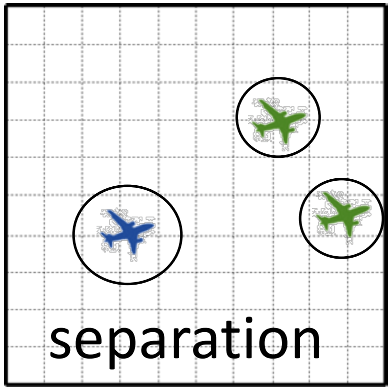
Conventional method cannot detect conflict including position shift

Proposed method

4D cells



Detecting conflicts every time



Experiment

- Environment
  - Charles de Gaulle Airport

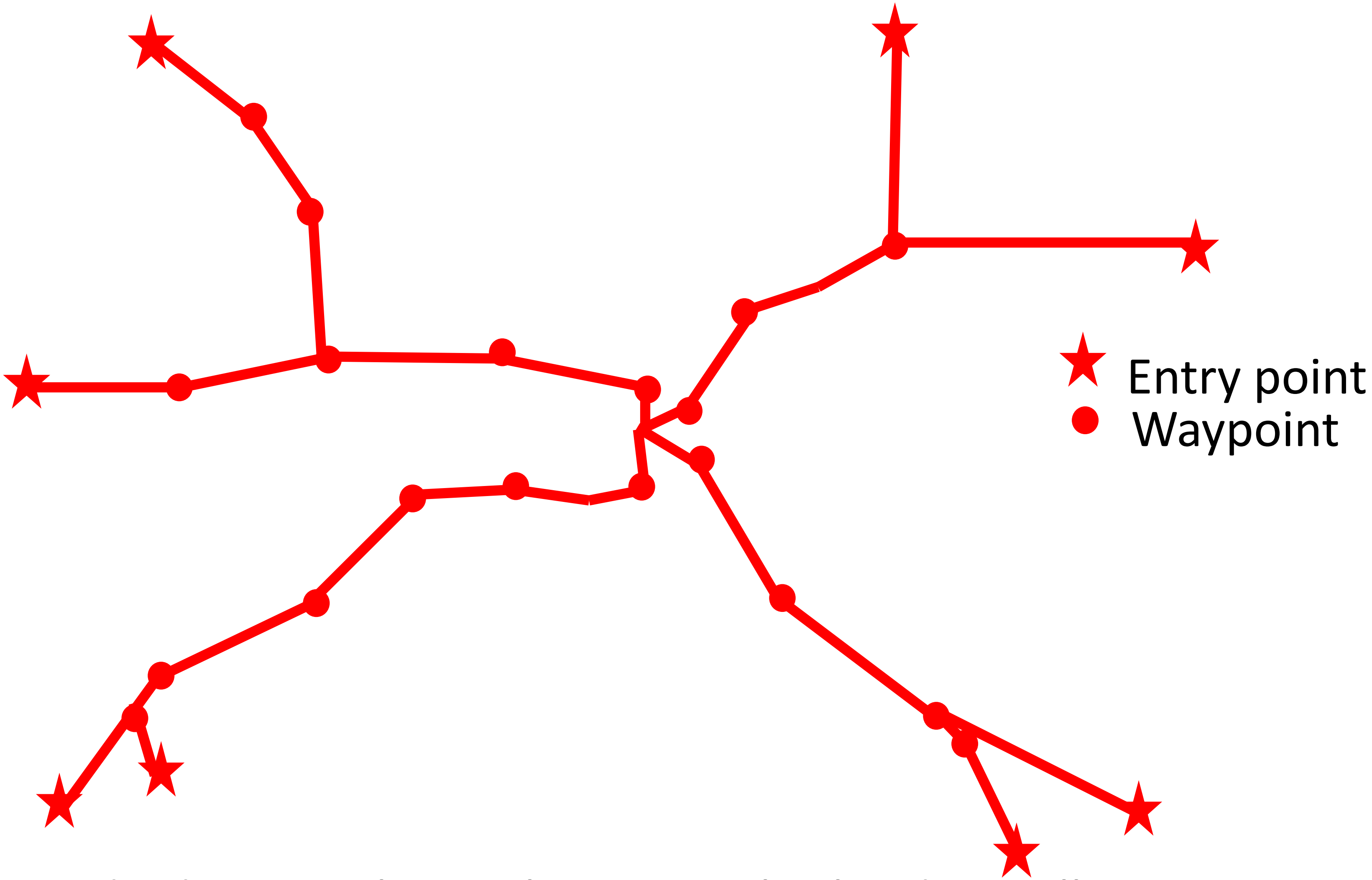
- Case (Situation)

Total aircraft	29(M,H)
Total schedule	60 min
Aircraft speed	$v_i' = v_i(1 + \Delta v), \Delta v \in \psi$ $\psi \in$ [-20%,5%]

- Evaluation Criteria
  - Total conflicts
  - Total delay

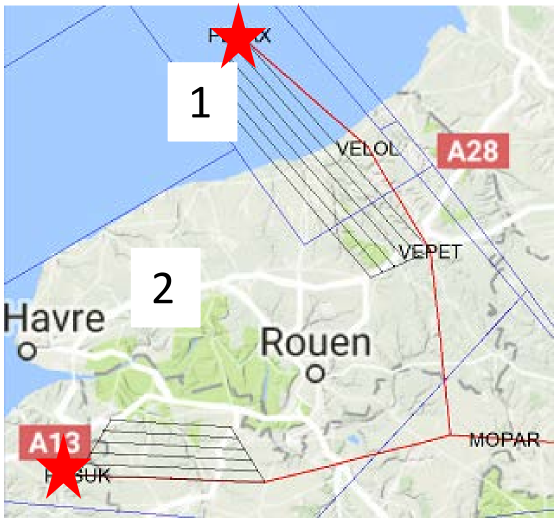
Environment: Overview

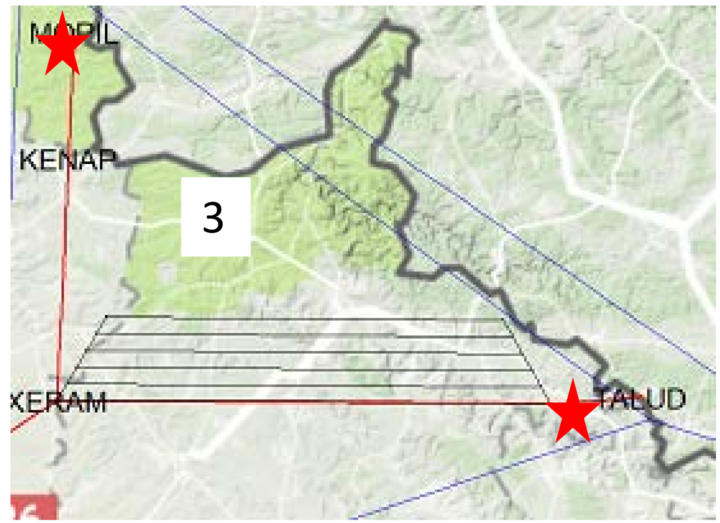
Environment: Modeling

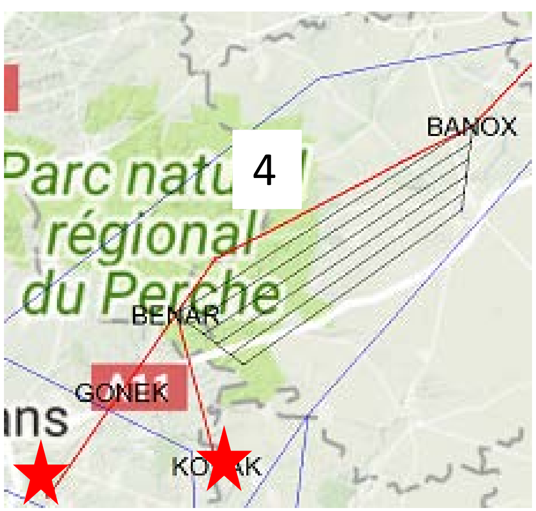


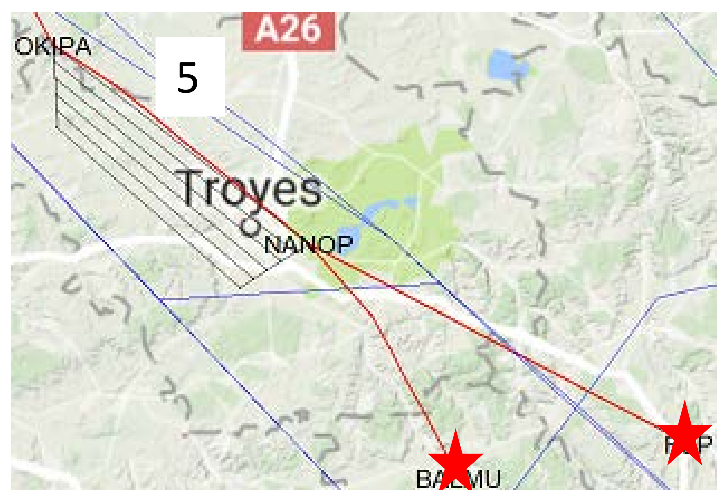
Standard terminal arrival route in Charles de Gaulle Airport

Environment: Sub-route









Experiment setting

Constraints: Minimum separation

Leading aircraft (NM)

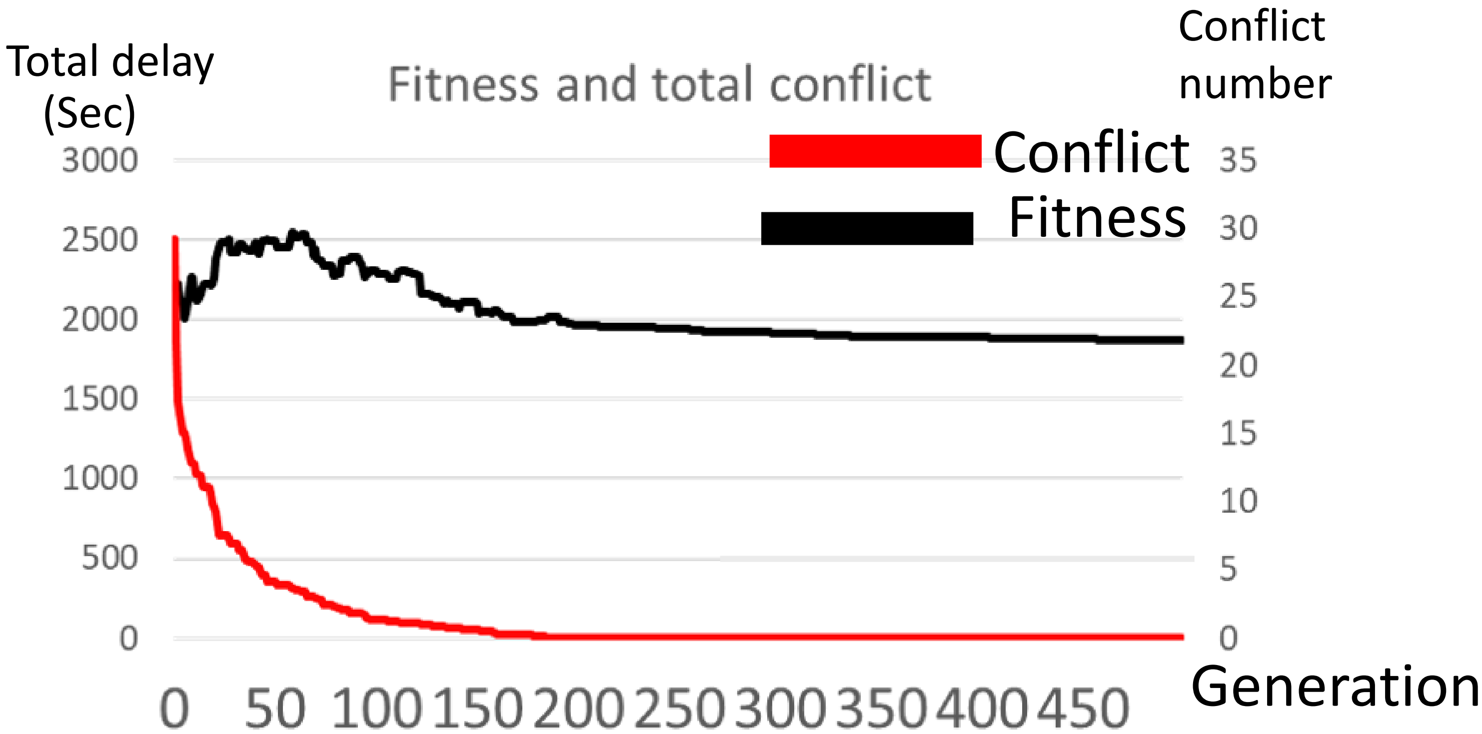
Trailing aircraft	Heavy	Medium	Light
Heavy	4	3	3
Medium	5	3	3
Light	6	4	3

Parameter Setting

parameter	value
population size	100
generation	500
crossover rate	1
mutation rate P_{Ms}	0.8
trial	10

mutation rate P_{Md} 0.3

Experimental result



Number of aircraft without detour	14.7
Average delay of schedule	79.3 s
Maximum delay	240 s
Maximum speed change	23.7 Nt
Minimum speed change	-93.9 Nt

Experimental result

Without our method

With our method

Conclusion

- Background
  - Importance: Merging aircrafts without conflicts and optimizing their landing sequence
  - Proposed method: flexible sub-route and optimization method based on GA

- Implication
  - Successfully merge all aircrafts without conflicts

- Future work
  - Compared with another method
  - Improving simulation procedure
  - Combination of route topology to increase runway throughput