NASA: Optimization to Surface planning and Scheduling

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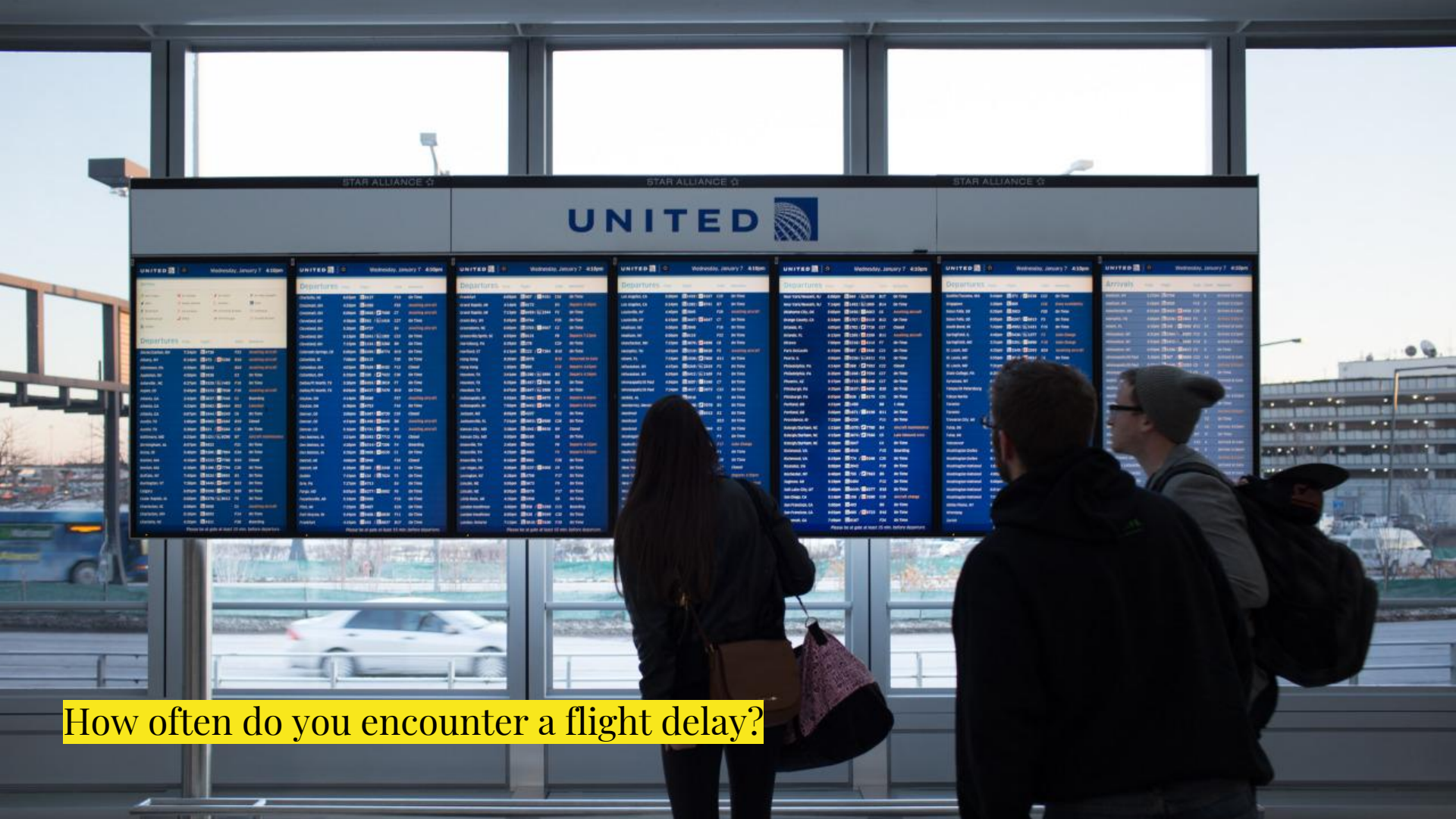


How often do you encounter a flight delay?

Motivation

“Flight delays cost the airline industry $8 billion a year”

“Reduce Airlines’ carbon footprint”

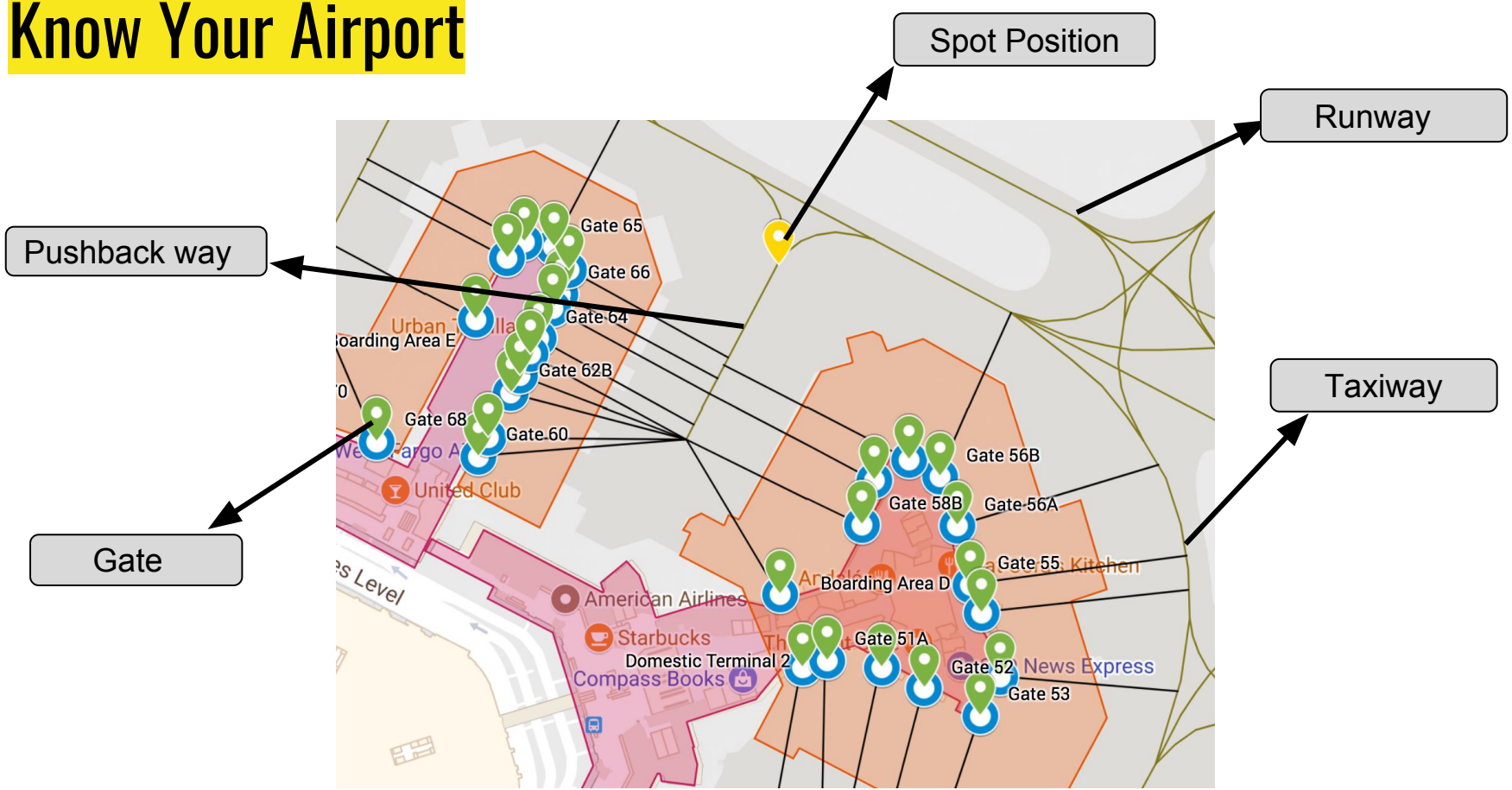
“Reduce probability of human error.”

Problem

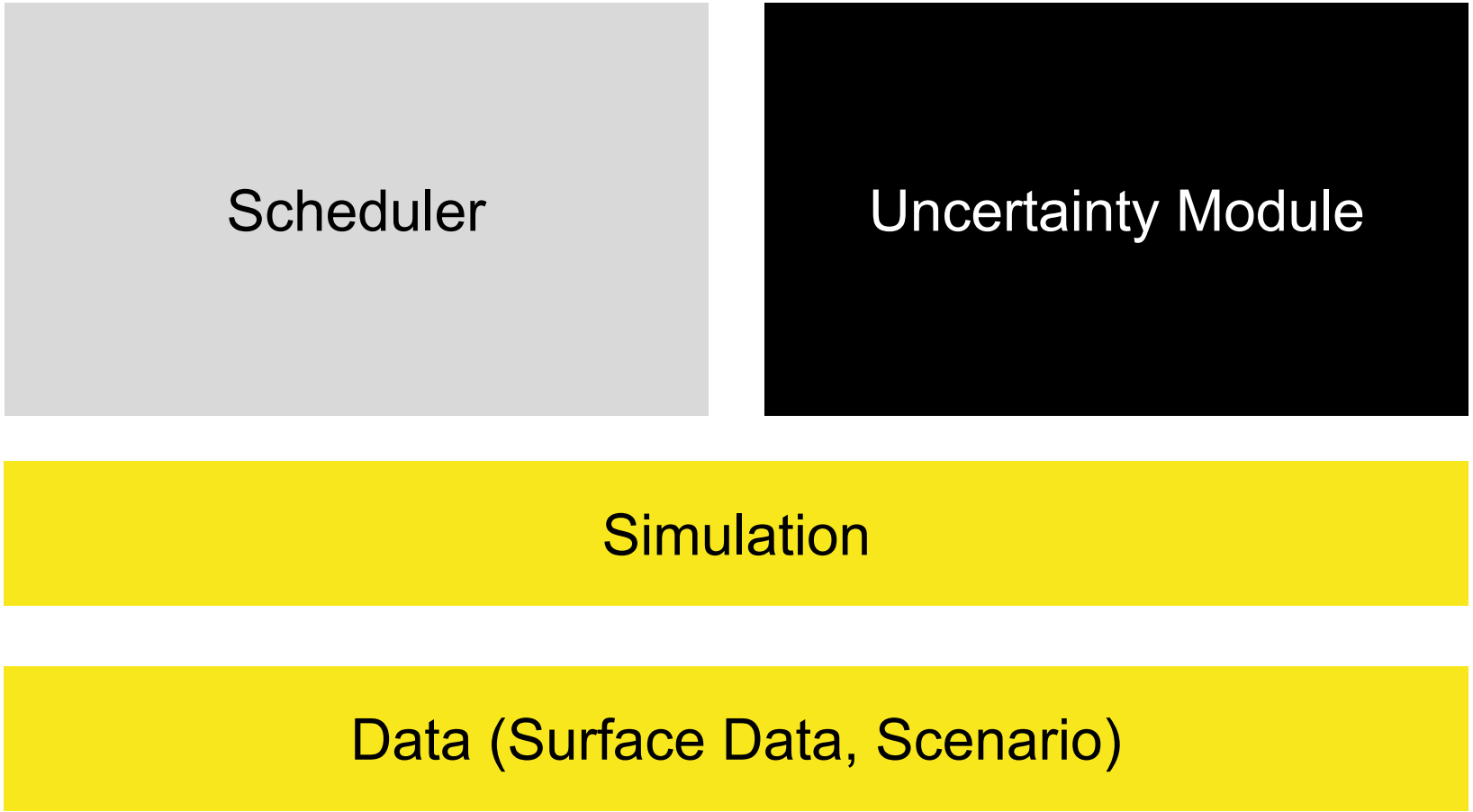
Goals

- To create a generic airport simulation tool
- To add uncertainty into simulation and to analyze the **performance and robustness** of different scheduling algorithms
- To explore different auto-scheduling methods and to compare with current FCFS method.

Know Your Airport



Structure


Scheduler
Uncertainty Module
Simulation
Data (Surface Data, Scenario)

Simulation

A generic airport simulation written in Python

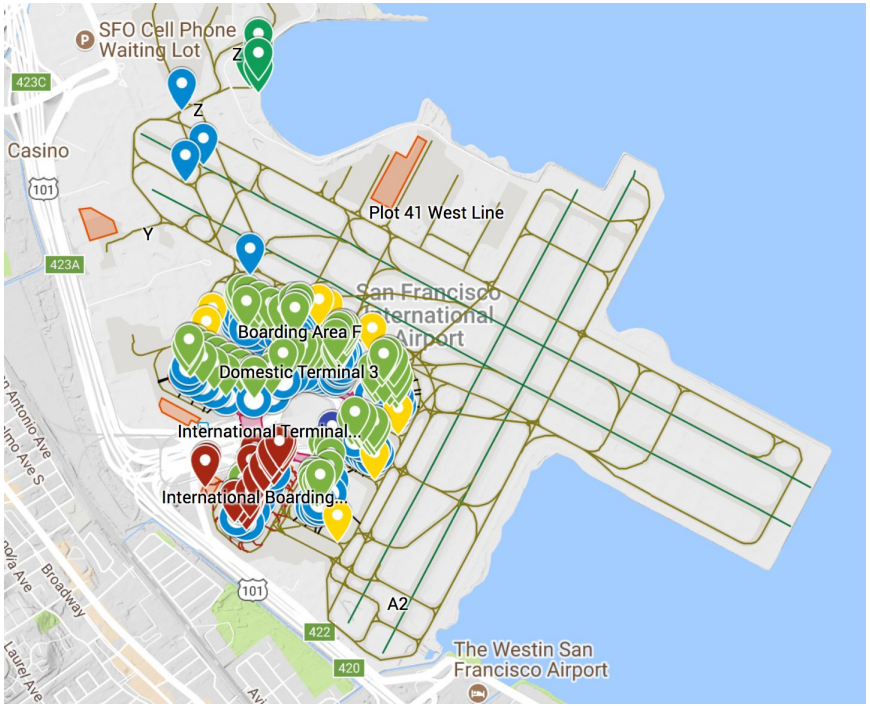
Designs an airport simulation works for multiple airports sharing the same link-node model

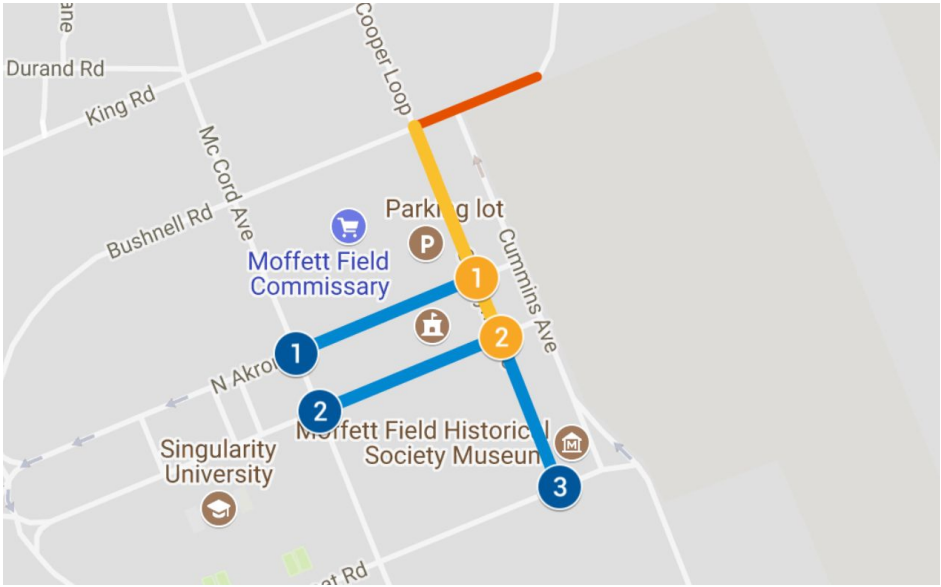
Works with an external scheduler in runtime, and be able to show performances

Be extensible for adding new constraints, features in the future

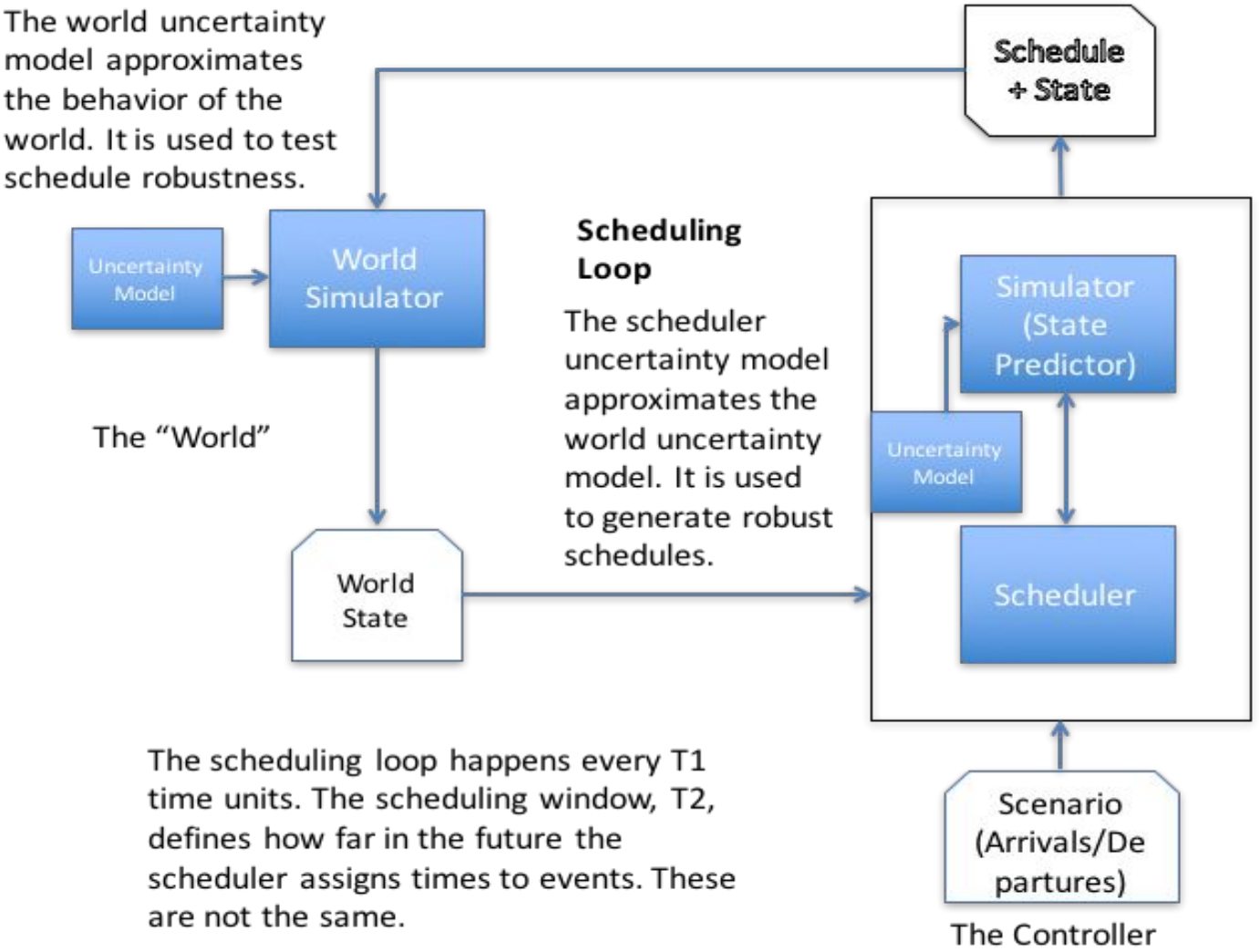
Data

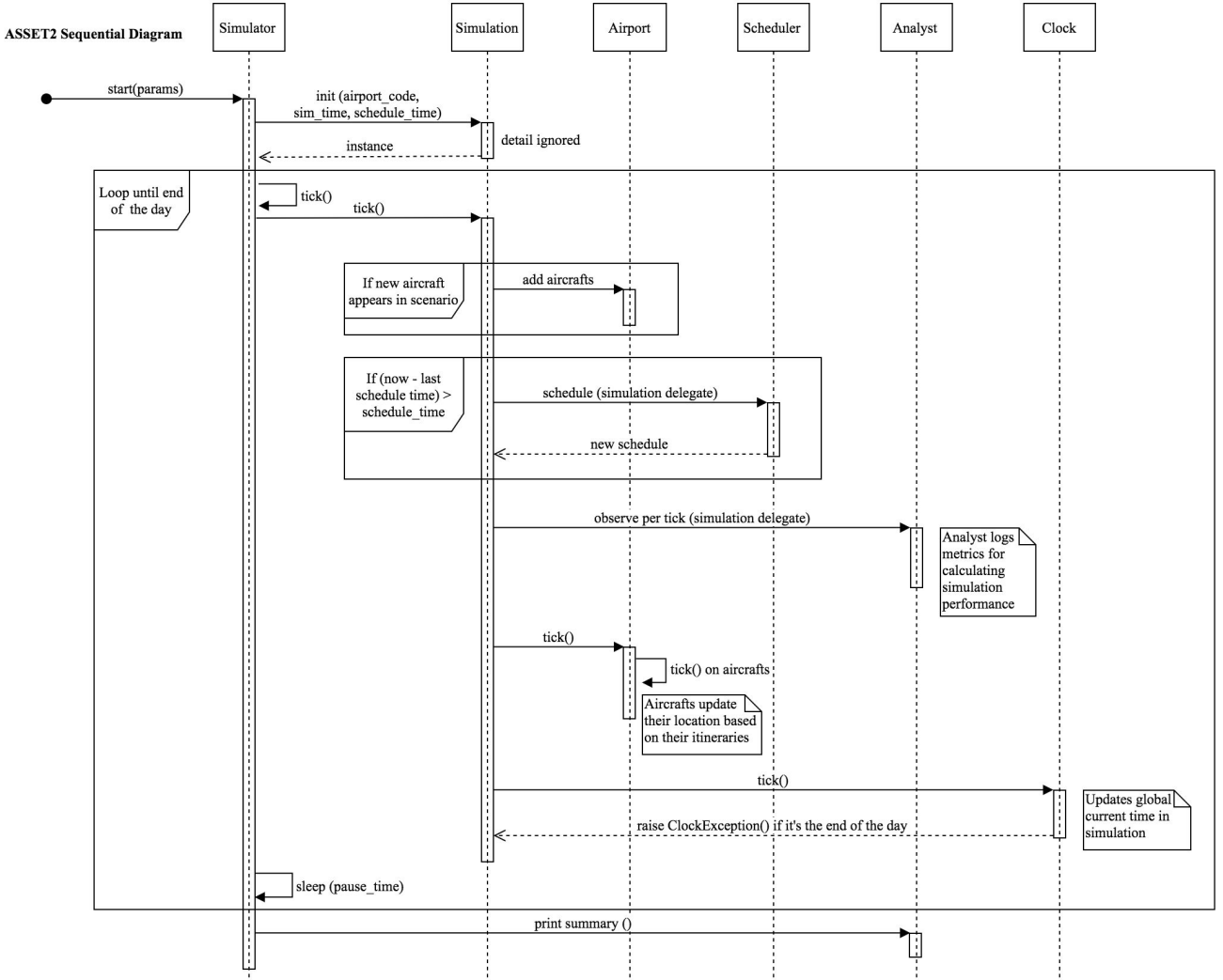
1. San Francisco Airport Data
    a. Open Street Data
2. Simple Test Data
    a. Automatically generated scenarios





Flow


The world uncertainty model approximates the behavior of the world. It is used to test schedule robustness.
Schedule + State
Uncertainty Model
World Simulator
Scheduling Loop
The scheduler uncertainty model approximates the world uncertainty model. It is used to generate robust schedules.
Simulator (State Predictor)
Uncertainty Model
Scheduler
The "World"
World State
The scheduling loop happens every T1 time units. The scheduling window, T2, defines how far in the future the scheduler assigns times to events. These are not the same.
Scenario (Arrivals/Departures)
The Controller


ASSET2 Sequential Diagram
Simulator
Simulation
Airport
Scheduler
Analyst
Clock
start(params)
init (airport_code, sim_time, schedule_time)
detail ignored
instance
Loop until end of the day
tick()
tick()
If new aircraft appears in scenario
add aircrafts
If (now - last schedule time) > schedule_time
schedule (simulation delegate)
new schedule
observe per tick (simulation delegate)
Analyst logs metrics for calculating simulation performance
tick()
tick() on aircrafts
Aircrafts update their location based on their itineraries
tick()
Updates global current time in simulation
raise ClockException() if it's the end of the day
sleep (pause_time)
print summary ()

Scheduler

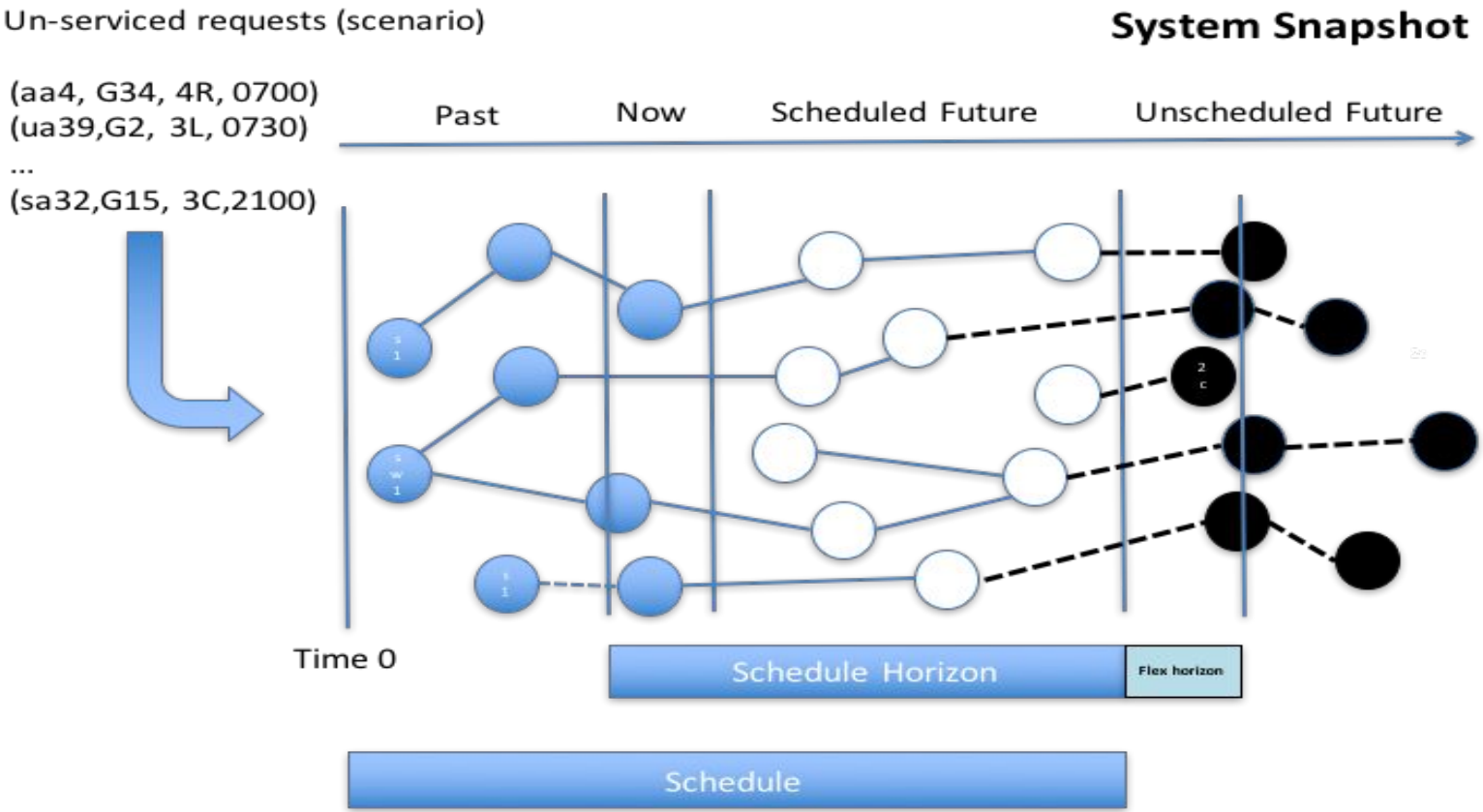
A scheduler for aircraft routes written in Python

Repeatedly generates schedules for aircrafts that enter the airport during the day

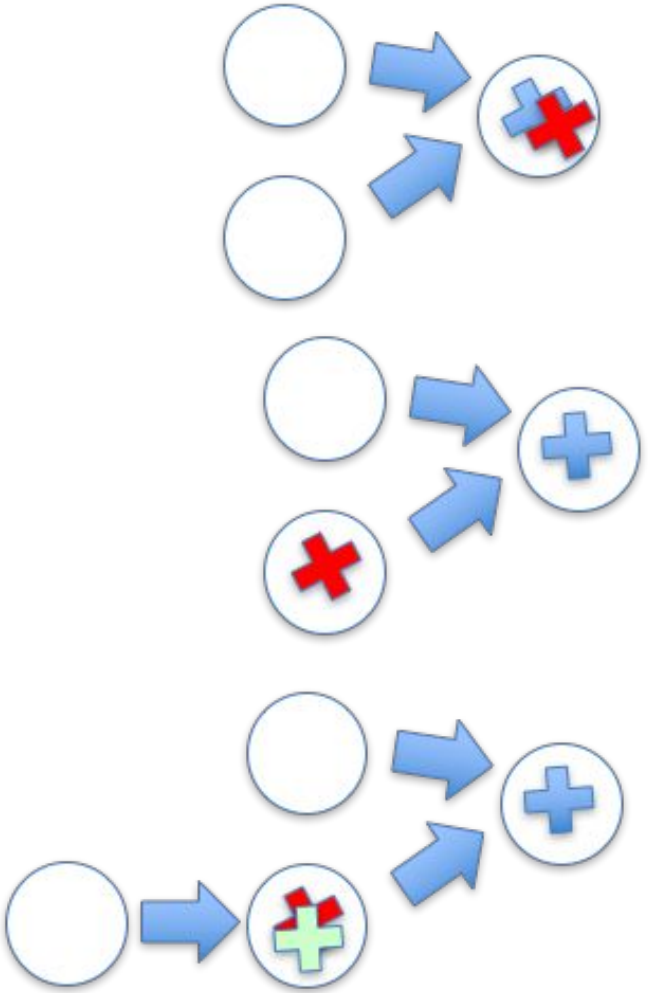
Ensure that the schedules generated are free of conflicts in the absence of uncertainty

Use the simulation to predict possible airport state in the future, and relax tightness at possible bottlenecks

Scheduler Optimization



Conflicts

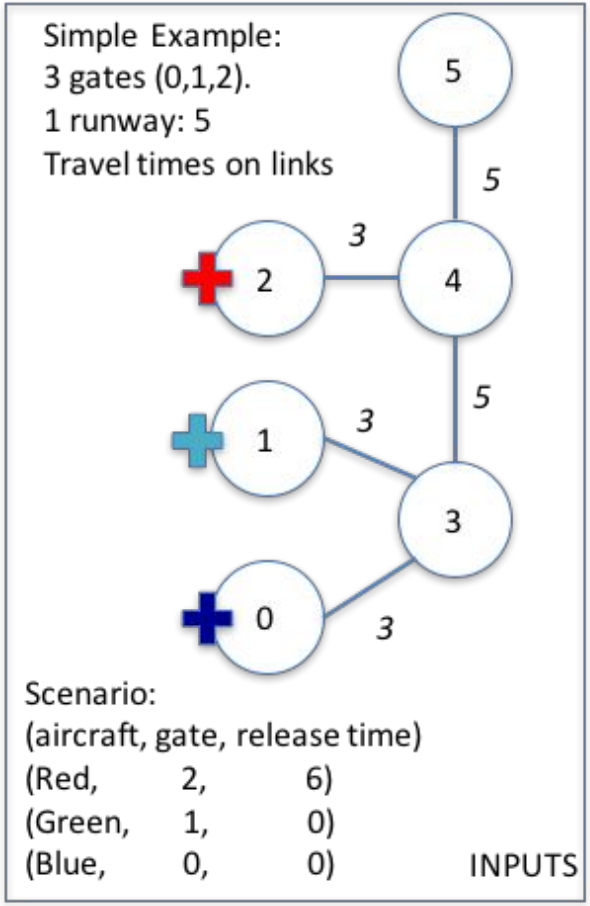


Definition of Conflict: Two aircraft occupy same position at same time.

Solution: Delay one of the aircraft at previous location.

Note: Inserting delays might cause other conflicts, either forward or backward in time.

A Simple Example



Predefined Routes

Blue: 0,3,4,5
Green: 1,3,4,5
Red: 2,4,5

Scheduling with conflict detection and resolution

Format: Time n: {(aircraft, locations)}

Time 0: (Blue,0), (Green,1)
Time 3: (Blue,3), (Green, 3) **Conflict**
Time 1: (Green,1) (Delay Green at previous location)
Time 4: (Green,3)
Time 6: (Red, 2)
Time 8: (Blue, 4)
Time 9: (Red,4), (Green,4) **Conflict**
Time 7: (Red,2) (Delay Red at previous location)
Time 10: (Red, 4)
Time 13: (Blue, 5)
Time 14: (Green, 5)
Time 15: (Red,5)

This schedule is optimal for the scenario. Total delay time: 2; makespan: 15

Final Schedule

Format: flight: {(location, time)}
Blue: (0,0),(3,3),(4,8),(5,13)
Green: (1,1),(3,4),(4,9),(5,14)
Red: (2,7),(4,10),(5,15)

Uncertainty Module

A module for simulating real-world uncertainty.

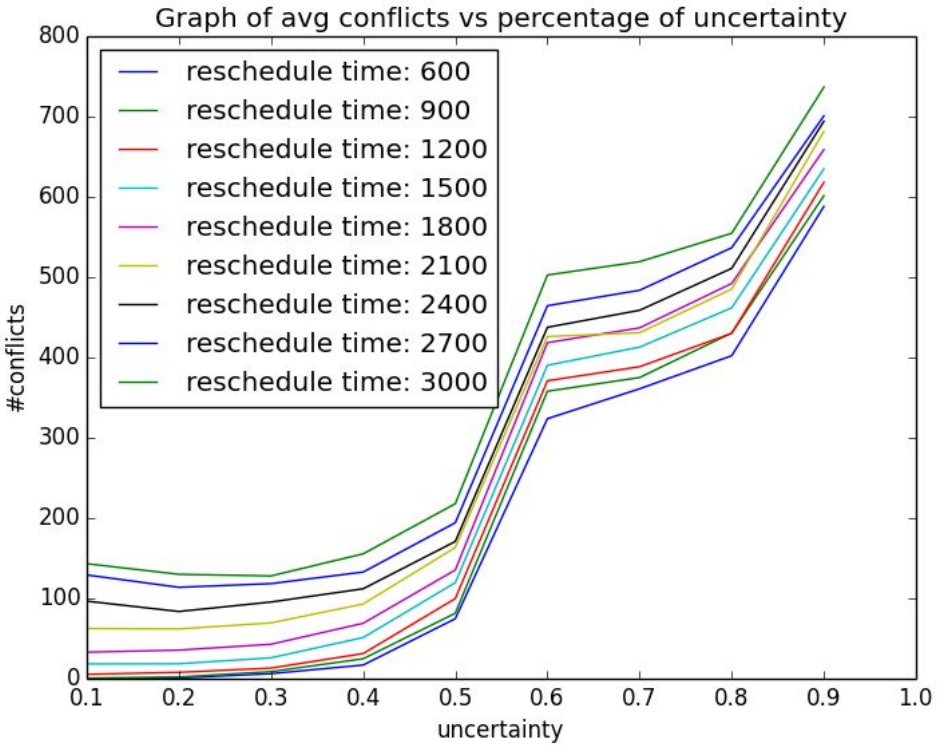
A generic module for uncertainty that can take into account multiple factors for calculating uncertainty.

Integrates with external scheduler and simulator in runtime. Controllable by user to inject randomness.

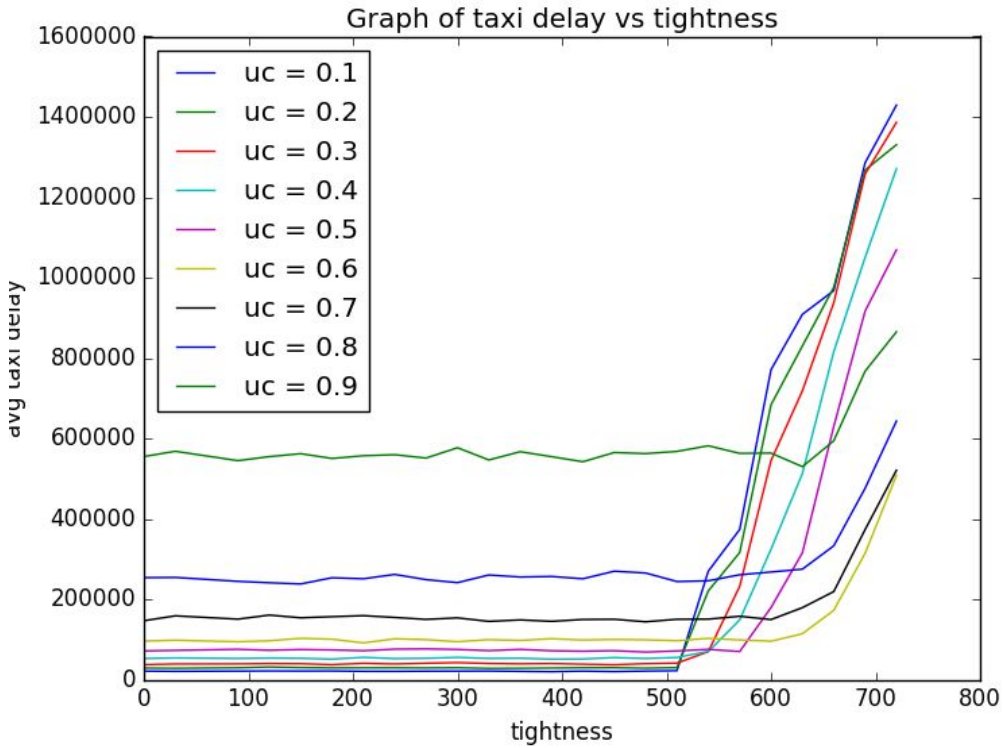
Takes into account terminal uncertainty at gates and runways.

Experiment

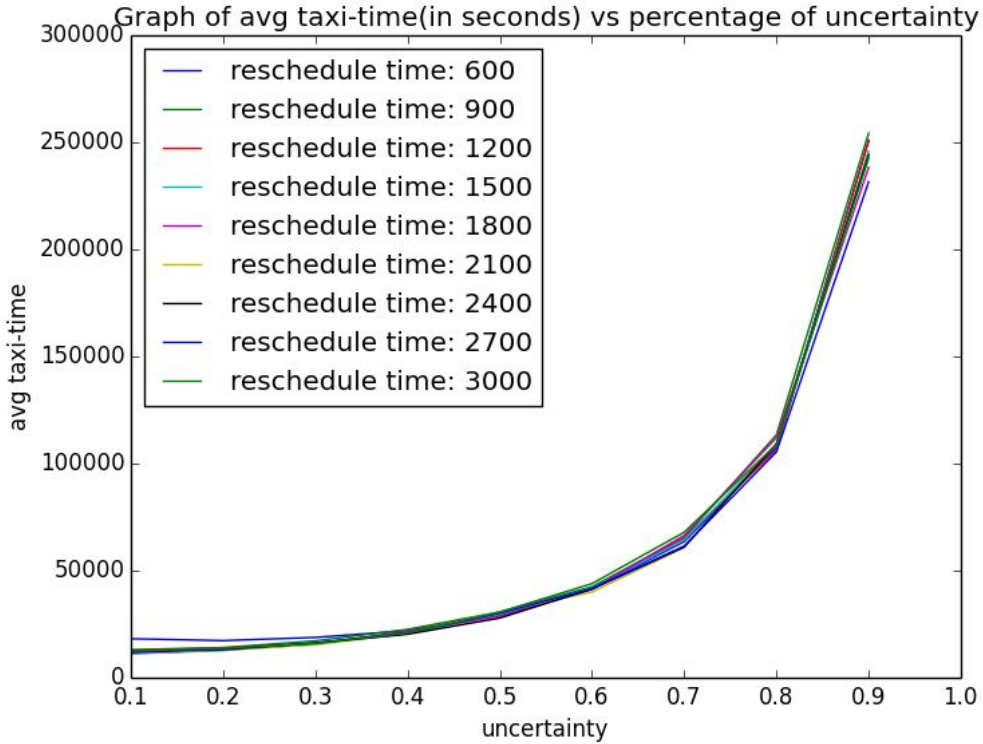
Experiment 1 : Conflicts v.s. Uncertainty



Experiment 2 : Taxi Delay v.s. Tightness



Experiment 3 : Taxi Delay v.s. Uncertainty



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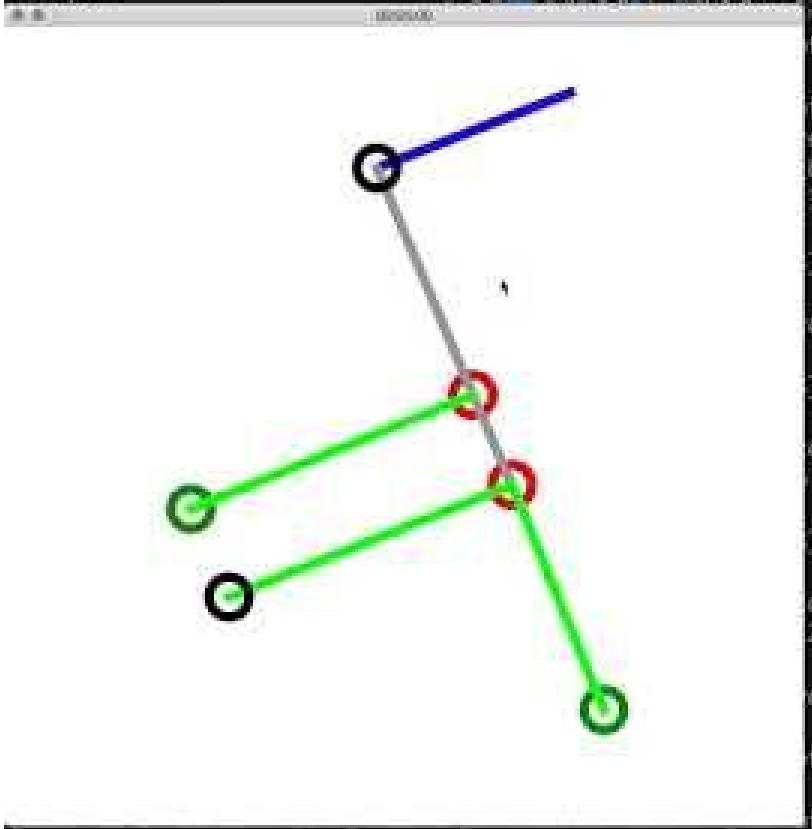
heronyang Merge pull request #24 from heronyang/scheduler_uc ... Latest commit ff9ec51 5 hours ago

data	Fixes bugs for uc	6 hours ago
doc	Moves contents in asset2 to root folder	4 days ago
tests	Adds tests for aircraft and itinerary	11 hours ago
.gitignore	Moves contents in asset2 to root folder	4 days ago
README.md	Moves contents in asset2 to root folder	4 days ago
aircraft.py	Fixes bugs for uc	6 hours ago
airport.py	Bug fix in scheduler and airport	8 hours ago
analyst.py	Moves contents in asset2 to root folder	4 days ago
cache.py	Moves contents in asset2 to root folder	4 days ago
ck.py	Moves contents in asset2 to root folder	4 days ago
		6 hours ago
		8 hours ago
flight.py	Moves contents in asset2 to root folder	4 days ago

Github Repo
https://github.com/heronyang/airport-simulation

Demo



```
t on <Aircraft: F6>>: It's too early to start

f conflicts found: 0
ent Time: 00:50:00
based_on_scenario:120] Adds flight <Departure
37.412284,-122.054973> runway:<RUNWAY: R1> ti

] <Aircraft: F7> changed location to <Node: G

aft (<Aircraft: F6>) location: <Node: G1|37.4

] <Aircraft: F6> changed location to <Node: G

o_next_target_node:147] <Pilot on <Aircraft:
,-122.057451> | exp arrive at 00:48:00 | exp

] <Aircraft: F6> changed location to <Node: N

o_next_target_node:147] <Pilot on <Aircraft:
26,-122.057451> | exp arrive at 00:48:00 | ex

aft (<Aircraft: F7>) location: <Node: G2|37.4

t on <Aircraft: F7>>: No on-going itinerary r

f conflicts found: 0
```