Formalizing Air Traffic Control Regulations in

PSOA RuleML

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Overview

- ATC Regulations/Separation minima/Wake Turbulence

- ICAO & FAA Regulations and Implementation

- Queries (Live Demo)

- Conclusions

Air Traffic Control

"The primary purpose of Air Traffic Control (ATC) is to prevent collisions between aircraft, organize and expedite the flow of air traffic, and provide information and other support for pilots."

- Collision prevention is realized by ensuring a minimum distance between aircraft, a concept also called *separation minimum*.

- Separation of aircraft serves an additional important role: the avoidance of *wake turbulence.*

Wake Turbulence

Source: https://www.flickr.com/photos/73886013@N06/35779717783

Source: https://imgur.com/WjBHC10

Wake Turbulence Encounter

Source: NTSB

ICAO/FAA Regulations: Aircraft Classes

- **ICAO:**

  Light - MTOM of 7000 kg or less.

  Medium - MTOM of greater than 7000 kg, but less than 136000 kg.

  Heavy - MTOM of 136000 kg or greater.

  Super - A separate designation that currently only refers to the Airbus A380 (MTOM 575000 kg, ICAO designation A388).

- **RECAT:** 6 Categories, extra parameter: **wingspan**.

- **FAA:**

  Small - Aircraft of 41000 pounds (≈19000 kg) or less MTOW.

  Large - Aircraft of more than 41000 pounds MTOW, up to, but not including, 300000 pounds (≈140000 kg).

  Heavy - Aircraft capable of takeoff weights of 300000 pounds or more.

  Super - A separate designation that currently only refers to the Airbus A380 and the Antonov An-225.

  B757 - Different separation standards are applied for the Boeing 757.

Example: ICAO Aircraft Classes in PSOA RuleML

```
Forall ?a (

 :AircraftIcaoCategory(?a :Heavy) :-

  Or(

    And(?a#:Aircraft(:mtom->?w :specialCase->:No)

        math:greaterEq(?w 136000))

    ?a#:Aircraft(:specialCase->:A225)

    )

  )
```

ICAO/FAA Regulations: Separation Minima

ICAO separation standards (nautical miles)

Leader		Follower			
		Super	Heavy	Medium	Light
	Super	MRS	6	7	8
	Heavy	MRS	4	5	6
	Medium	MRS	MRS	MRS	5
	Light	MRS	MRS	MRS	MRS

MRS: Minimum Radar Separation.

FAA wake separation standards (nautical miles, at the threshold)

Leader/Follower	Super	Heavy	B757	Large	Small
Super	MRS	6	7	7	8
Heavy	MRS	4	5	5	6
B757	MRS	4	4	4	5
Large	MRS	MRS	MRS	MRS	4
Small	MRS	MRS	MRS	MRS	MRS

MRS: minimum radar separation

Example: ICAO Separation Minima in PSOA RuleML

```
Forall ?x ?y (
 :icaoSeparation(:leader->?x :follower->?y :miles->:Mrs):-
 Or(
    And(:AircraftIcaoCategory(?x :Medium)
        AircraftIcaoCategory(?y :Medium))
    And(:AircraftIcaoCategory(?x :Medium)
        :AircraftIcaoCategory(?y :Heavy))
    :AircraftIcaoCategory(?x :Light)
    :AircraftIcaoCategory(?y :Super)
)
```

Aircraft Database

- Source: FAA website (`.xlsx` file), converted to PSOA RuleML syntax by a Python script.

- More than 261 different aircraft types with variations, more than 440 aircraft entries in total.

- Variations → many duplicates for different versions of aircraft with differences in `mtom/mtow`, and `wingspan`.

- Quality of the dataset questionable for real-life application but very useful for this prototype.

  – How good is this dataset?

Aircraft Database

```
:b738#:Aircraft(
    :mtom->79015.79
    :mtow->174200.0
    :wingspan->117.83
    :appSpeed->142.0
    :specialCase->:No
)
```

- `mtow`, `mtom` **for ICAO, FAA regulations.**
- `wingspan`, `mtow` **for RECAT (supported in the KB).**
- `appSpeed` **for future expansion towards Time-Based-Separation.**
- `specialCase` **for exceptions.**

Representative Queries

LIVE DEMO:

Using the PSOA Engine

Conclusions

- A large KB consisting of rules —implementing ATC regulations— and aircraft facts —containing the required characteristics— was implemented.

- The resulting KB is capable of computing the separation minima mandated by ATC regulations, while using the self-contained database of aircraft facts.

- PSOA RuleML proved to be a suitable environment for the formalization of ATC Regulations.

Future Work

Formalization of ATC Regulations:

- **Implement a larger subset of ATC regulations, e.g.:**
  - Spatial reasoning/rules for airport layout (applicable to separation minima reduction), incident management.

Real-time framework:

- **Use the KB with real radar data**
  - Decision support tool
  - Real-time separation monitoring

Download the code:
http://users.ntua.gr/mitsikas/ATC_KB/