Automated DCB Hotspot detection

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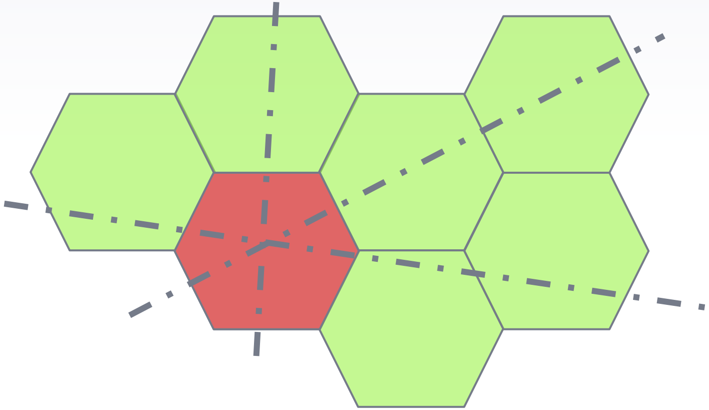
Content

Demand-Capacity Balancing

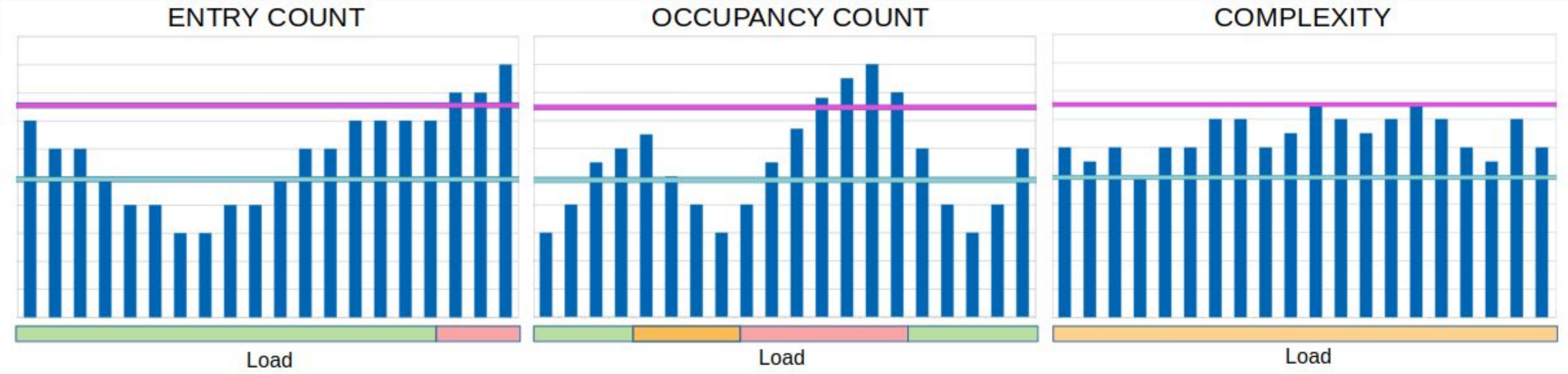
- DCB **protects** the ATC sectors in order to expedite safe and manageable traffic,
- This protection is ensured by two keys:
  - **Detect future problems;**
  - Resolve identified problems.



ATFCM regulations detection

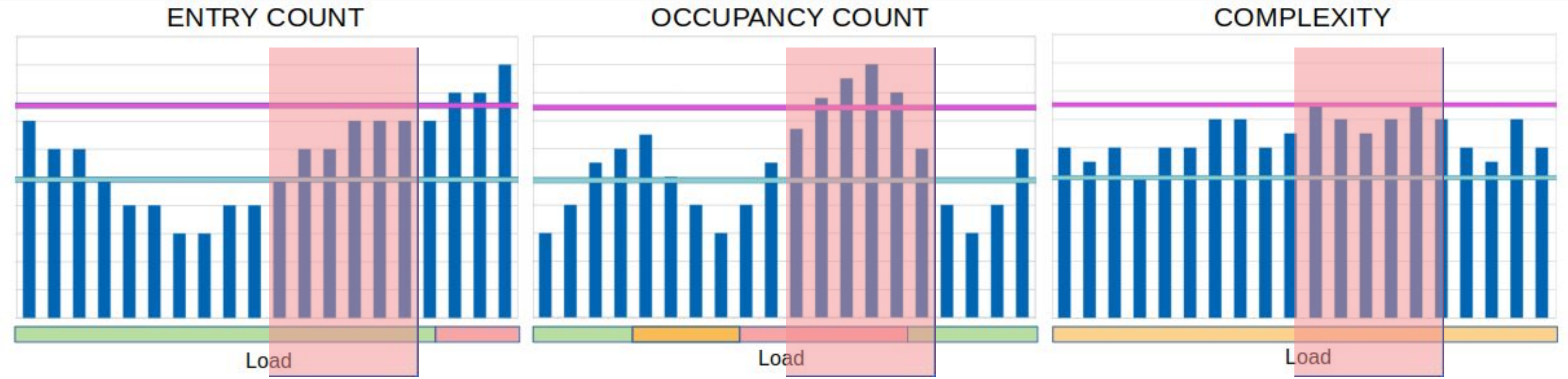
- **Cyclic process**,
- **Identification of required operational constraints** to ensure that the available declared capacity meets the traffic demand,
- It is based on pure **human know-how**.
- **Supervised deep learning techniques** to automatically detect required ATFCM regulations

ATFCM regulations detection



Many metrics need to be analyzed → A **Huge amount of information** needs to be **manually processed.**

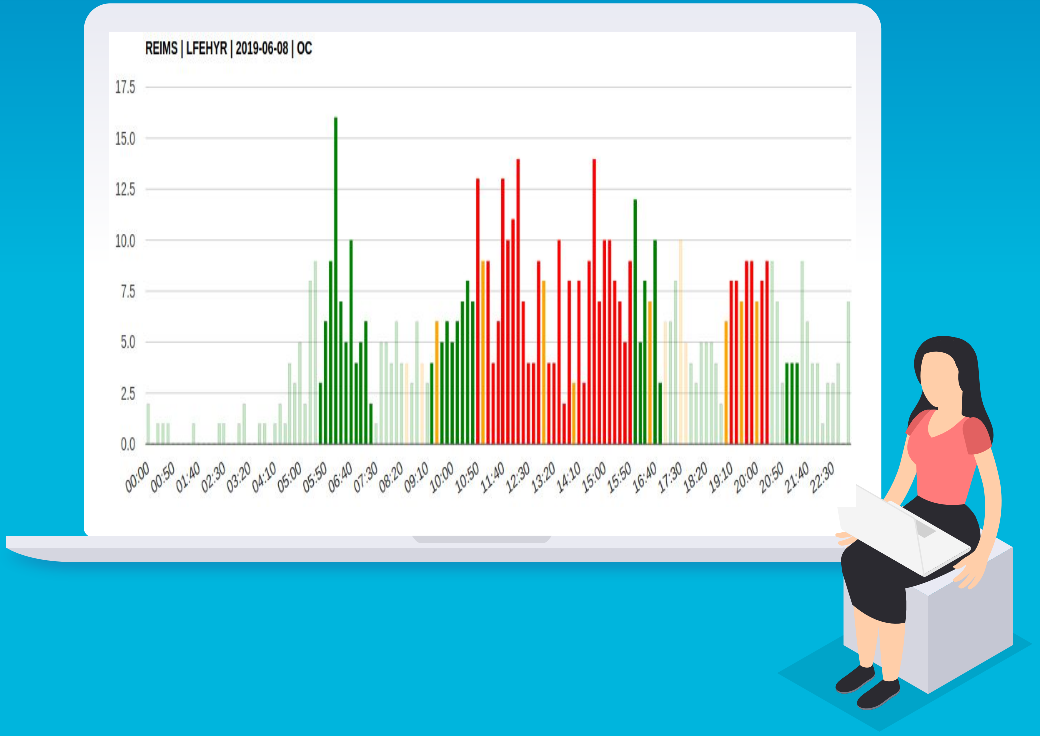
ATFCM regulations detection



Machine learning could be really beneficial → It **can process** huge **amounts of information** really **fast** and **efficiently.**

Web application?

- User friendly
- Visual
- Interactive



Methodology

C-ATC Capacity regulations

RNN-base model

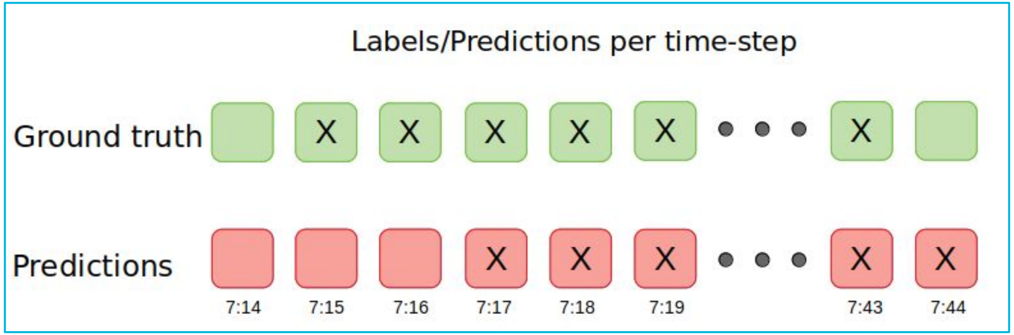
- Scalar variables
- Time-distributed LSTM

CNN-base model

- Artificial Images
- Time-distributed CNN

RNN-CNN hybrid model

- Cascade architecture



RNN-base model (C-ATC)

- RNNs are able to process **scalar variables** that evolve on time,

- Input features:
  - Timestamp,
  - Capacity,
  - Occupancy count
  - Entry count (20 and 60 minutes)
  - Workload
  - Climbing, cruising and descending

7:14	7:15	7:16	...	7:44

Time.	Time.	Time.	Time.	Time.
Cap.	Cap.	Cap.	Cap.	Cap.
OC.	OC.	OC.	OC.	OC.
...	...	...	...	...
Desc.	Desc.	Desc.	Desc.	Desc.

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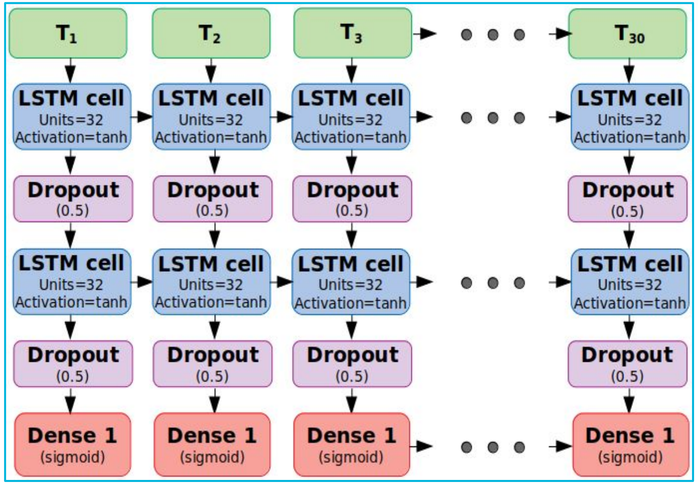

CNN-base model (C-ATC)

- CNNs are most commonly applied to analyze **static visual imagery**

- Input images:
  - From trajectory file (interpolation)
  - TV's shape from Newmaxo ASCII Region file

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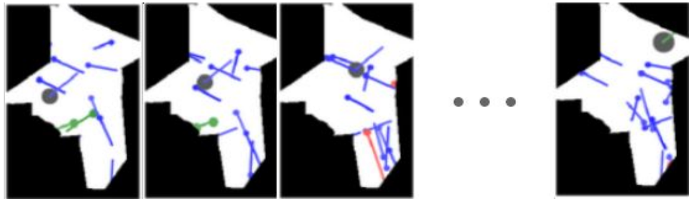
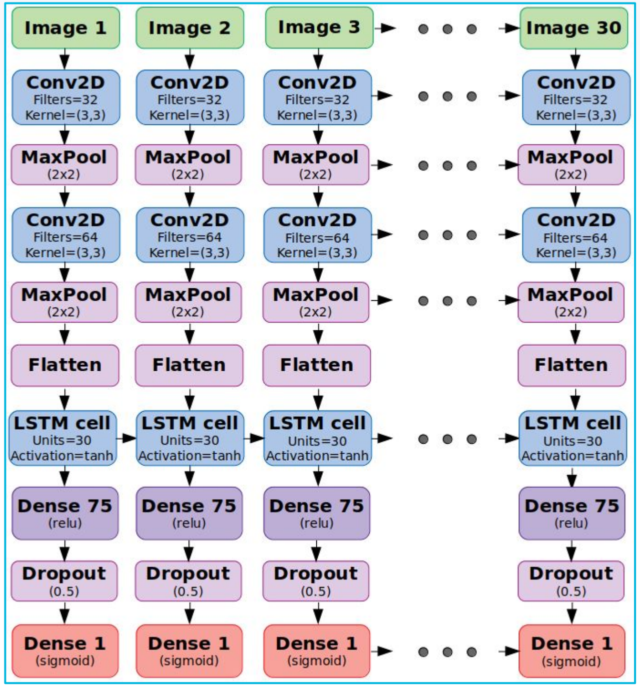
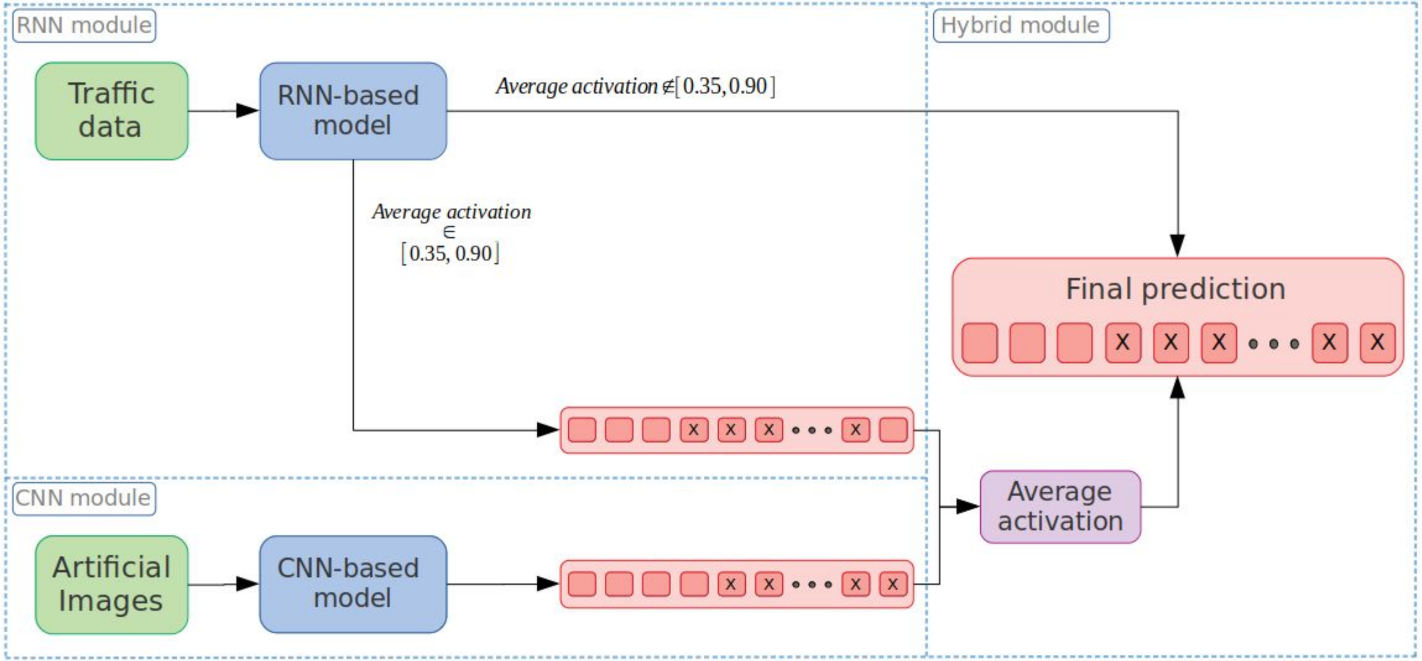




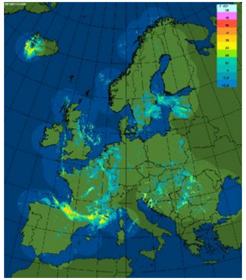
RNN-CNN hybrid model (C-ATC)

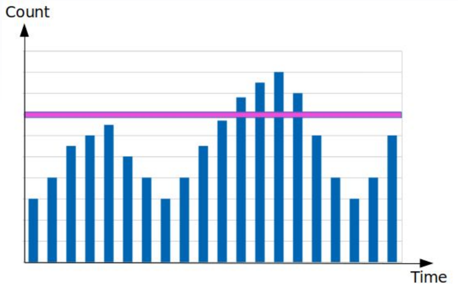


W-Weather regulations

RNN-base model

- **Scalar variables**
- Time-distributed LSTM





RNN-base model (W-Weather)

- Traffic input features:
  - Timestamp,
  - Capacity,
  - Occupancy count
  - Entry count (20 and 60 minutes)
  - Workload
  - Climbing, cruising and descending

- Weather input features:
  - Cloud cover
  - Vorticity
  - Humidity
  - Cloud ice / water content
  - Cloud rain / snow content
  - Temperature
  - Wind

7:14	7:15	7:16	...	7:44
Time.	Time.	Time.	Time.	Time.
Cap.	Cap.	Cap.	Cap.	Cap.
OC.	OC.	OC.	OC.	OC.
...	...	...	...	...
Desc.	Desc.	Desc.	Desc.	Desc.
Cloud.	Cloud.	Cloud.	Cloud.	Cloud.
Wind.	Wind.	Wind.	Wind.	Wind.
Humid.	Humid.	Humid.	Humid.	Humid.
...	...	...	...	...
Water.	Water.	Water.	Water.	Water.

RNN-base model (W-Weather)

- Traffic input features:
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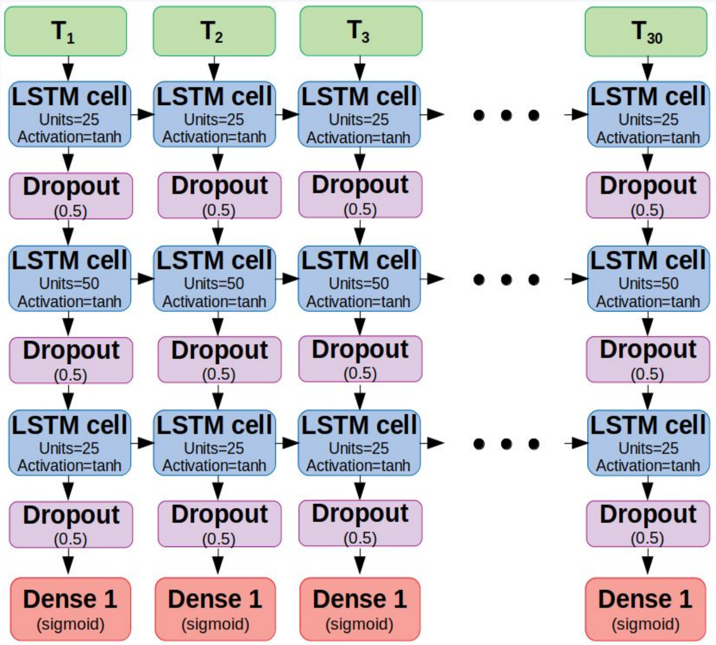


Evaluation of the models

Accuracy

Fraction of predictions the model got right

Recall

Proportion of positive samples correctly identified

How many regulations are detected?

Precision

Proportion of positive identifications correctly identified

How many predicted regulations are right?

F1-Score

Harmonic mean of the precision and the recall

Results

Regions

- **Two different regions** have been studied to **predict ATFCM regulations** using **4 AIRACs**:

MUAC

- 359 C-ATC Capacity regulations
- 151 W-Weather regulations.

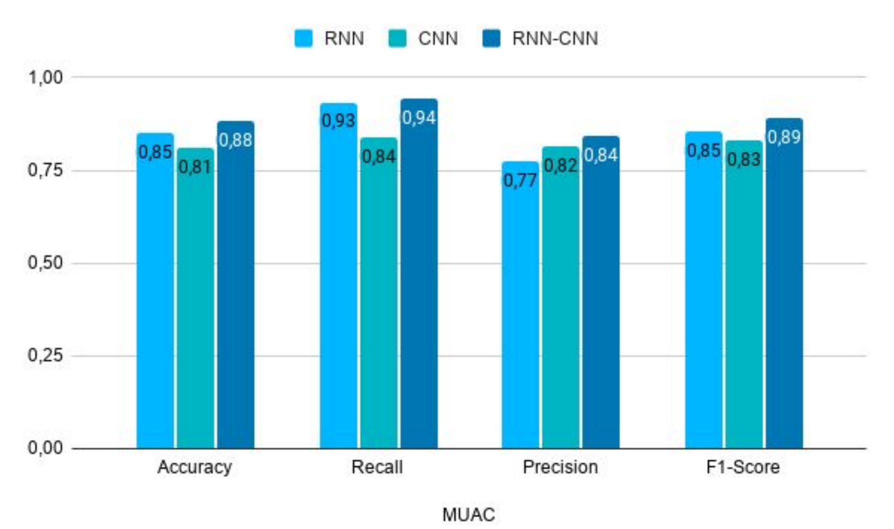
REIMS

- 764 C-ATC Capacity regulations;
- 582 W-Weather regulations.

- In both cases, around **1200 different 30-minutes intervals** have been used
- We have used a **balance dataset**. More or less, we have used the same number of positive and negative time-steps for the training/testing.

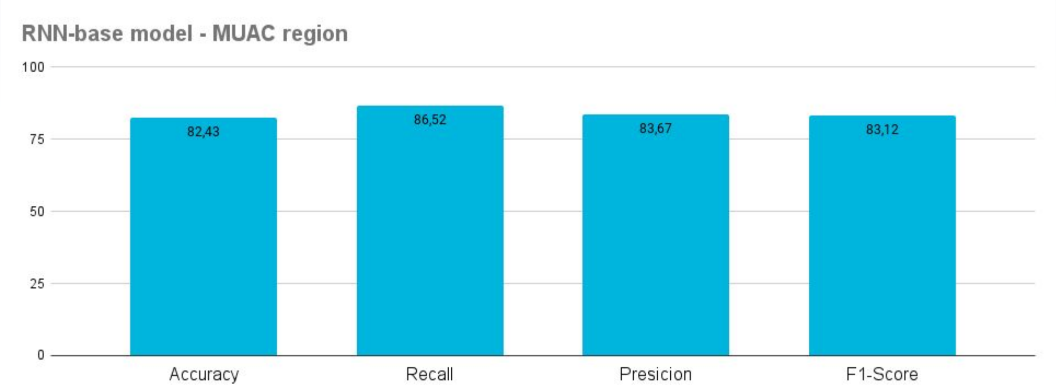
MUAC C-ATC regulations

- Average results given the region
- Individual TV:
  - MASB0LN
  - MASB3EH
  - MASD6WH
- Model for the entire region with slightly worse performance



MUAC W-Weather regulations

- Average results given the region
- Individual TV:
  - MASHRHR
  - MASHSOL
  - MASB3LL
- Model for the entire region with slightly worse performance



DASC 40th Digital Avionics Systems Conference
San Antonio, Texas, USA – September 28–30, 2021

UPC EUROCONTROL Engage

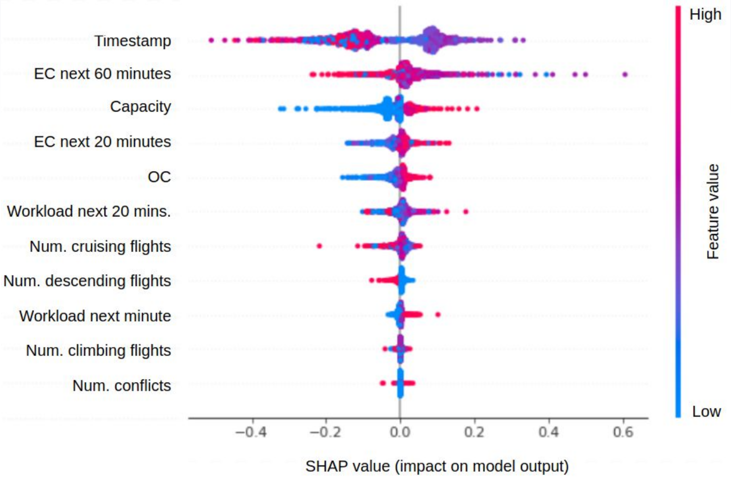
Model explainability - SHAP

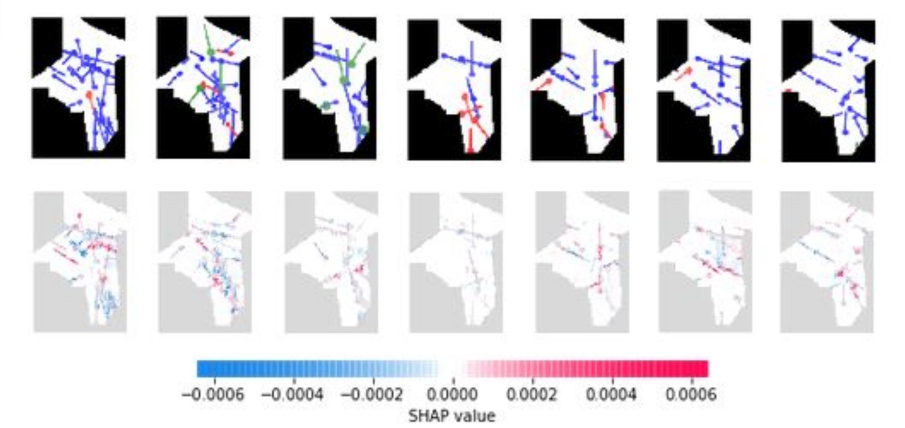
- **Understand the accuracy of the findings**, providing the ability to **explain the model** to possible stakeholders,
- Moreover, **understanding the reason behind the predictions** is crucial to ensure compliance to industry standards and gain trust,
- **SHapley Additive exPlanations (SHAP)** [2] is a game theory approach, to explain the output of any model,
  - It aims to identify which input features are more relevant for the trained model

SHAP

[2] S. M. Lundberg and S.-I. Lee, "A unified approach to interpreting model predictions," 2017

C-ATC regulations - MAUC





Conclusions

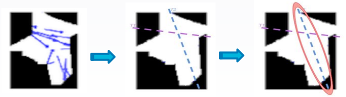
- **Deep learning models** can be used to **predict ATFCM regulations** across **different regions** of the European airspace:
  - MUAC and REIMS

- For **specific ATC sectors**, the model exhibits an **accuracy higher than 82%**, a **recall of higher than 84%**, and a **precision around 85%** when predicting specific time-steps,
  - Despite the small dataset used,

- The SHAP analysis has proved that the models have a **behavior close to the current methodology,**
  - Important to gain trust on the predictions and ensure compliance with industry standards,

- There is **room for improvement**.

Future work



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Integrate the models for **W-Weather** regulations into the Web application

Uncertainty study

Study other tools for **model explainability**

Integration of the models in **R-NEST**

Model-based simulation tool dedicated to research

Improve **advise capabilities** of the framework

Improve how we show the information to the FMPs

THANKS!

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