



a new wave of digital transformation

SCATTERERID

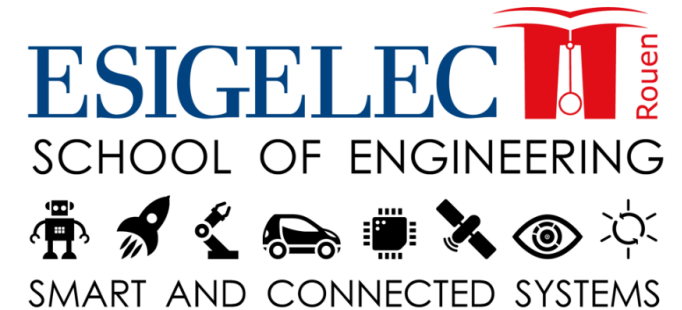
AI & RFID

Tahar Berradia, ESIGELEC
Christophe Loussert, Tagsys

ESIGELEC, TAGSYS

ESIGELEC:

1. Engineering school in Rouen with specialization in DataScience and AI
2. IRSEEM laboratory, embedded electronics for:
 - a. smart and connected systems
 - b. logistics
3. Tahar Berradia, researcher in AI and optimization for 20 years
4. Collaborating with Tagsys for 5 years



TAGSYS:

1. Founded in 1995, Pioneer in RFID
2. Started as a pure hardware player: 1Bu tags, 10Ku readers
3. Technology oriented: 15 PhDs and Post Docs, 50 patents
4. Acquired by Mojix in 2017, IoT platform
5. Markets: industry, luxury, food



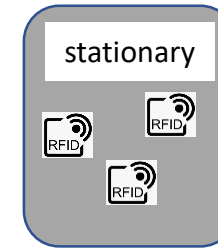
RFID state of the Art, poor localization

RFID @ dynamic checkpoints

→ dock door in a warehouse, for traceability



→ store exit door, for security

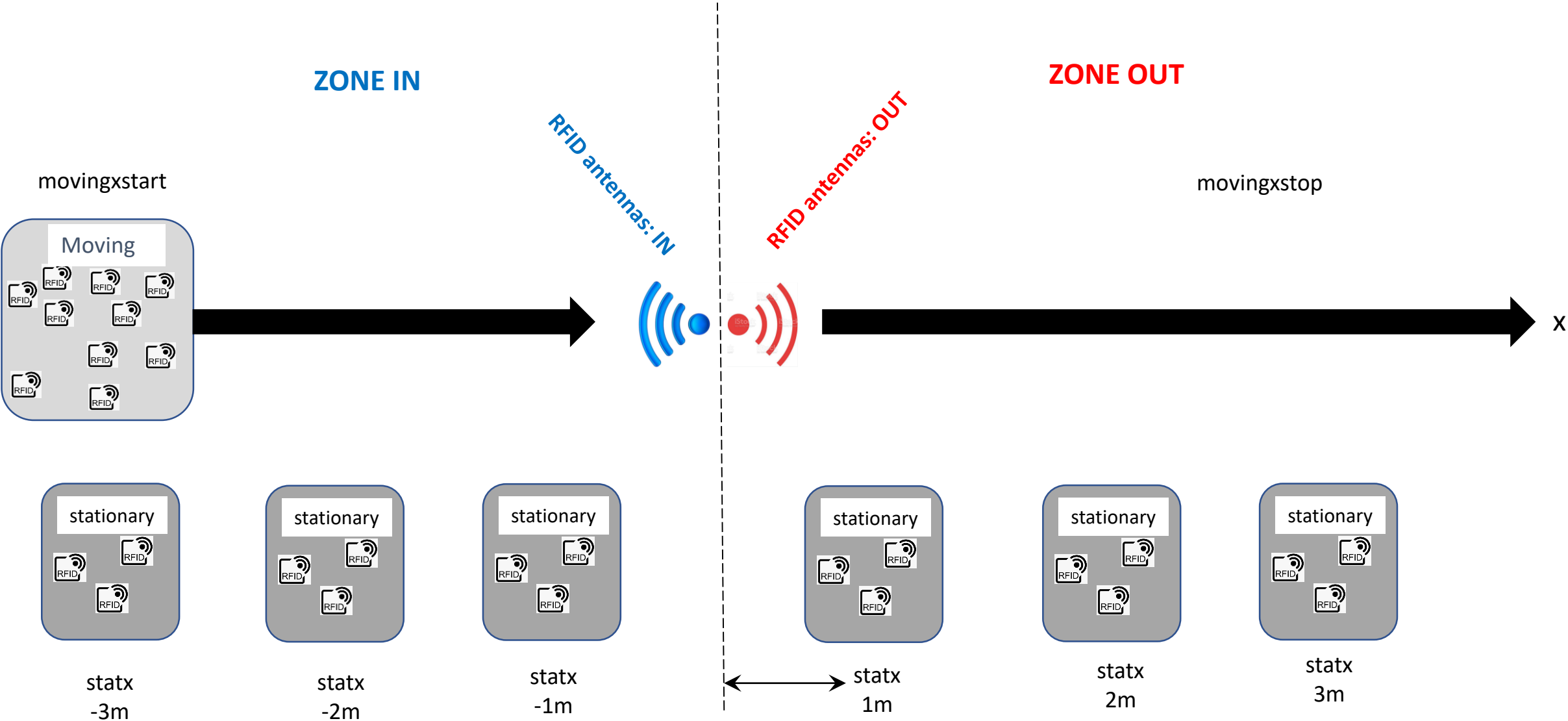


RFID state of the Art:

1. 100% detection for moving tags less than 2m away an RFID antenna
2. Also, erratic detection for stationary tags up to 10m

Unresolved issue: moving / stationary tag classification

Demo

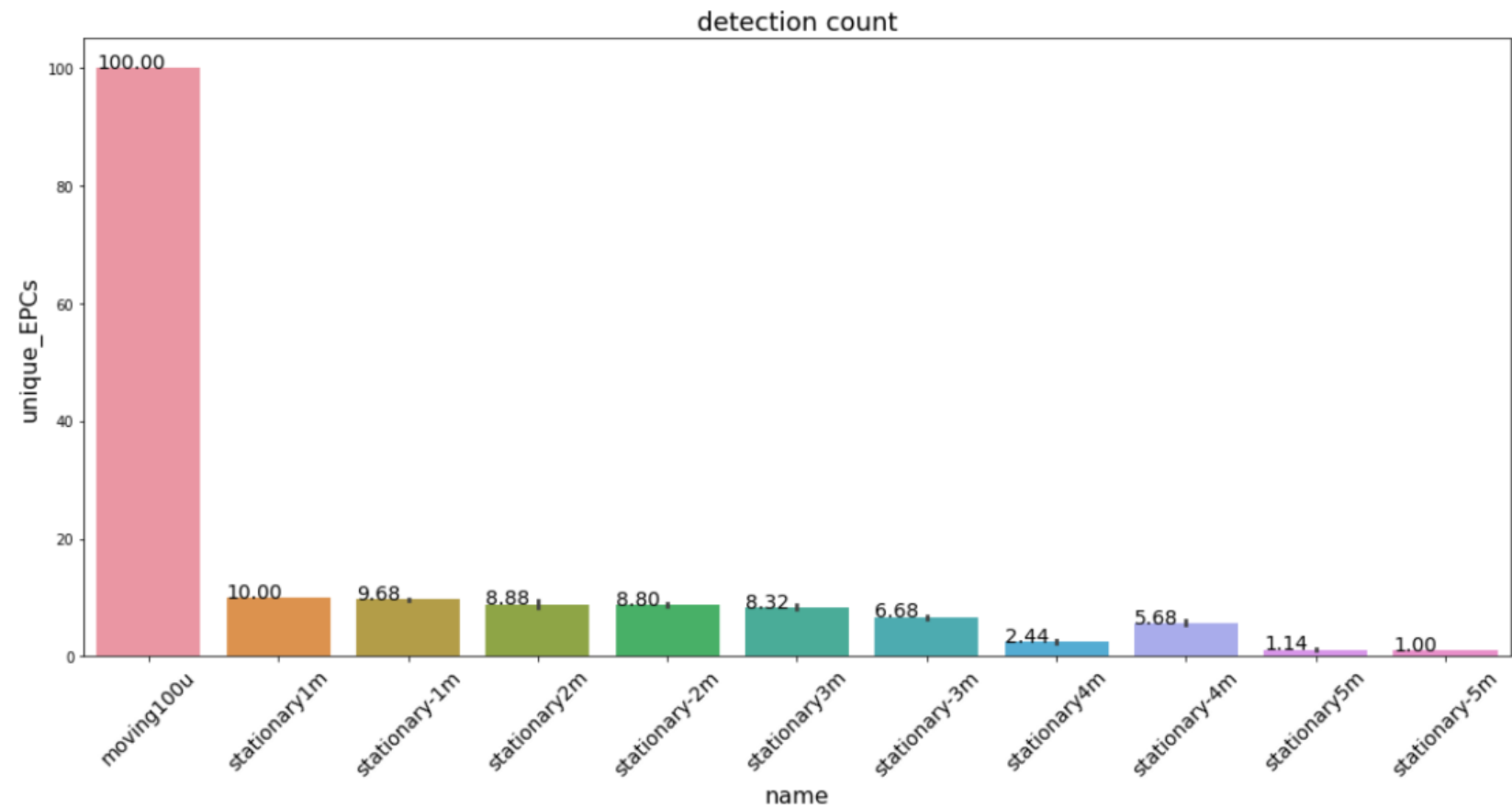


30/06/2022 Journée scientifique - « Communication par rétrodiffusion et rétro modulation »

Detection count

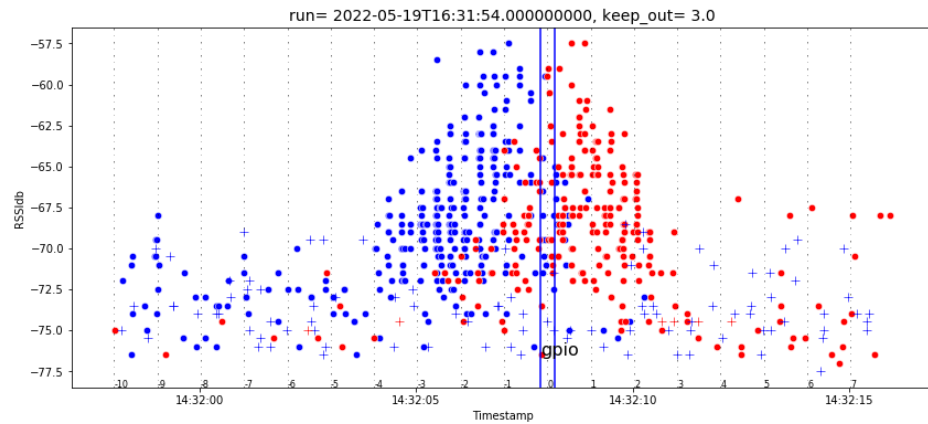
100% detection rate for moving tag <2m from antennas

➔ How to filter out stationary tags detected as well??



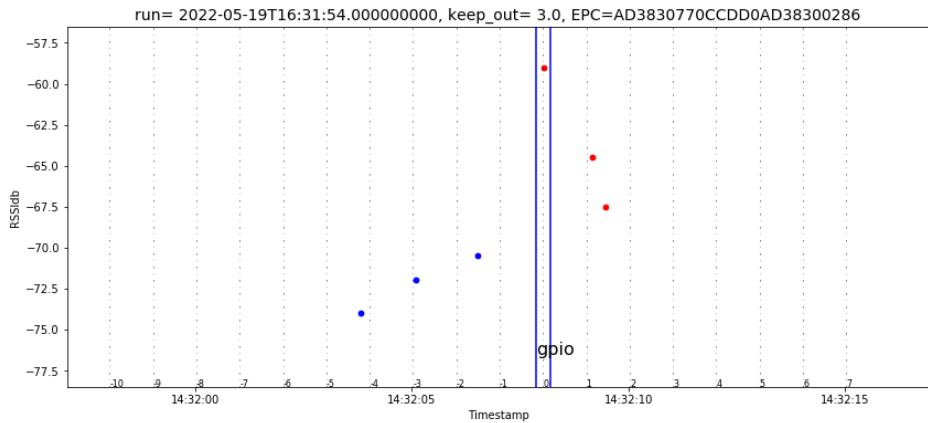
Visualization: “free space behavior”

All tags

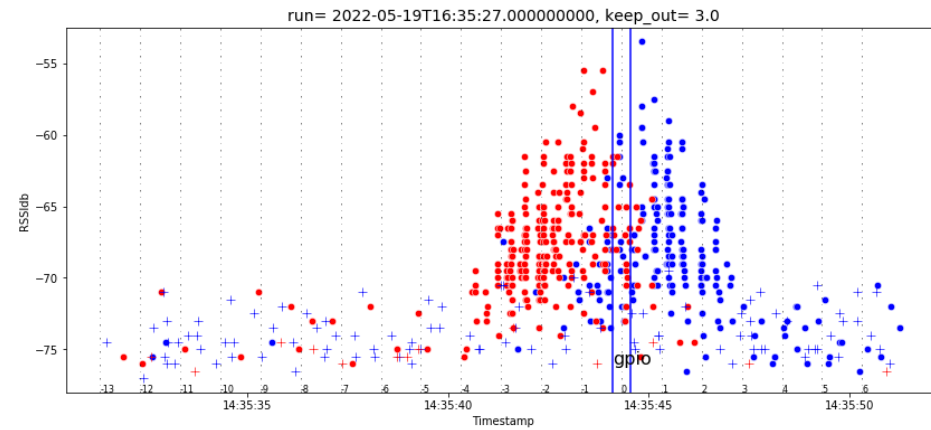


1 moving tag:

1. 15dB bell curve
2. detected by “in” antennas first and “out” after

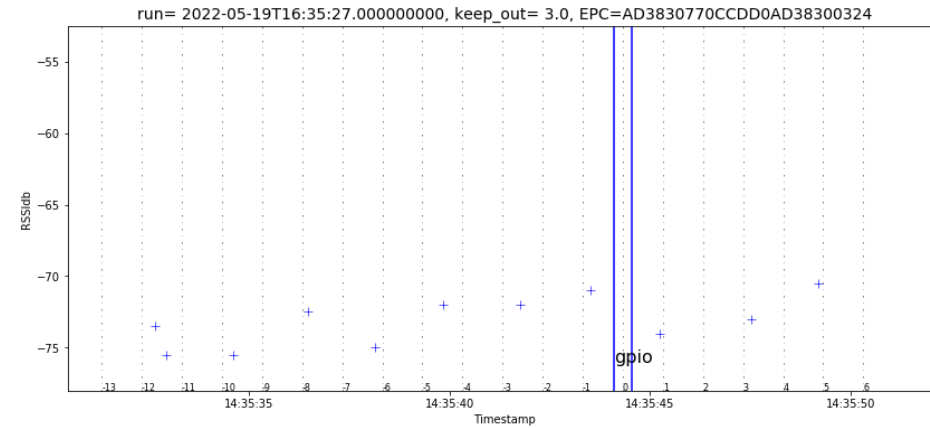


All tags



1 stationary tag:

1. continuous & flat detection
2. Detected only by “in” antennas

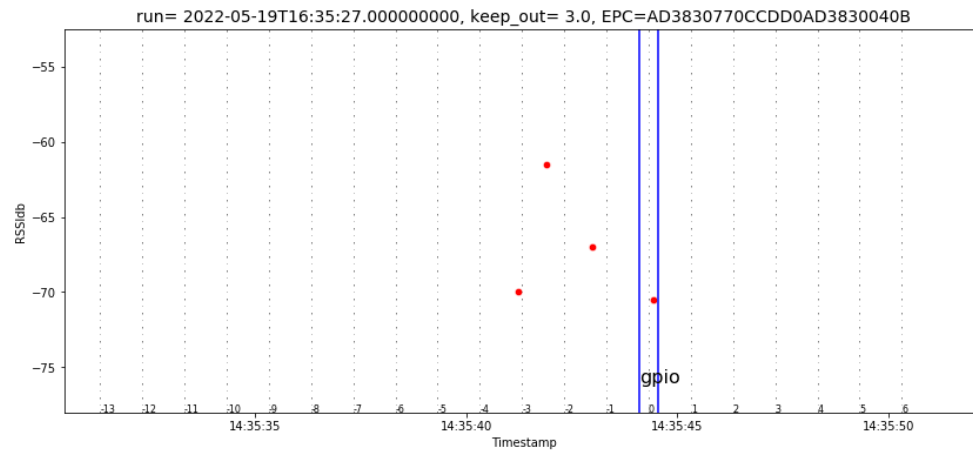


30/06/2022 Journée scientifique - « Communication par rétrodiffusion et rétro modulation »

Visualization, “no free space behavior”

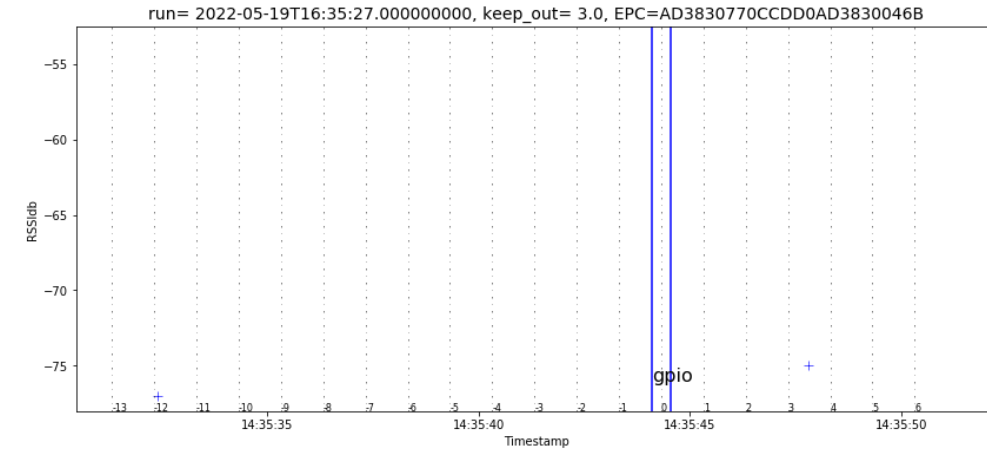
moving tag:

1. detected only by “out” antennas



stationary tag:

1. 2 detections only



RFID tags: timeseries

Basic RFID data:

- 1. EPC: Electronic Product code, unique ID
- 2. Timestamp: detection timestamp
- 3. Antenna: up to 32, automatically switching
- 4. RSSI: tag echo

```
tags [['EPC', 'run', 'Timestamp', 'Antenna', 'RSSI']].head()
```

	EPC	run	Timestamp	Antenna	RSSI
0	E28068900000400305C60431	2021-12-16 15:10:31	2021-12-16 15:35:11.313204+01:00	1	-56.5
1	E28068900000400305C60434	2021-12-16 15:10:31	2021-12-16 15:35:11.314722+01:00	1	-60.5
2	E28068900000500305C60433	2021-12-16 15:10:31	2021-12-16 15:35:11.316928+01:00	1	-59.5
3	E28068900000500305C6014E	2021-12-16 15:10:31	2021-12-16 15:35:11.319102+01:00	1	-69.5
4	E28068900000500305C60153	2021-12-16 15:10:31	2021-12-16 15:35:11.321297+01:00	1	-67.0

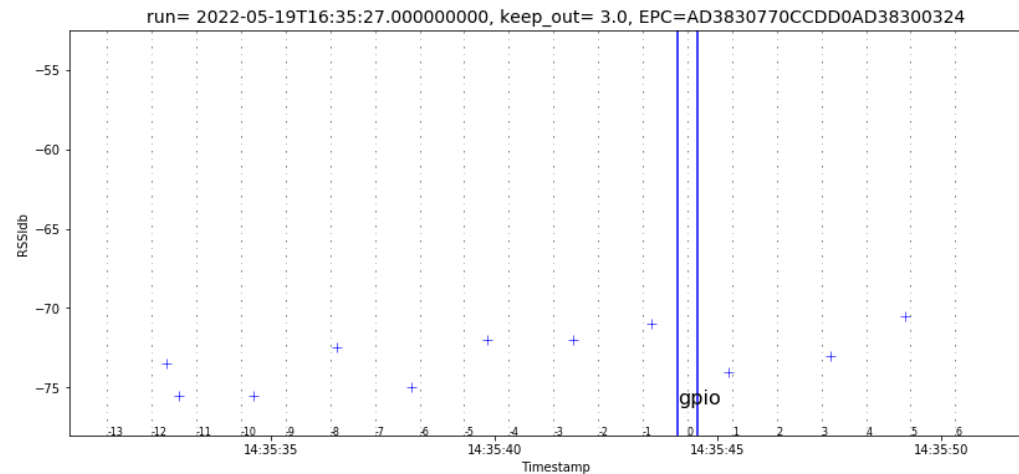
Preprocessing: from RFID time series to structured dataset

Sample: EPC in a window (typically 10sec)

➔ What we want to predict: « moving » / « stationary » ?

Features: available structured data for prediction calculation

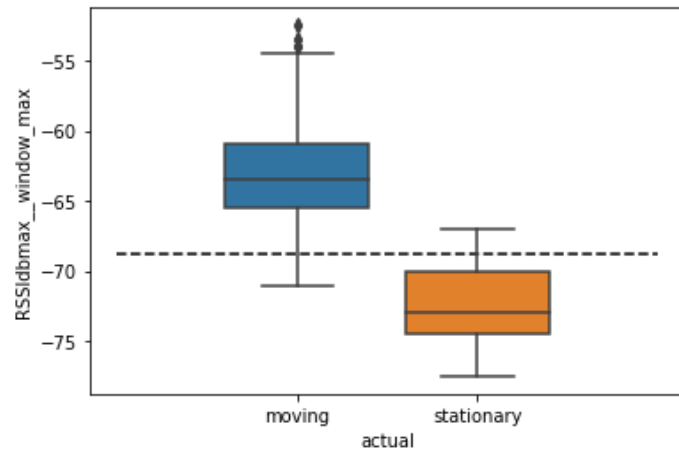
1. per EPC = x1
 2. per antenna: individual (4) + « in / »out » (2) + all (1) = x7
 3. 4 physical features: RSSI_{max}, RSSI_{average}, RSSI_{min}, ReadCount
 4. per time unit: 1sec slot (10) + window:max, average, mini (3) = x13
- ➔ $1 \times 7 \times 4 \times 13 = 364$ features !!



Analytical

Analytical: one single feature (out of 364) → RSSI_{max}__window_max

Above a certain threshold: moving, underneath: stationary → 96% accuracy



```
1 crit = ds_EPC_crossing_ko['RSSImax__window_max']>threshold
2 pred_ana = np.where(crit, 'moving', 'stationary')
3 (ds_EPC_crossing_ko['actual']==pred_ana).mean()
```

0.9615384615384616

Note: DecisionTree, max_depth=1 (best out of 364)

1. RSSI_{max}__window: best separating feature
 2. Accuracy = 96%
- ... aligned with RF physics expert

Machine Learning

364 features taken into account

Supervised, statistically ML

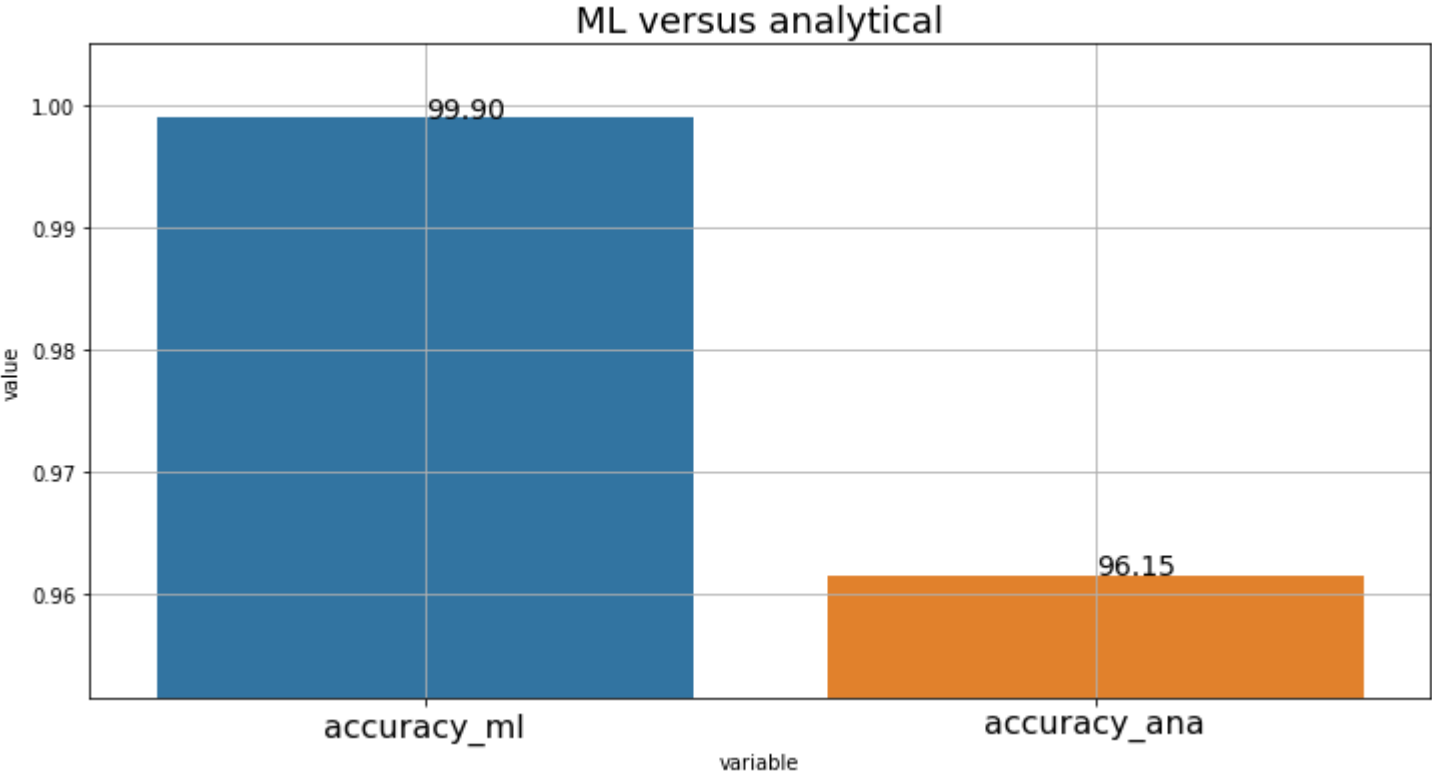
Scikit-learn classifier:

1. data split: train, test
2. fit with train
3. predict with test
4. Accuracy: difference between test and predict



Machine Learning versus analytical

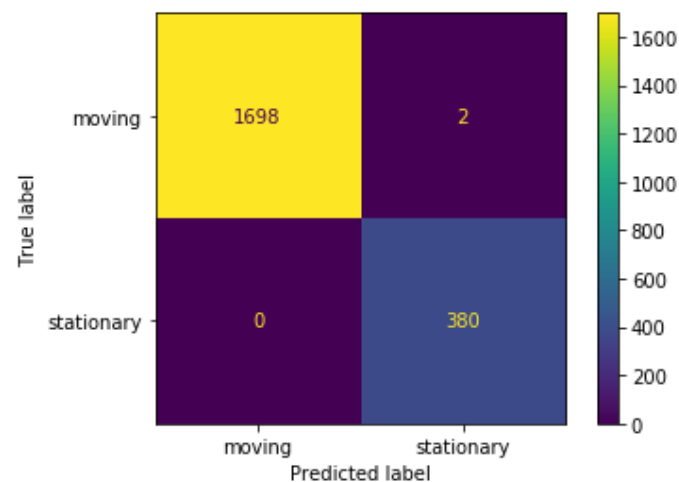
X30 less errors



Machine Learning errors

```
1 ConfusionMatrixDisplay.from_predictions(ds_shuffle['actual'], ds_shuffle['pred_ml'])
```

<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x26968264988>



```
1 print(classification_report(ds_shuffle['actual'], ds_shuffle['pred_ml'], digits=4))
```

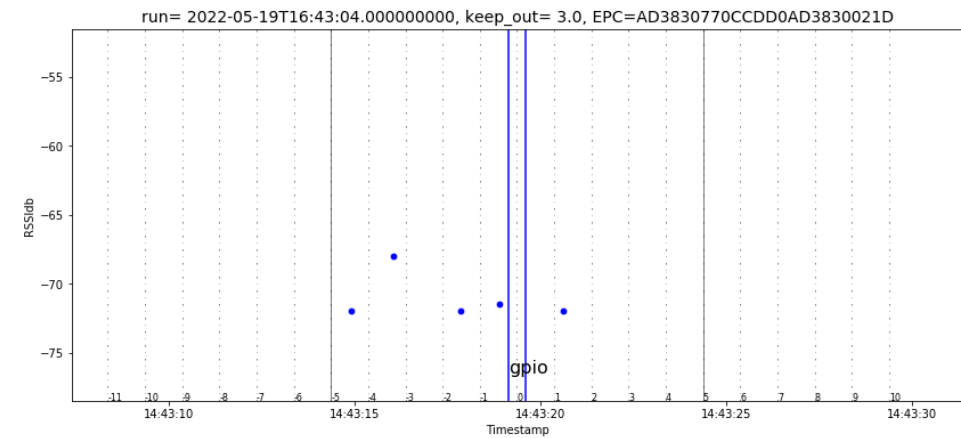
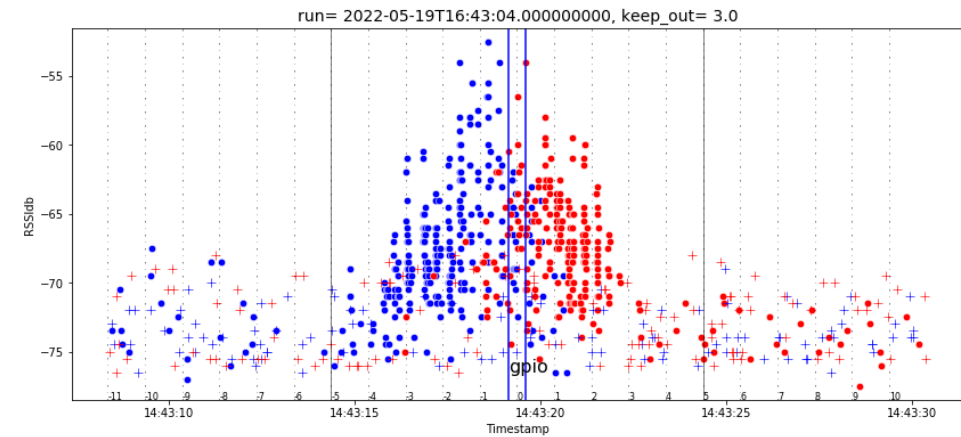
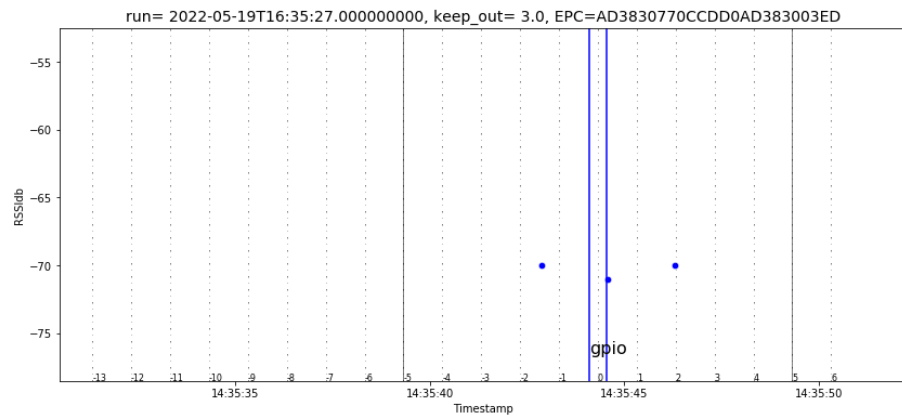
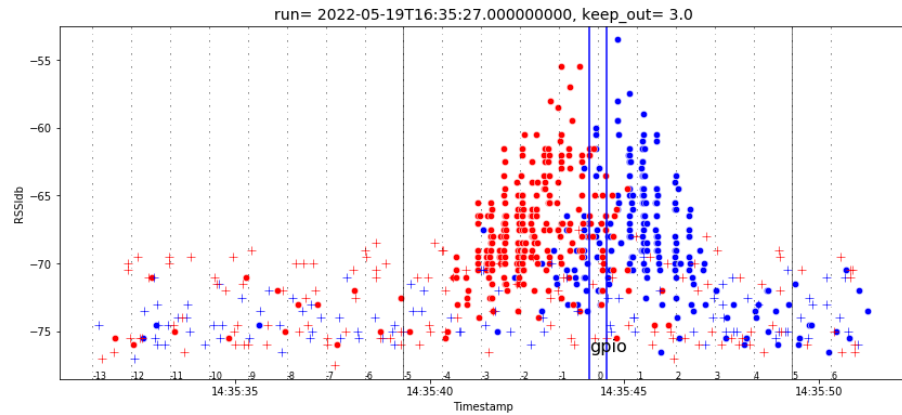
	precision	recall	f1-score	support
moving	1.0000	0.9982	0.9991	1700
stationary	0.9922	1.0000	0.9961	380
accuracy			0.9986	2080
macro avg	0.9961	0.9991	0.9976	2080
weighted avg	0.9986	0.9986	0.9986	2080

Machine Learning errors

moving predicted stationary (FalseNegative)

Human eye: mistaken as well

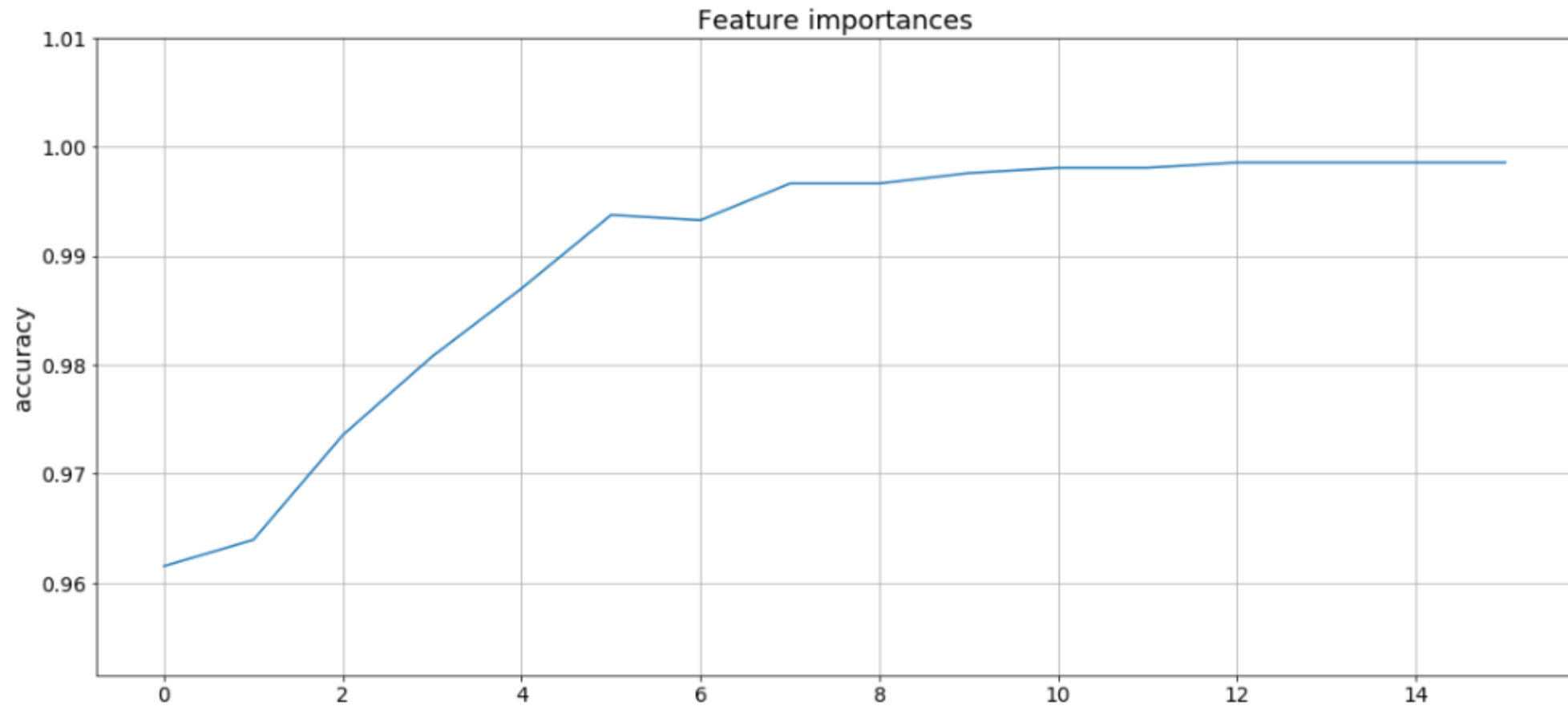
1. No bell curve
2. Detected by « in » antennas only ... no crossing
3. Similar to many « stationary » tags popping up during crossing



30/06/2022 Journée scientifique - « Communication par rétrodiffusion et rétro modulation »

feature_importance

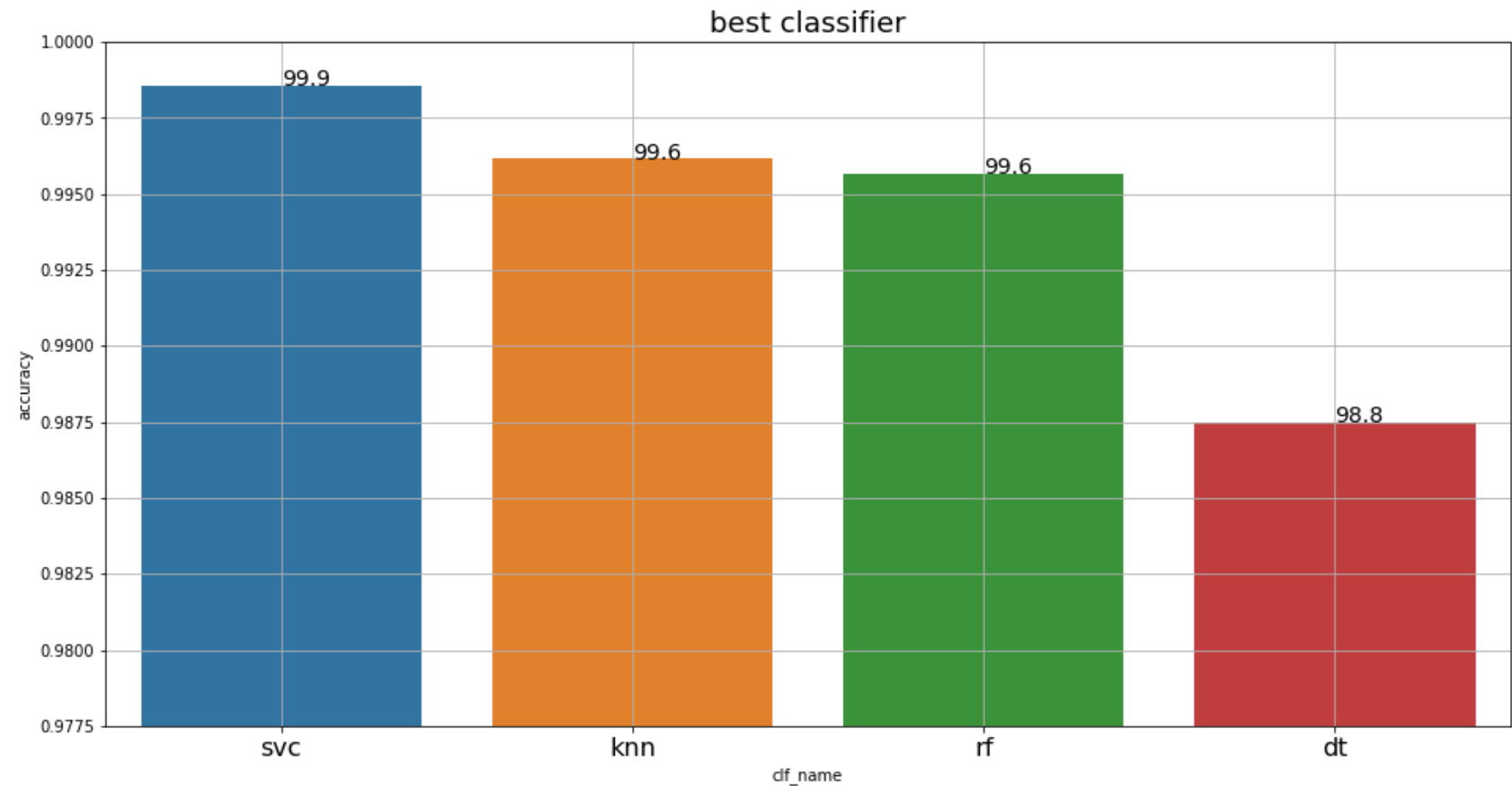
top 15 features bring all benefits



30/06/2022 Journée scientifique - « Communication par rétrodiffusion et rétro modulation »

Best classifier

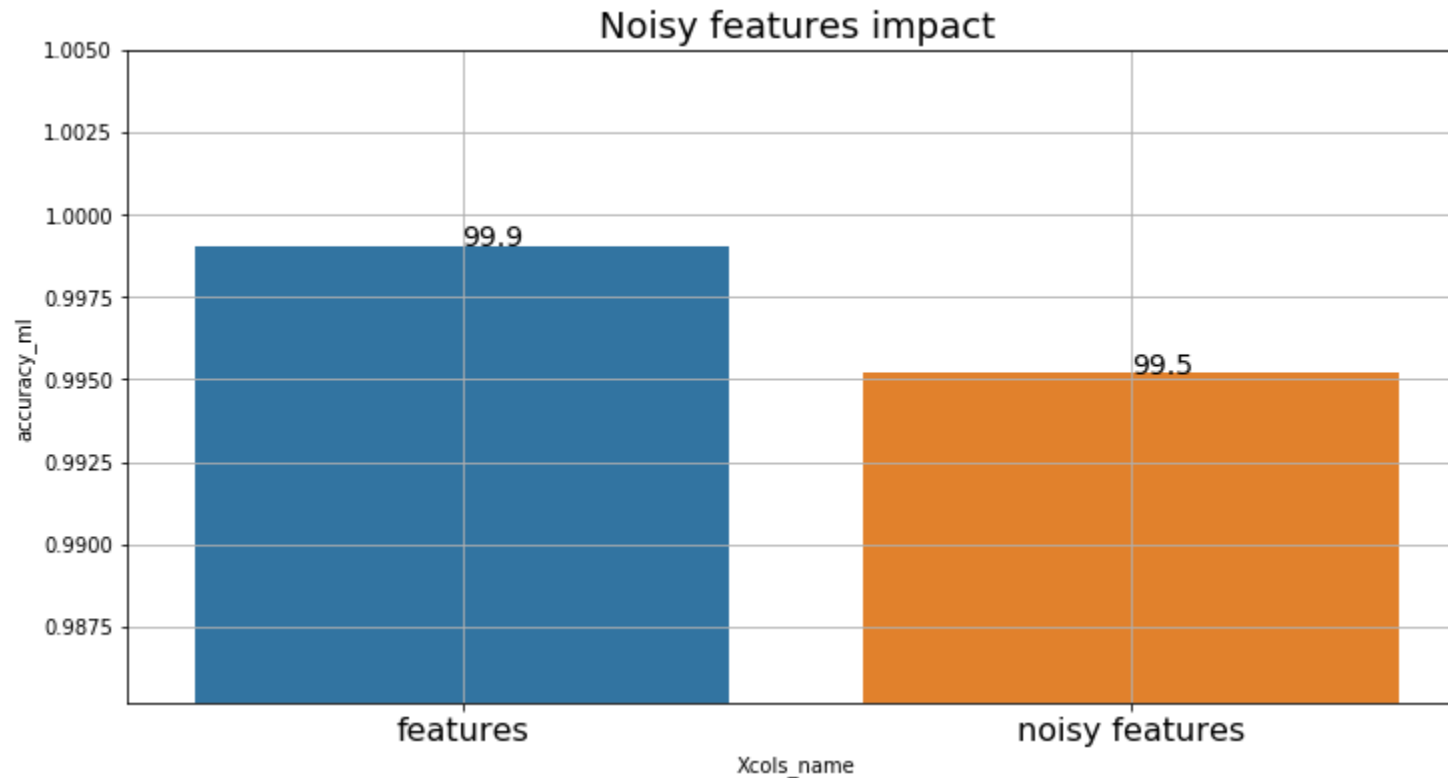
Support Vector Classifier: champion classifier (many RFID publications converge)



Robustness , overfitting

noise (random from 0.5 to 1.5) as a multiplicator coefficient on each features

➔ Limited accuracy impact, robust model, no overfitting



Next

1. RFID first step:
 - a. Richest antenna diversity in a limited footprint 50x50cm
 - b. Small and directive radiating element: $<90^\circ$, 6dBiL
2. RFID major step: third harmonics
 - a. Tx @900MHz, Rx @900MHz ... and also @2700MHz (3rd harmonics)
 - b. small size highly directive 2700MHz Rx antennas
 - c. LCIS fruitfull PoC
3. Edge AI with a \$10 microController
4. AI for ScatteredID ?? Tahar Berradia is listening to you ...