R User Meetup

NOTAM classifier in R

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Swiss International Airlines, Lta
S/IBC
S/ZC

13.11.2019

Topics we'll touch on

- Me: I'll be quick (promise)
- The Introduction: What is a NOTAM?
- The Problem: What is the difficulty?
- The Approach: What methods did we use?
- The Results: What can we conclude?

Me!
Very short summary

The boring part (Me)

Setúbal 1991

Lisboa

(2008-2015)

Technical University of Lisbon – MSc.

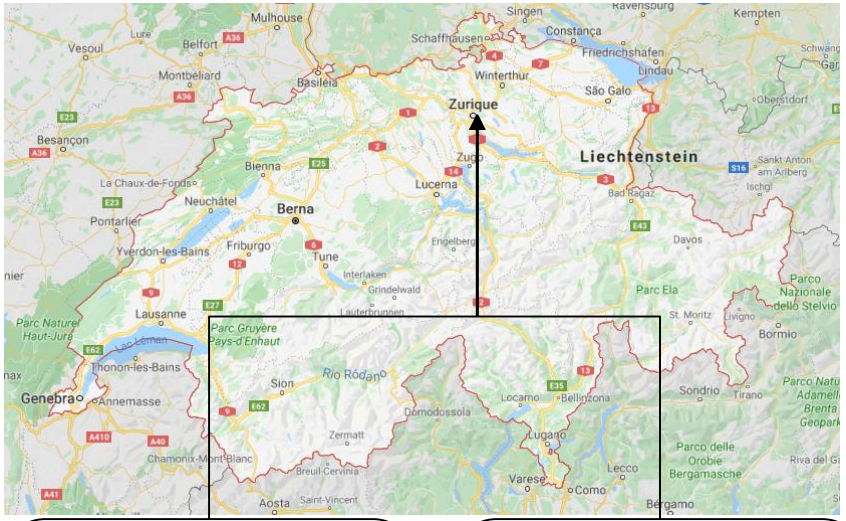
Aerospace Engineering

Lisboa

(June 2016-May 2018)

TAP Maintenance & Engineering

Avionics Specialist



Zürich

(July 2018–December 2018)

SWISS International Airlines - IT

Intern

Zürich

(January 2019 - Present)

SWISS International Airlines

Operations Steering Business Analyst

The Introduction
What is a NOTAM

The Introduction

What if?

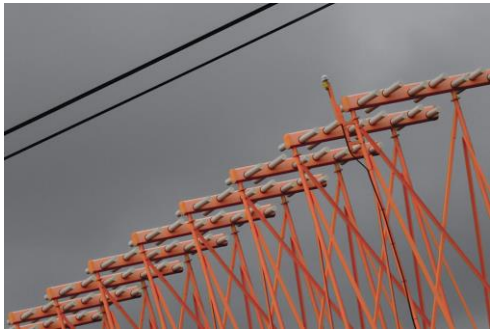
Military area

New structure near airport

Closed airport/runway

Fireworks

Unavailability of services/systems



The Introduction

What if?

New structure near airport

Military area

Closed airport/runway

Need to inform pilots

Fireworks

Unavailability of services/systems

SWISS

The Introduction

What if?

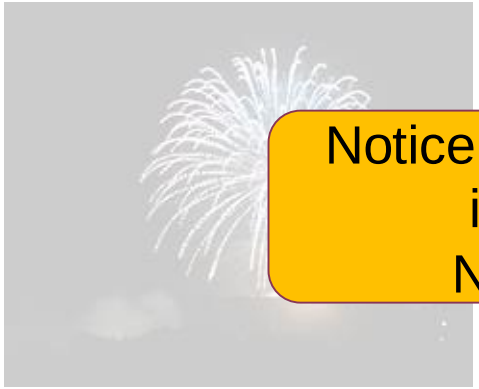
New structure near airport

Military area

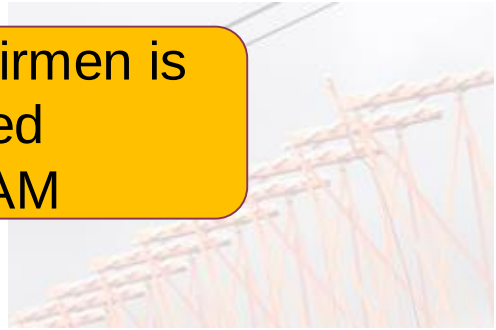
Closed airport/runway

Need to inform pilots

Fireworks



Unavailability of services/systems



Notice to airmen is issued
NOTAM

The Introduction
Format of a NOTAM

H7501/18 NOTAMN Q)EGPX/QWGLW/IV/M/W/100/195/5716N00443W124 A)EGPX B)1810050700 C)1810051742 E)GLD FLY WO SSR TRANSPONDER WI AREA 553000N 0063000W - 563000N 0063000W - 571500N 0050000W - 590000N 0050000W - 590000N 0024500W - 573000N 0013000W - 570000N 0013000W - 560700N 0023000W - 560703N 0040000W - 561400N 0040926W - 555330N 0050000W - 553000N 0050000W - 553000N 0063000W REF AIP ENR 1.1 F)FL100 G)FL195

A0701/18 NOTAMN Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO B)1808311700 C)1809010300 E)RWY 08/26 W 2800FT CLSD. DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT.

A1884/17 NOTAMR A1302/17 Q)DRRR/QMRAP/IV/NBO/A/000/999/2015N00059E005 A)GATS B)1712231134 C)1803241200EST D)MON WED FRI 0800-1200 E)NO LANDING AND TAKING OFF IN TESSALIT A/D DUE TO RWY CLOSED FOR UNAUTHORIZED FLIGHTS. AUTHORIZATION MUST BE OBTAINED FROM MALIAN AIR FORCE. OPERATIONS COORDINATION CENTRE E-MAIL: PLANIF.CCOA1(AT)GMAIL.COM PHONE:(00223)20221631 TESSALIT UNPAVED RWY 05R/23L IS CLOSED DUE TO MAINTENANCE WORKS EVERY MONDAY,WEDNESDAY AND FRIDAY FROM 0800Z TO 1200Z. TESSALIT RWYS 05L/23R AND 15/33 REMAIN OPENED FOR ALL AUTHORIZED TRAFFIC. FOR EMERGENCY FLIGHTS ON RWY 05R/23L DURING MAINTENANCE, AIR OPERATORS MUST CORDINATE WITH MINUSMA TESSALIT TELEPHONE : (+223)95999596 AND MINUSMA AVIATION E-MAIL: MINUSMA-AIROPERATIONSCENTRE(AT) UN.ORG TELEPHONE : (+223)94951019/94951018 GND TO FL160

The Introduction
Format of a NOTAM – Structured & Unstructured Data

A0701/18 NOTAMN
Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO
B)1808311700 C)1809010300 E)RWY 08/26 W 2800FT CLSD.
DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT.

Tags (Q, A, B, C, D, E, F, G) identifying structured data (green), and free-text (blue)

The Problem

The Problem
What (else) is wrong?

A0701/18 NOTAMN
Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO
B)1808311700 C)1809010300 E)RWY 08/26 W 2800FT CLSD.
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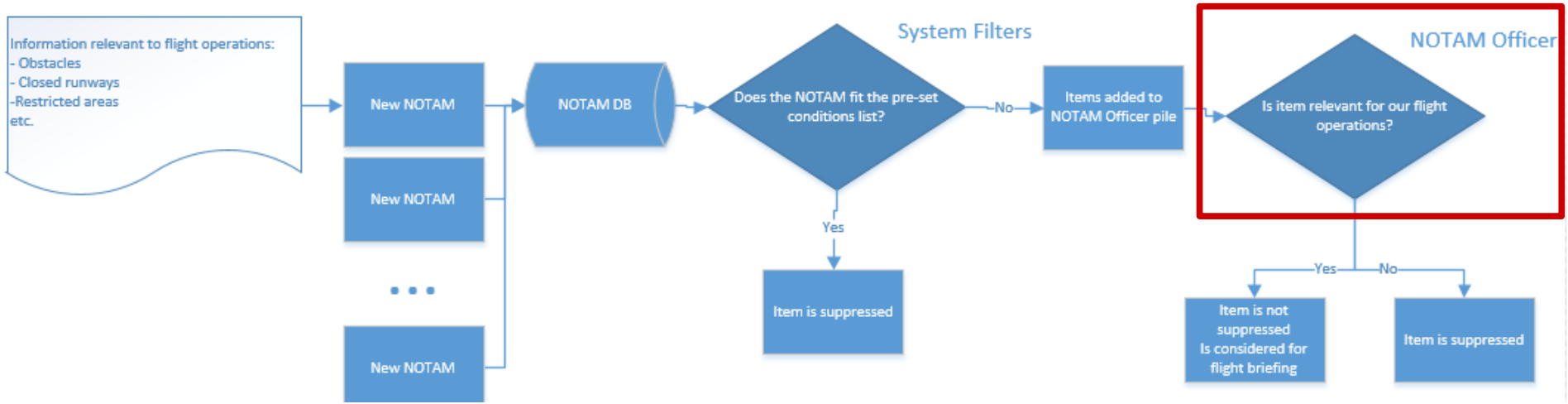
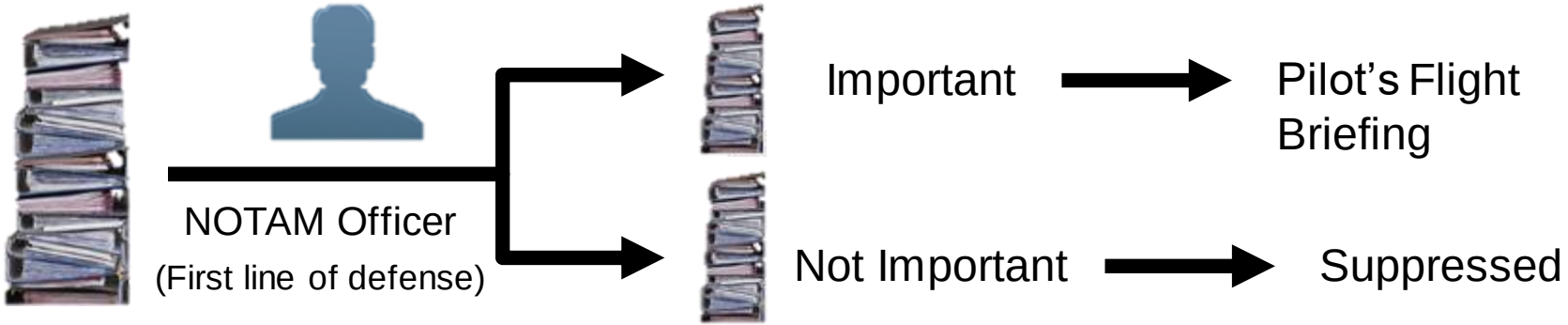
LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT.

X ~3000 / day
(~1M/year)

The Introduction
How does it work within SWISS?

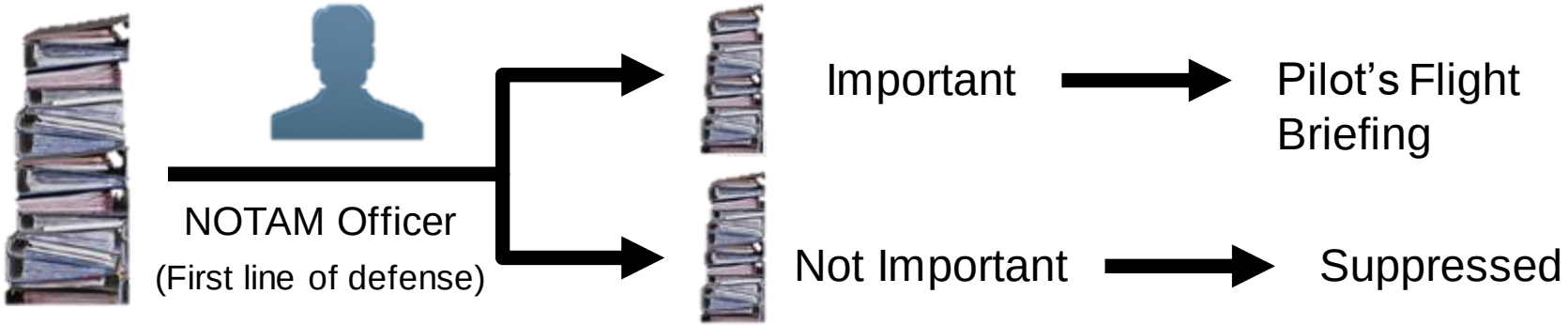


The Introduction
What are we looking at?



The Problem
Quantity overview

The Introduction
What are we looking at?



Can we help on this step?

The Approach

The Approach
Easy part

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LDA 7000FT.

The Approach
Easy part

Geospatial coordinates

Subject condition

Radius

Flight Levels (height)

Message subject

A0701/18 NOTAMN
Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO
B)1808311700 C)1809010300 E)RWY 08/26 W 2800FT CLSD.
DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT.

Region

Valid date range

The Approach
Easy part

Geospatial coordinates

Subject condition

Radius

Flight Levels (height)

Message subject

A0701/18 NOTAMN
Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO
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DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT.

Region

Valid date range

Free features!

SWISS

The Approach
Fun part

Whatever someone decided to write

Too much / Too little

Contractions (sometimes !)

Coordinates / Flight Levels (again ?)

A0701/18 NOTAMN
Q)PHZH/QMRLC/IV/NBO/A/000/999/1943N15503W005 A)PHTO
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SWISS

The Approach
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LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT
LDA 7000FT.

Not ready to use information!

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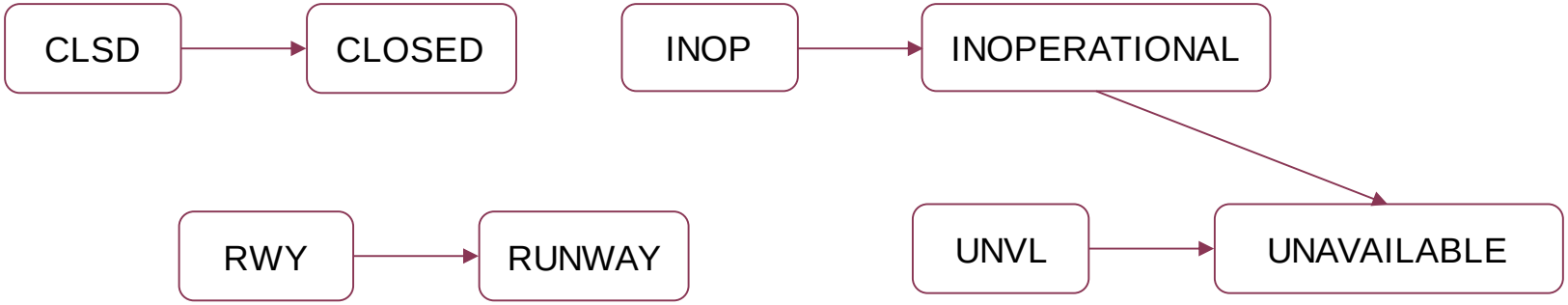
The Approach
Processing free text



E)RWY 08/26 W 2800FT CLSD. DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT.

The Approach
Processing free text

```
ABN;airport beacon
U/S;UNSERVICEABLE
ABV;above
ACC;area control center ARTCC
ACCUM;accumulate
ACFT;aircraft
ACR;air carrier
ACT;active
AD;AERODROME
ADJ;adjacent
ADZD;advised
AFD;airport facility directory
AFSS;automated flight service station
AGL;above ground level
ALS;approach light system
ALT;altitude
ALTM;altimeter
ALTN;alternate
ALTNLY;alternately
ALSTG;altimeter setting
AMDT;amendment
AMGR;airport manager
AMOS;automatic meteorological observing system
AP;airport
APCH;approach
```

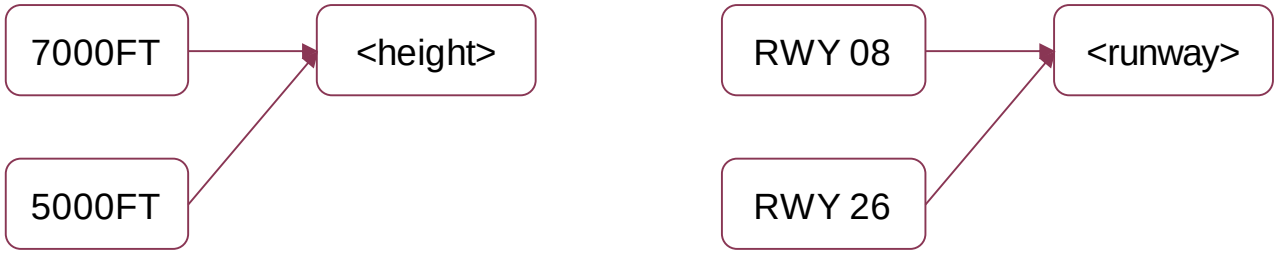
■ ■ ■

```
UNMKD;unmarked
UNMNT;unmonitored
UNREL;unreliable
UNUSBL;unusable
VASI;visual approach slope indicator
VDP;visual descent point
VIA;by way of
VICE;instead versa
VIS;visibility
VMC;visual meteorological conditions
VOL;volume
VOR;vhf Omni-directional radio range
VORTAC;VOR and TACAN
W;west
WB;westbound
WED;Wednesday
WEF;with effect from or effective from
WI;within
WKDAYS;Monday through Friday
WKEND;Saturday and Sunday
WND;wind
WPT;waypoint
WSR;wet snow on runways
WTR;water on runways
WX;weather
```

Mapped contractions to full words

SWISS

The Approach
Processing free text



E)RWY 08/26 W 2800FT CLSD. DECLARED DIST: RWY 08 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT. RWY 26 TORA 7000FT TODA 7000FT ASDA 7000FT LDA 7000FT.

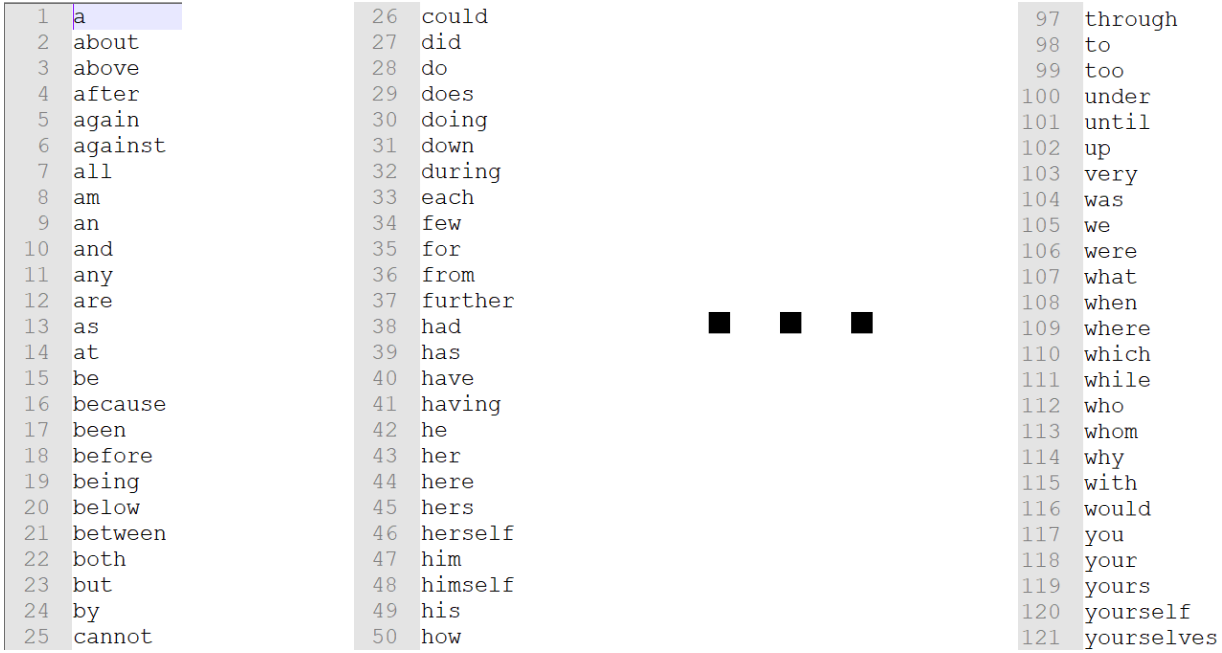
The Approach
Processing free text

```
1  \b\d+([,.]\d{1,2})? ?(K|M)HZ\b;<frequency>
2  \bCH[0-9]{2}[XY]\b;<channel>
3  \bFL[0-9]{3}\b;<flightlevel>
4  \b[0-9]+[.]?[0-9]? ?FT( ?(AMSL|AGL))?\b;<height>
5  \b[0-9]+[NS] ?[0-9]+[EW]\b;<coordinate>
6  \b\d+([,.]\d{1,2})? ?(M|KM|NM)\b;<distance>
7  \b(RUNWAY|RWY) ?[0-9]{2}(R|L|C)?(/[0-9]{2}(R|L|C)?)?(?!\w);<runway>
```

Special numbers mapped with regular expressions

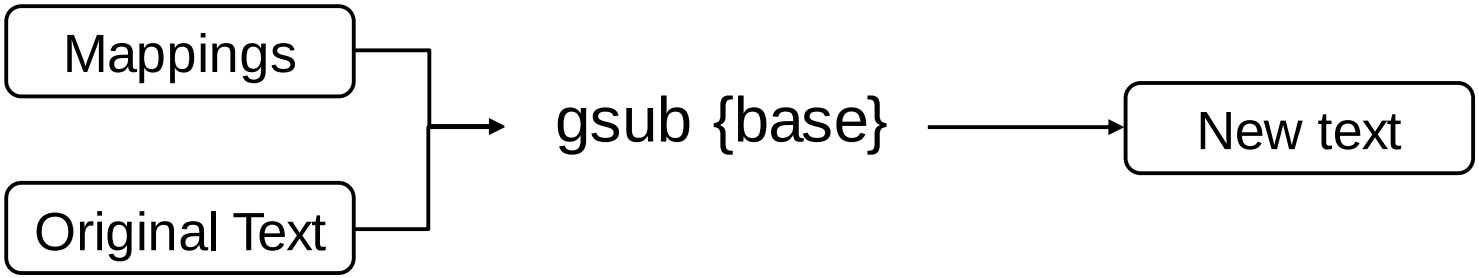
SWISS

The Approach
Processing free text



Listed stop words

The Approach
Processing free text




```
> message <- "All the good stuff"
> gsub("stuff", "things", message)
[1] "All the good things"
```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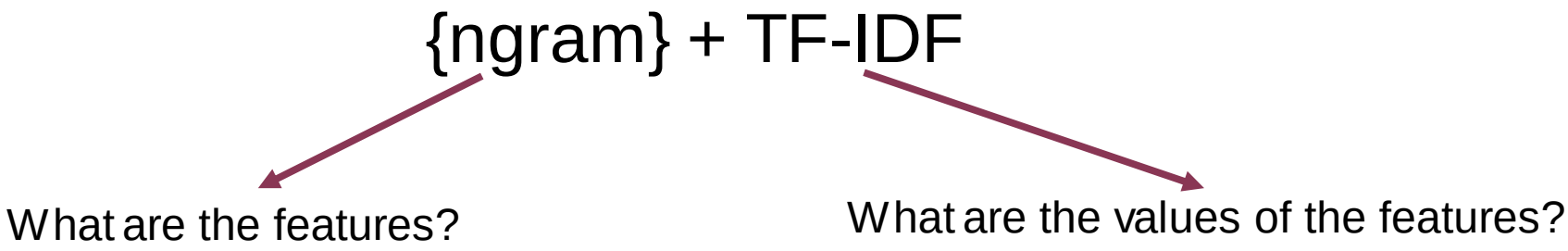
The Approach
Extracting features from free-text



The Approach
{ngram} + TF-IDF

{ngram}

1-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

{ngram}

1-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

{ngram}

1-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

{ngram}

2-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

{ngram}

2-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

{ngram}

3-gram

A3936/17 NOTAMR A0537/16 Q)ENOR/QNXAW/V/B/A/000/999/6829N01641E005 A)ENEV B)1710301454 C)PERM E)VDF 120.100 MHZ WITHDRAWN REF AIP NORWAY AD 2 ENEV 4-3, 4-7, 4-11, 4-13 AND 4-15, SID AND STAR CHARTS DATED 29 MAY 2014, AD 2 ENEV 5-7, 5-9 AND 5-10, INSTRUMENT APPROACH CHARTS DATED 30 MAR 2017.

The Approach
{ngram} + TF-IDF

$$f_{t,d} = \frac{number\ of\ occurences\ in\ message}{number\ of\ terms\ in\ message}$$: Term Frequency

$$idf_t = \log(\frac{number\ of\ messages}{number\ of\ messages\ where\ term\ appears})$$: Inverse Document Frequency

$$w_{t,d} = f_{t,d} * idf_t$$: Overall Importance

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The Approach
Feature Engineering – Expert Intuition

What information can we include that is accounted for by experts?

The Approach
Feature Engineering – Expert Intuition

What information can we include that is accounted for by experts?

- How close is the NOTAM center to an airport we operate?

  Feature: closestDestAirportDistance

- How close is the NOTAM center to an alternate airport?

  Feature: closestAltAirportDistance

- How long is the free text portion of the NOTAM?

  Feature: freeTextSize

SWISS

The Approach

Feature Collection

Feature matrix:

- 16 features from structured section
- 3 engineered features
- 200 ngram features

Label from historical data of messages that were/ weren‘t suppressed (0/1)

```
 [1] "flmin"                       "flmax"                                   "lat_rad"                          "long_rad"                        "rad"
 [6] "nat_N"                       "traffic_ifr"                             "traffic_vfr"                      "traffic_checklist"               "purp_N"
[11] "purp_B"                      "purp_O"                                  "purp_M"                           "scope_A"                         "scope_E"
[16] "scope_W"                     "closestDestAirportDistance"              "closestAltAirportDistance"        "freeTextSize"                    "<coordinate> "
[21] "<coordinate> <coordinate> "  "<coordinate> <coordinate> <coordinate> " "<distance> "                      "<distance> ABOVE "               "<distance> ABOVE GROUND "
[26] "<distance> RADIUS "          "<flightlevel> "                          "<flightlevel> <flightlevel> "     "<frequency> "                    "<height> "
[31] "<number> "                   "<number> <number> "                      "<number> <number> <number> "      "<number> <number> PCT "          "<number> PCT "
[36] "<number> PCT WET "           "<runway> "                               "<runway> <number> "               "<runway> <number> <number> "     "<runway> CLOSED "
[41] "ABOVE "                      "ABOVE GROUND "                           "ABOVE GROUND LEVEL "              "ACTIVATED "                      "ACTIVATED AIRSPACE "
[46] "ACTIVATED AIRSPACE CLOSED "  "ACTIVATED TEMPORARY "                    "ACTIVE "                          "AERODROME "                      "AIP "
```

...

```
[166] "RAIM "                "RANGE "                          "REF "                              "REF AIP "                              "REMARK "
[171] "RESTRICTED "          "RESTRICTED AREA "                "RESTRICTED AREA ACTIVATED "        "ROUTE "                                "RUNWAY "
[176] "RUNWAY <runway> "     "RUNWAY <runway> <number> "       "RUNWAY CLOSED "                    "RUNWAY CLOSED <runway> "               "SERVICE "
[181] "SERVICE NOW "         "SIDE "                           "SOUTH "                            "SURFACE "                              "SURFACE <flightlevel> "
[186] "SURFACE <height> "    "SYSTEM "                         "SYSTEM <runway> "                  "SYSTEM UNSERVICEABLE "                 "TAKE "
[191] "TAKE PLACE "          "TAXIWAY "                        "TAXIWAY CLOSED "                   "TAXIWAY CLOSED TAXIWAY "               "TAXIWAY TAXIWAY "
[196] "TEMPORARY "           "TEMPORARY RESTRICTED "           "TEMPORARY RESTRICTED AREA "        "TOWER "                                "TRAFFIC "
[201] "UNSERVICEABLE "       "UNSERVICEABLE <runway> "         "UNSERVICEABLE INSTRUMENT "         "UNSERVICEABLE INSTRUMENT LANDING "     "VHF "
[206] "VHF OMNI "            "VHF OMNI DIRECTIONAL "           "WET "                              "WET OBSERVATION "                      "WET OBSERVATION <number> "
[211] "WILL "                "WILL TAKE "                      "WILL TAKE PLACE "                  "WIP "                                  "WITHIN "
[216] "WITHIN <distance> "   "WITHIN AREA "                    "WORK "                             "WORK PROGRESS "
```

The Approach
Model Training

Model training:

```
xgbparams <- list(booster = "gbtree",
                  silent = 0,
                  eta = 0.3,
                  max_depth = 10,
                  subsample = 0.5,
                  objective = "binary:logistic",
                  nthread = 4)
```

```
bst_model <- xgb.train(params = xgbparams,
                       data = dtrain,
                       nround = 150,
                       early_stopping_rounds = 5)
```

{xgboost}

~ 10min training time (laptop)

SWISS

The Results

The Results
Model – Feature Importance

```
model <- xgb.dump(bst_model, with_stats = TRUE)

feature_names <- dimnames(dtrain)[[2]]

importance_matrix <- xgb.importance(feature_names, model = bst_model)

xgb.plot.importance(importance_matrix[0:20])
```


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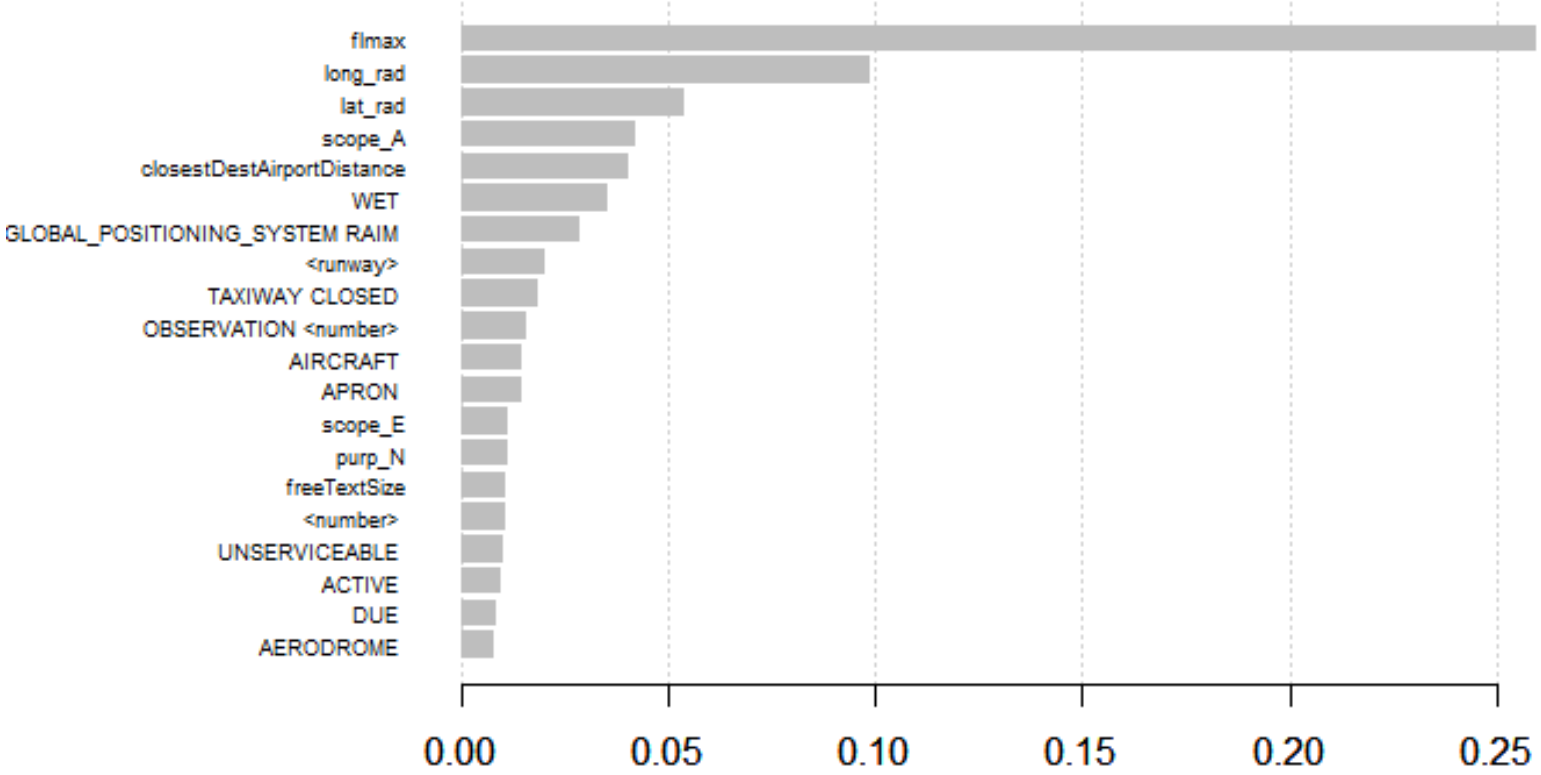
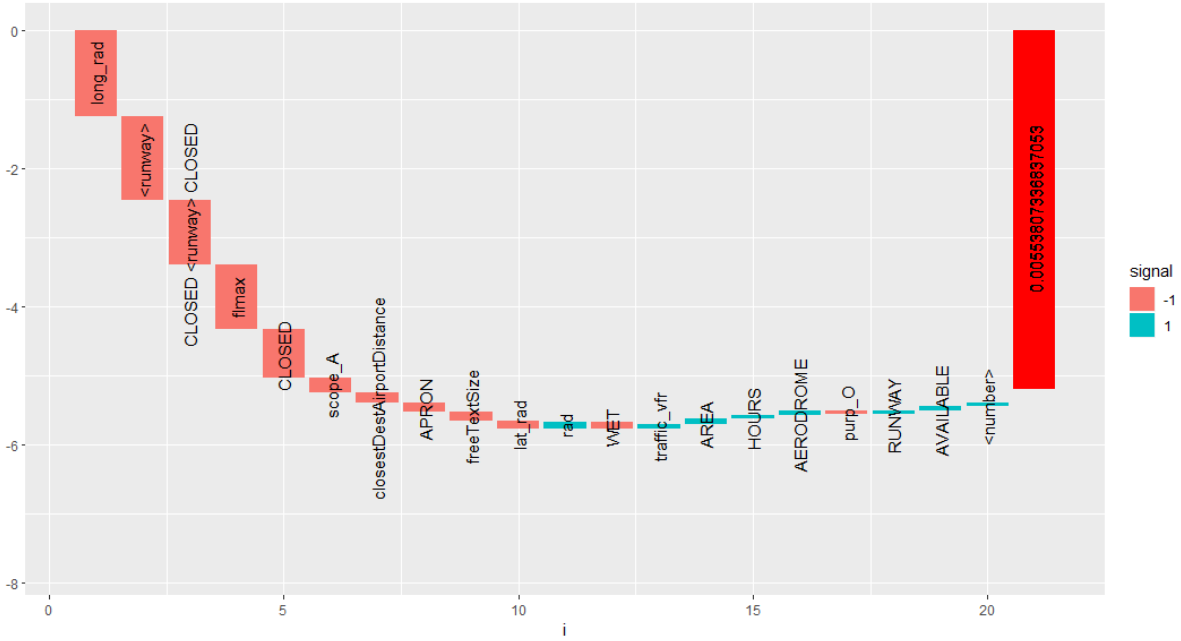
The Results
Model – Feature Importance



The Results
Model – Feature Importance on one item



The Results
Model – Prediction

Prediction on Test Dataset:

```
pred <- predict(bst_model, dtest)

pred.resp <- ifelse(pred > 0.5,1,0)
```

{stats}

SWISS

The Results
Model – Accuracy

```
               Accuracy : 0.9413
                 95% CI : (0.9403, 0.9422)
    No Information Rate : 0.5501
    P-Value [Acc > NIR] : < 2.2e-16
```


SWISS

The Results
Model – Confusion Matrix

```
               Accuracy : 0.9413
                 95% CI : (0.9403, 0.9422)
No Information Rate : 0.5501
P-Value [Acc > NIR] : < 2.2e-16
```

How good is this really?

SWISS

The Results
Model – Confusion Matrix

```
               Accuracy : 0.9413
                 95% CI : (0.9403, 0.9422)
    No Information Rate : 0.5501
    P-Value [Acc > NIR] : < 2.2e-16
```

```
   Confusion Matrix and Statistics

             Reference
   Prediction      0      1
            0 120477   7781
            1   5690  95385
```


SWISS

The Results
Model – Confusion Matrix

```
               Accuracy : 0.9413
                 95% CI : (0.9403, 0.9422)
    No Information Rate : 0.5501
    P-Value [Acc > NIR] : < 2.2e-16
```

```
Confusion Matrix and Statistics

          Reference
Prediction      0      1
         0 120477   7781
         1   5690  95385
```

Potentially not important information being shown

SWISS

The Results
Model – Confusion Matrix

```
               Accuracy : 0.9413
                 95% CI : (0.9403, 0.9422)
    No Information Rate : 0.5501
    P-Value [Acc > NIR] : < 2.2e-16
```

```
Confusion Matrix and Statistics

          Reference
Prediction      0      1
         0 120477   7781
         1   5690  95385
```

Potentially important information being hidden

Potentially not important information being shown

SWISS

The Results
Model – Deeper Analysis

The Results
Model – Deeper Analysis

What to discuss with demo:

- How probabilities are distributed
- How, dividing by bins of probabilities, we can achieve greater accuracies
- How, choosing the bins of greater accuracy,

we can reduce rather than eliminate the workload (3 piles suggestion)

The Results
Model – Demo

What to discuss with demo:

- How accuracy within clusters differs (pure clusters – candidates for automization)
- Point out how types of clusters may be characteristic of certain geographical areas
- Point out how the clustering can bring insight to how people group messages instinctively (bring the user's learning to the paper)

Gradient Boosted Trees - Classification Distribution

- [x] Left Hand
- [x] Right Hand

Width of bins:

0.05

Number of left bins:

1

Left hand NOTAM removal:

Percentage of NOTAMs removed: 40.11
Accuracy of removal of NOTAMs: 98.92

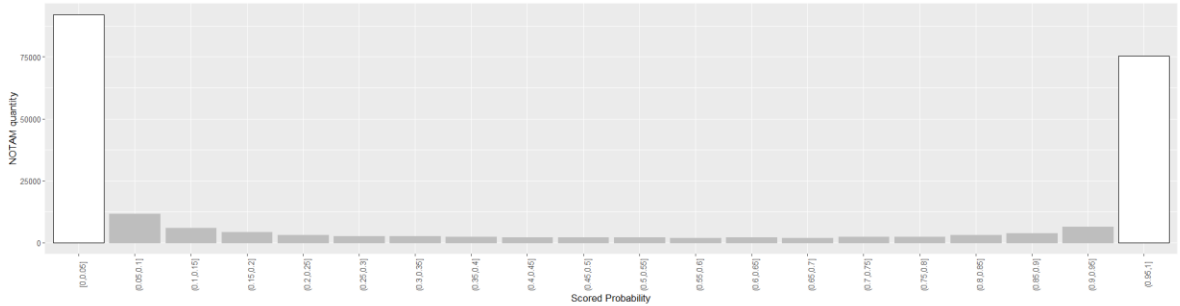
Right hand NOTAM removal:

Percentage of NOTAMs removed: 32.87
Accuracy of removal of NOTAMs: 99.32

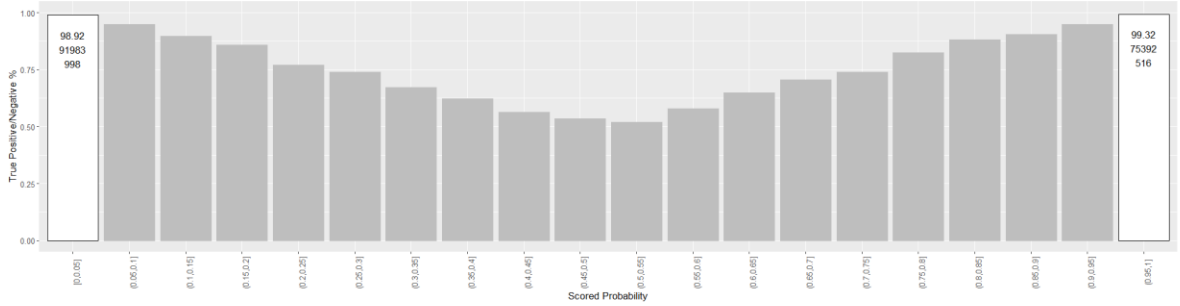
Overall NOTAM removal:

72.98

Probability distribution of test data



Accuracy distribution of test data

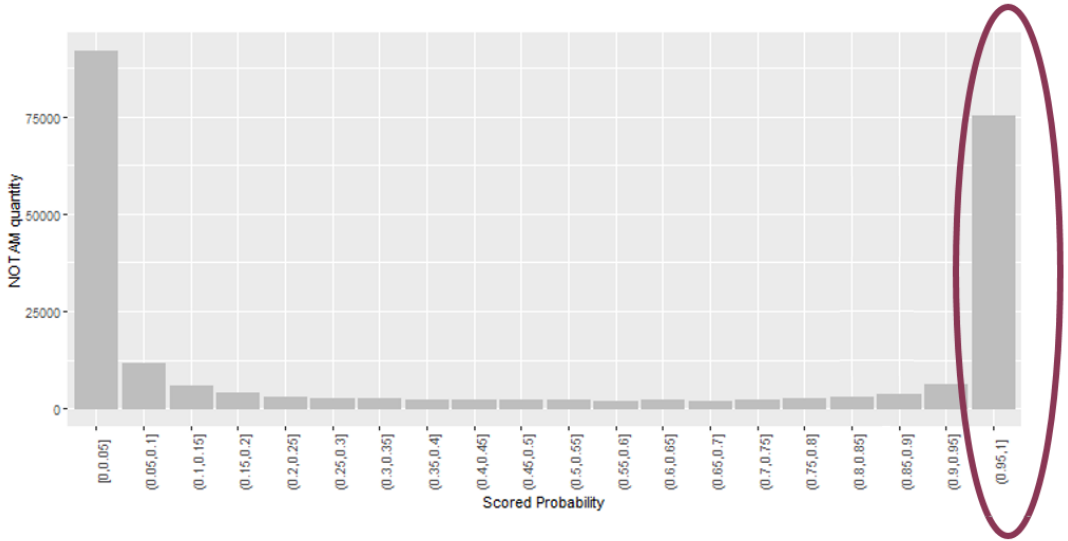


Conclusions:

- Maybe there isn't "sufficient" accuracy that justifies automatically throwing out messages.
- We can instead suggest if a message should be suppressed by pre-classifying.
- We have a large number of messages either automated or "pre-classified", leaving more time to evaluate other, more ambiguous messages

SWISS

The Results
Model – Deeper Analysis



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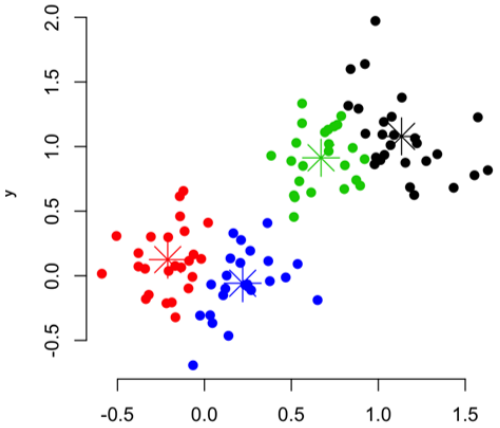


kmeans {stats}

SWISS

NOTAM ML | Classifier | Clustering - 1 | Clustering - 2 | Summary | Last

Precision of selected cluster: 99.45 %

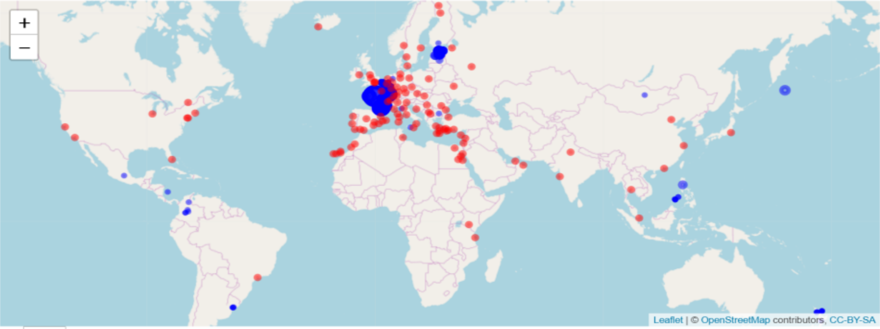
Cluster Selection

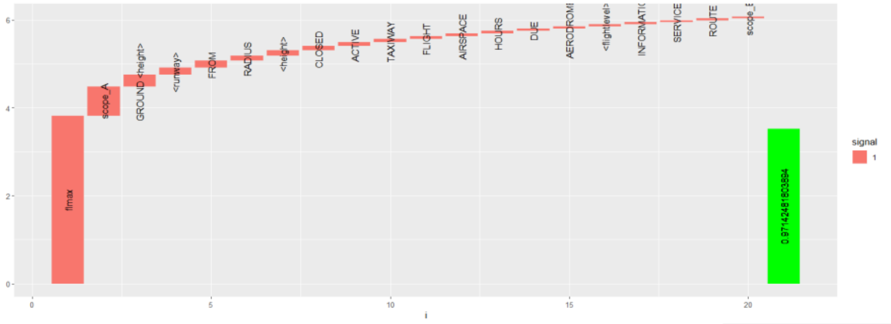
10

Show only mismatches

Item ID for explanation

4085635





Show 10 entries

Search:

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The Summary

- Current state: the challenge of **how to implement**
- Within this context **full automation is not advisable**
- However, **supervised** and **unsupervised ML** can both provide valuable **insights** as well as **assistance in decision making**

Thank you

Questions?