ITU KALEIDOSCOPE
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Machine learning for a 5G future

Message Collision Identification Approach Using Machine Learning

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Introduction

ITU Context

- Extend terrestrial ADS-B coverage with LEO satellites.
- Inclusion to the WRC-19 Agenda.

ADS-B Messages

- Message collisions in highly congested areas.

Purpose of this study

Use of machine learning to estimate collisions

Detection Problem

$$\begin{cases} \omega_0 : x = b & \longrightarrow hypothesis: noise \\ \omega_1 : x = b + s & \longrightarrow hypothesis: identifiable\ signal \end{cases}$$

- The general detection problem

$$P_e(d) = p(d(X) \neq Y)$$

- Minimize the error probability

$$\begin{cases} H_0 : X \in \omega_0, & X \sim p(X|\omega_0) \\ H_1 : X \in \omega_1, & X \sim p(X|\omega_1) \end{cases}$$

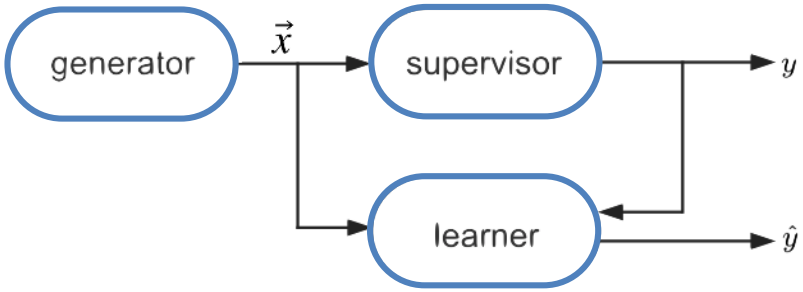
- A dataset obtained by sampling is compared against a synthetic dataset from an idealized model.
- The distribution of the random proces X has to be known to use the former method.

Machine Learning

- A learning system that use past data to infer new solutions
- Supervised ML
- Classification Problem
- SVM and kNN

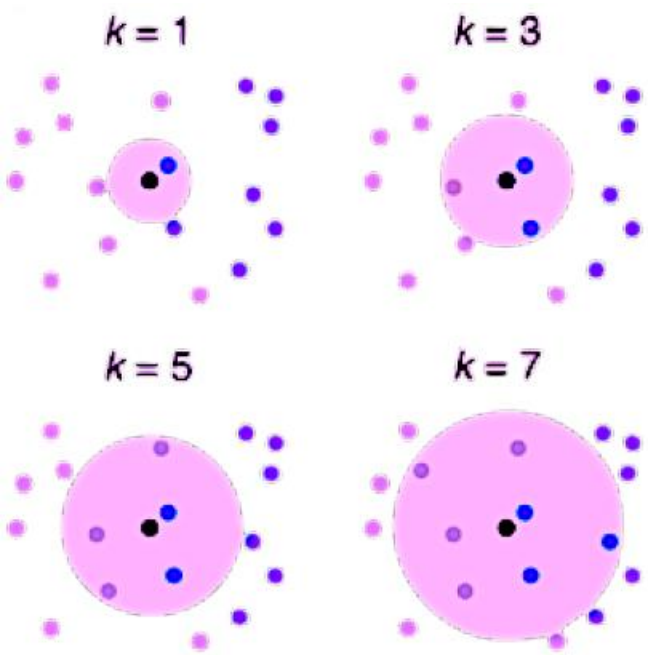
Features Extraction

- Derived information from the input data relevant to the problem
- Make algorithms more efficient

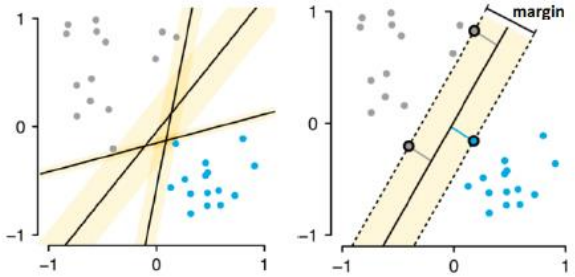


ML Methods

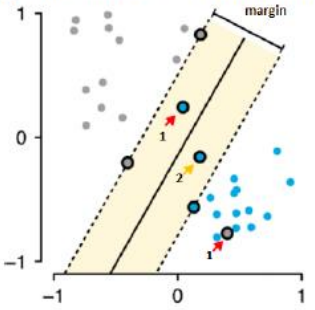
K-Nearest Neighbors



Support Vector Machine



(a) Linearly separable classes. (b) Maximum margin.



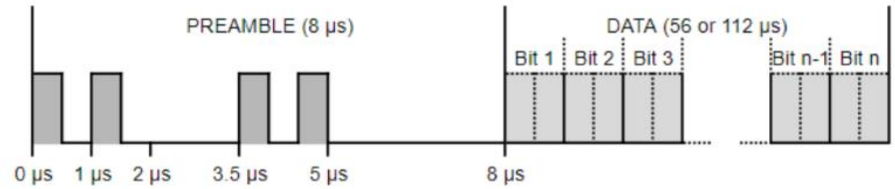
(c) Margin violation and misclassification.

Training Simulator

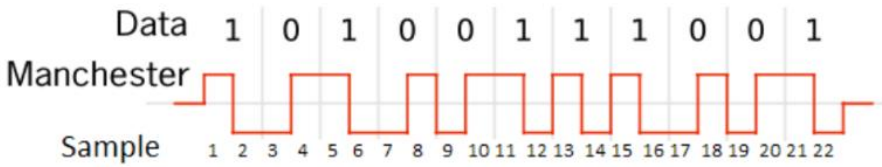
Models the input data → Generator

Labels the input data → Supervisor

ADS-B Messages



- Duration of 120 µs
- Random periodicity with mean of 161 ms
- Manchester-coded
    - Two sates per bit



Signal Generator & Supervisor

Scenario

- LEO satellite orbiting at 400km.
- 1000 planes uniformly distributed in it's footprint.
- Specific gain for each aircraft-satellite channel.

Classification

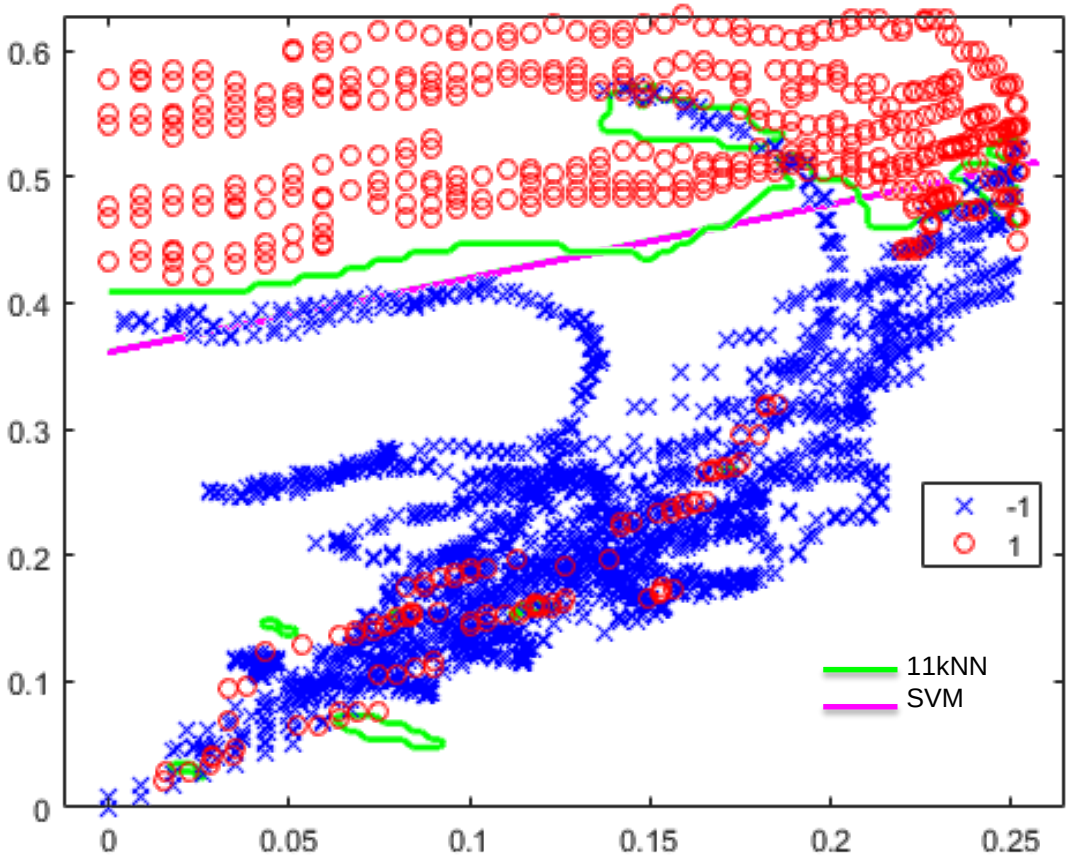
- Two classes defined
  - It is possible to decodify
  - It is not possible to decodify
- Depends on
  - Message collisions
  - Received power above receiver's sensitivity

ADS-B Signal Features Extraction

Feature Vector

- Samples of the same length.
- The means of consecutive pair of samples.
- The variance of each set was calculated.
- The greatest and the smallest value were the two chosen features.
- The vector X was generated with the value of the two features for each sample.

ML Classification



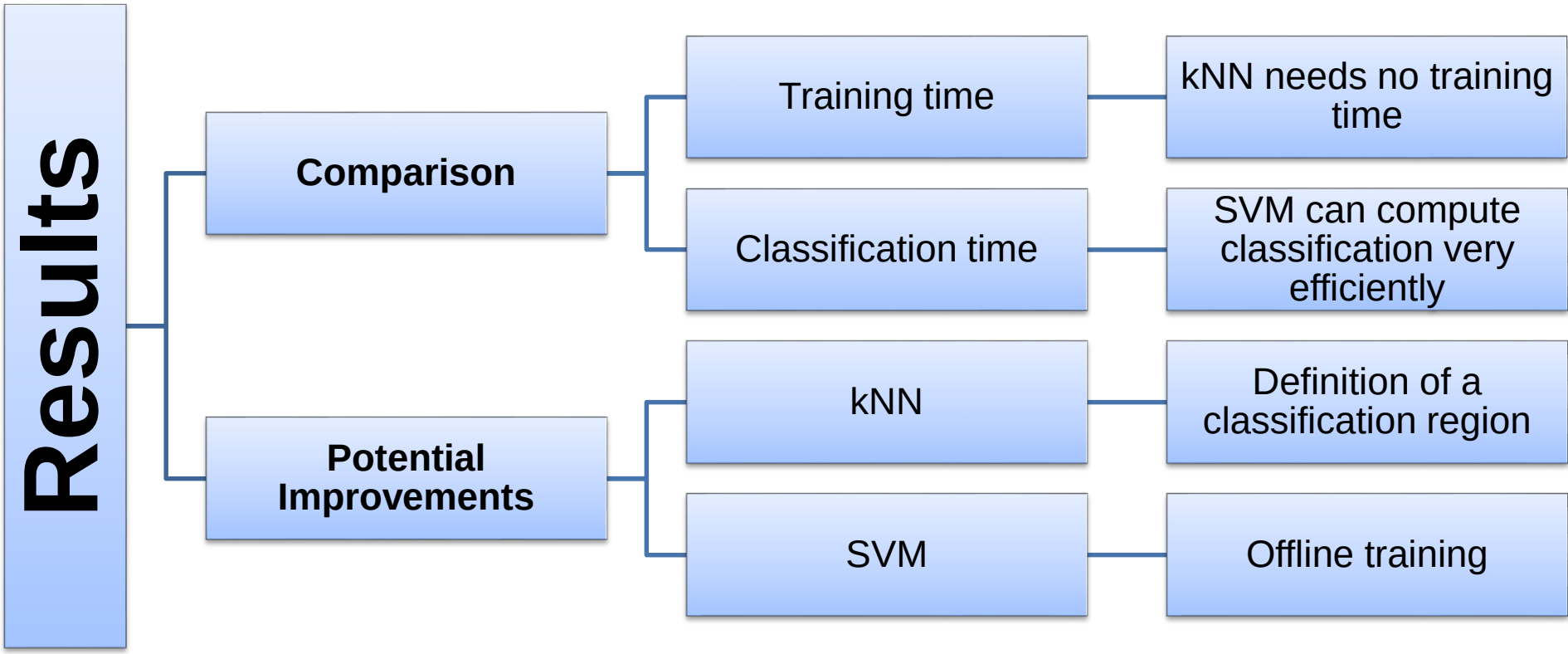
kNN Performance

- $P_e = 0.059$

SVM Performance

- $P_e = 0.049$

Results


Results
Comparison
Potential Improvements
Training time
Classification time
kNN
SVM
kNN needs no training time
SVM can compute classification very efficiently
Definition of a classification region
Offline training

Conclusions

Future Work

- Improvements in signal modeling.
- Improvements in feature extraction.
- Experimental tests.
- Evaluation of reduction of energy due to improvement in efficiency.
- Work on development of International Recommendations.

Conclusions

Potential Impact

- Using ML can increase overall efficiency.
  - The lifespan of satellites could be improved.
  - Launch costs could be significantly lower.
- Including details of useful ML techniques in International Recommendations could benefit all stackeholders.
- ML is an enabler of a new real-time global flight tracking system.
  - Impact in the safety, ecology and costs of flights.

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Thank you