Should I stay or should I go?

Machine Learning applied to Conjunction Analysis

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Agenda

• Introduction
• Objectives
• Risk level change prediction
• State vector propagation improvement
• Conclusions
Introduction

• Crowded LEO environment
  • Increase of close approach events frequency
• S3TOC research activities for resource optimization
• Research aimed at reducing time devoted to conjunction analysis
• Two independent studies are proposed:
  • Risk level change prediction
  • State vector propagation improvement
Objectives

- Explore the **applicability of ML** technologies to CA services
- **Improve** event monitoring **accuracy**
- **Accelerate** event resolution and **decrease** operator **workload**
Risk level change prediction
Description

INFO → ALERT → ALERT → WARNING → INFO

CDM₁ → CDM₂ → CDM₃ → CDM₄ → CDM₅ → TCA
Objective

- Predict the probability of the CA event changing its risk level in the future
• 1.8 million CDMs
• Median of 8 CDMs per event
• From May 2017 to Nov 2021
Dataset: 19 features

- a, e, i of P/S
- Time to TCA
- Area P/S
- CDM originator
- Operational status P/S
Dataset: 19 features

- Angle P and S orbital planes
- Miss distance
- Relative speed
- Covariance in B-plane
- Angle pos. and vel.
Methodology

• Ensemble learning based on decision trees:
  – Random forest (RF), Extremely randomized trees (ERT), gradient boosting (GB)
• Robust scaling based on interquartile range (IQR)
• Unbalanced dataset → upsampling for training set
• Test set: from March 2021 to Nov 2021 (24%)

• Automatic hyperparameter search → LightGBM
Results
State vector propagation improvement
Objective

• Apply a correction to a propagated state.
• Each CDM contains the state at TCA.
• The algorithm generates a correction.
Dataset

- ~150,000 CDMs from EUSST O/O users
- Only secondary objects
- Primaries on polar orbits
Methodology

- Single CDM approach
- State vector of last CDM as true value
- Inputs from CDM + F10.7 index
- Feedforward deep neural network
Methodology

- State vector in last CDM ($A_2$) propagated to TCA of input CDM ($TCA_1$)
Results

• Results are tested on 30% of the data

• The error of the corrected value is projected to a RTN reference frame

• Results are compared against a baseline

• Baseline is best knowledge at prediction time (i.e., no correction)
Results

Mean Absolute Error Values - R Position Component (km)

Mean Absolute Error Values - T Position Component (km)

Relative Improvement of the ML model (%) - R Position Component (km)

Relative Improvement of the ML model (%) - T Position Component (km)
Results
Results

Mean Absolute Error Values - T Velocity Component (km/s)

- ML Model
- Classical Propagator

Mean Absolute Error Values - N Velocity Component (km/s)

- ML Model
- Classical Propagator

Relative Improvement of the ML model (%) - T Velocity Component (km/s)

Relative Improvement of the ML model (%) - N Velocity Component (km/s)
Conclusions

• Machine learning can provide meaningful value to SSA operations
• Applicability has been proven and both tasks tackled successfully in research activities with actual operational data

• Continued deployment must be closely monitored
• Additional studies outside the used dataset are required
THANK YOU VERY MUCH!

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