Mooring Integrity User Group

Mooring Line failure Detection in the Absence of Load Monitoring

SS Rotterdam
June 16, 2022
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Motivation

- Regulatory compliance (e.g. ABS Position mooring systems – May 2020)

> **9.1 Mooring Line Failure Detection**
>
> Where required, the design of the mooring system is to include suitable arrangements and/or equipment for the crew to periodically verify that each mooring leg remains intact. Suitable arrangements might include, but are not necessarily limited to, mooring line load monitoring arrangements, inclinometers, laser measuring devices, excursion monitoring systems (GPS), and submersible cameras. Noting that these arrangements will have to operate for the life of the vessel, the design should take into account:

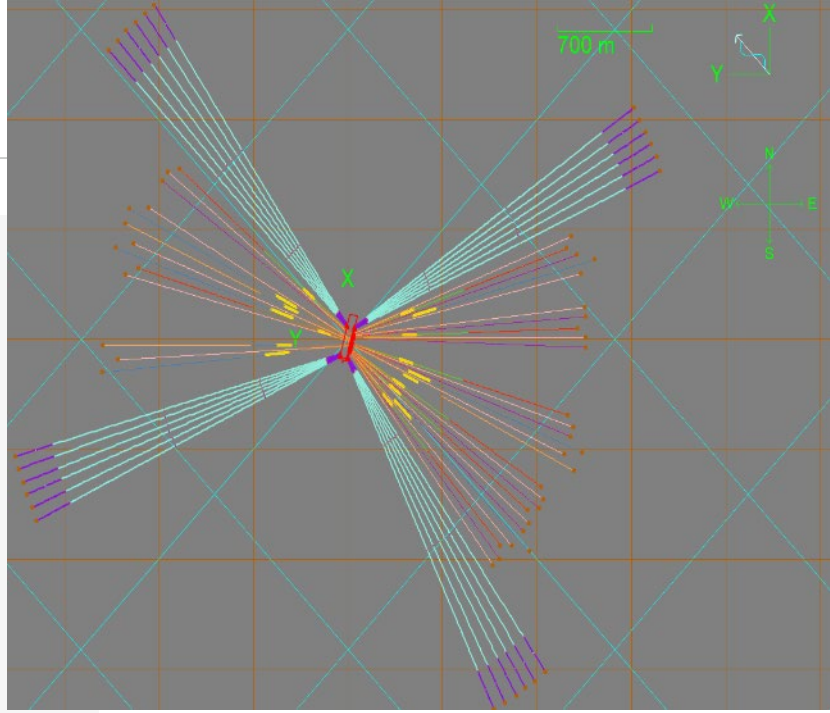
- Anchor Line Load Monitoring Systems (ALLMS) notorious for not functioning over FPSO design life
- Alternative approach to mooring integrity needed
- Data Science techniques available…
- Could an Intelligent Agent (IA) be developed?

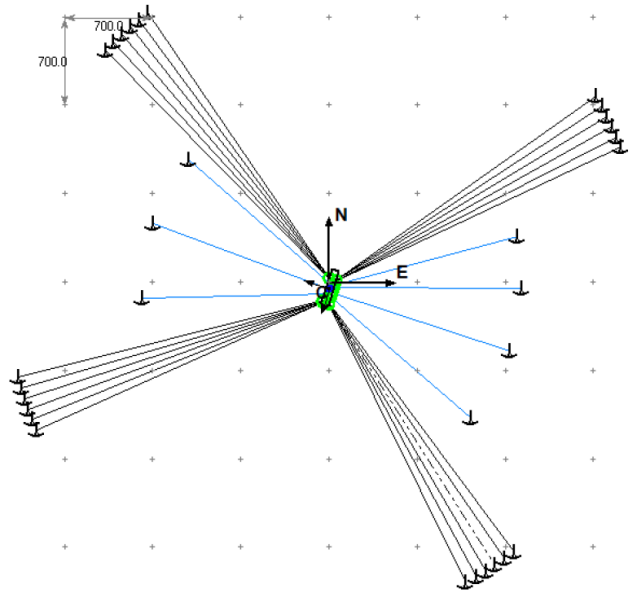
Content

- Use case description
- Training dataset
- IA model description
- IA model validation
- New Technology Qualification
- Conclusions

Use case description

- Offshore Brazil - Santos Basin
- 2100m water depth
- FPSO Cidade de Saquarema (Converted VLCC)
- Spread moored
- 4 bundles of 6 mooring lines each (24 lines)
- 2° between adjacent lines
- Chain-polyester-chain
- 45 risers





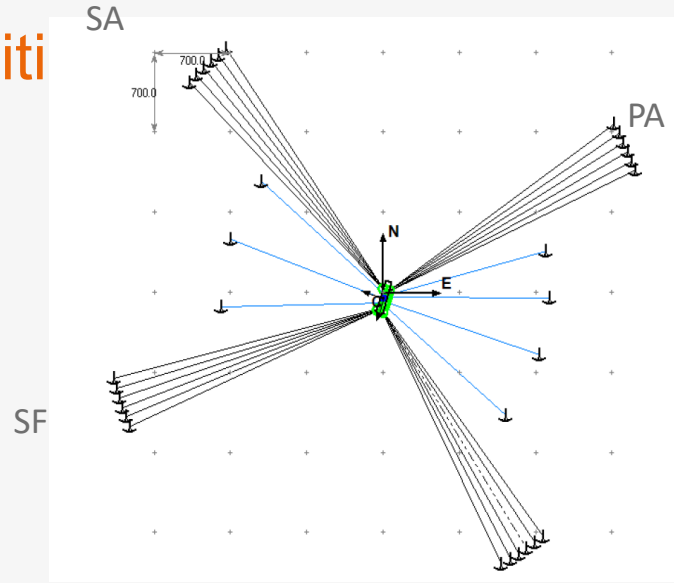
24+45=69 tension members !

Training dataset

- IA trained with a large set of representative scenarios
- Numerical approach selected
- Metocean conditions:
  - Waves: Hs in [1m; 4m] & Tp in [6s; 15s]
  - Wind: 1-hour average speed in [2m/s; 15m/s]
  - Current: surface speed in [0.05m/s; 1.0m/s]
  - Collinear waves, wind and current
  - Direction in [0deg; 360deg]
  - Randomly select 10,000 sets of metocean conditions

Training dataset (cont)

- Randomly selected 10,000 metocean conditi
- 3 FPSO loading conditions
- 3-hour time domain simulations performed
- 5 mooring system conditions
  - Intact
  - SA4 broken
  - PA4 broken
  - SF3 broken
  - PF3 broken
- In total: 10,000 (metocean)*3(drafts)*5(moorings)=150,000 simulations

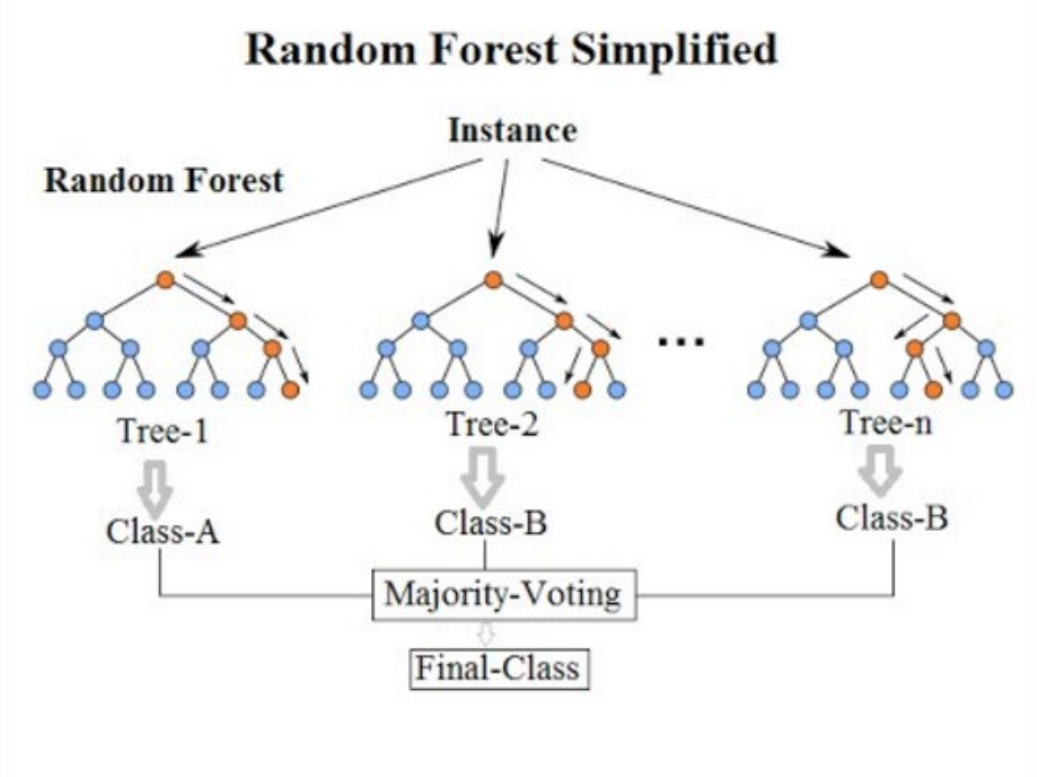


Training dataset (cont)

- Simulation output → FPSO position in horizontal plane
  - Amidships Easting
  - Amidships Northing
  - Heading
- Feature definition
  - Standard statistical properties of 3-hour time series
  - Wind speed

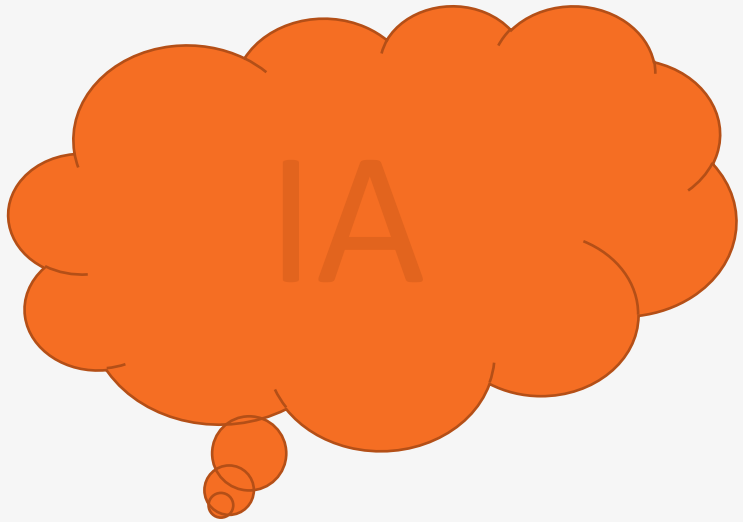
IA model description

- Random forest algorithm : meta estimator fits decision tree classifiers on sub-samples of training dataset

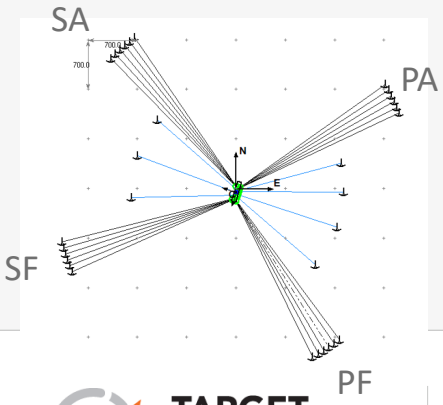


IA model description (cont)

- Features
  - #1
  - #2
  - #3
  - #4
  - ..

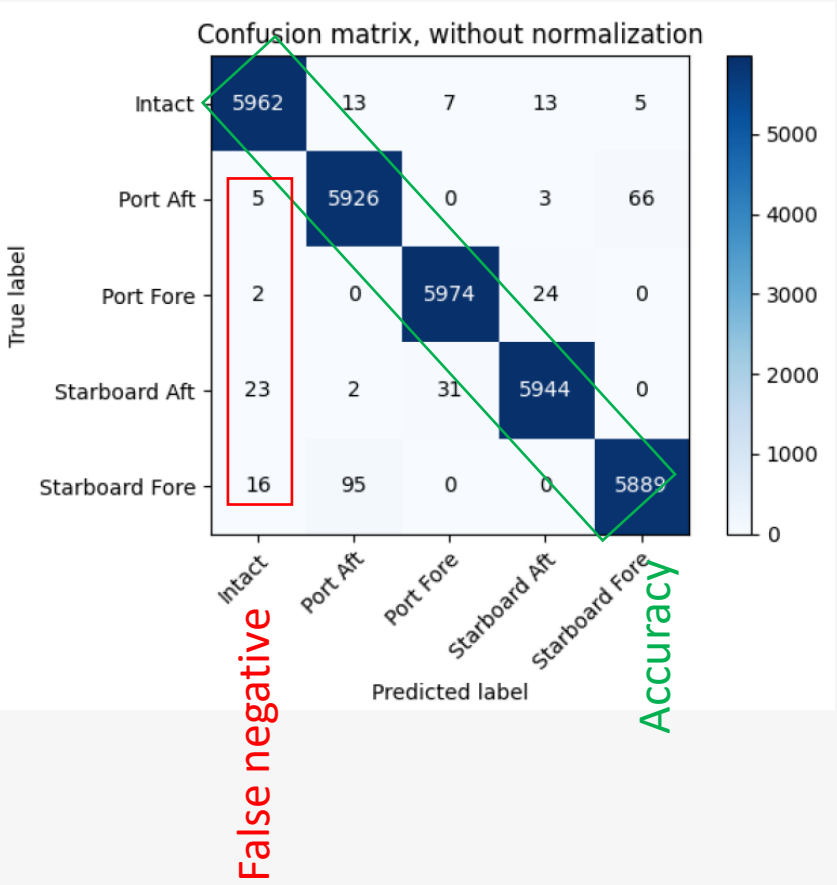


- Integrity status
  - Intact
  - PA impaired
  - PF impaired
  - SF impaired
  - SA impaired



IA model validation

- Training done on 80% of dataset (i.e. 120,000 cases)
- Validation on remaining 20% (i.e. 30,000 cases)
  - Confusion matrix computed
  - Accuracy: 98.98% i.e.
    (5962+5926+5974+5944+5889)/30000
  - False negative (*): 0.19% i.e. (5+2+23+16)/24000



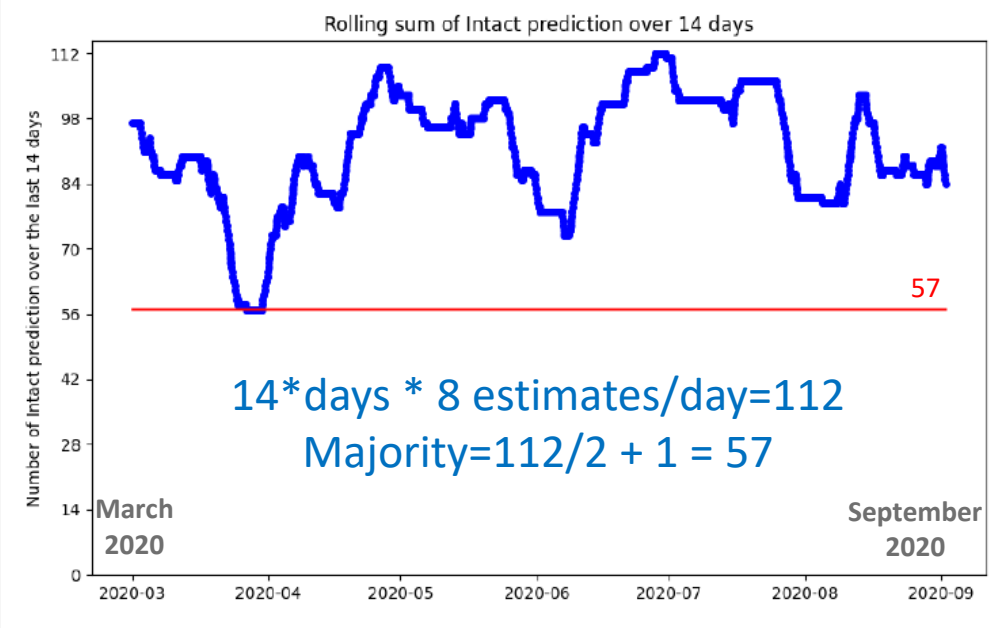
(*) IA meant to detect mooring line failures → Positive prediction means line failed

IA model validation (cont)

- 1st validation step performed with features from numerical simulations
- Ambition is to use features extracted from signals measured *in situ*
  - FPSO amidships position → DGPS system
  - FPSO heading → Gyroscope
  - Wind speed → Anemometer on deckhouse
- Challenges
  - Does metocean load case matrix represent sufficiently well Santos basin metocean conditions?
  - Does the numerical mooring model represent sufficiently well the as-installed station-keeping & riser systems?

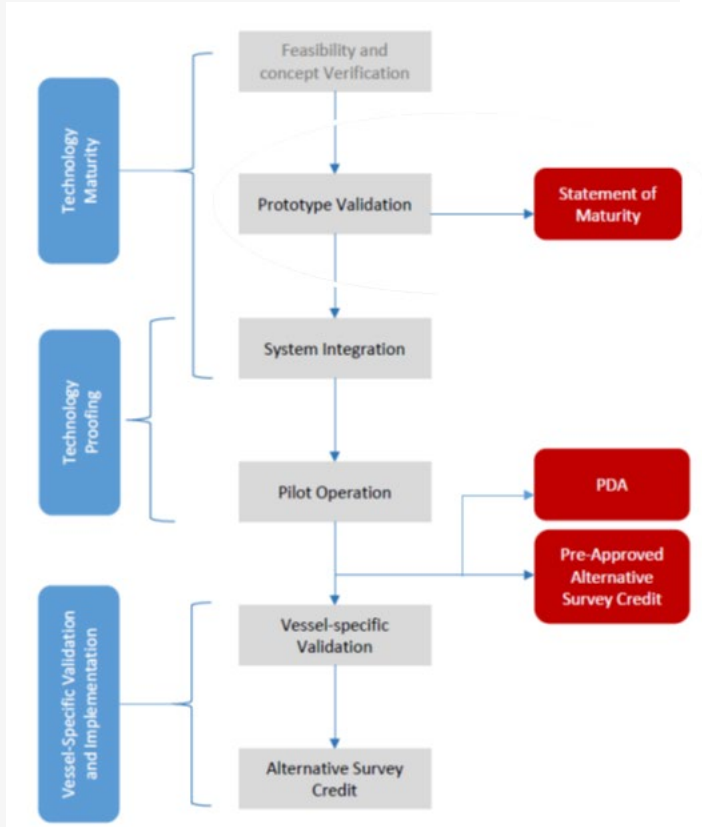
IA model validation (cont)

- 2nd validation step performed with features extracted from data measured *in situ*
- Period: March 2020 to September 2020
- Predictions performed at 3-hour intervals
- Majority vote performed over sliding elapsed fortnight
- 100% of majority votes → Intact



New Technology Qualification

- IA subjected to NTQ by ABS against:
  - ABS Guidance notes on Qualifying New Technology – April 2017
  - ABS Guide for Smart Functions for marine vessels and offshore units – July 2020
  - ABS Guide for Position Mooring – May 2020
- Product Design Assessment for IA awarded in Jan 2022



Conclusions

- Alternate means of assessing mooring system integrity status successfully developed using data science techniques
- IA subjected to NTQ process with ABS → PDA obtained in Jan 2022
- IA deployed on Cidade de Saquarema (Santos Basin – Brazil)
- Extension to other spread-moored units in Santos Basin under development

Questions ?

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See OMAE2022-79591- paper

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