

PREDICTING ROTATING MACHINERY FAILURE - A DATA SCIENCE JOURNEY

ABOUT ME AND TOUMETIS

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Challenges requiring creativity and problem solving

Real-life examples of:

- data
- approaches
- product



OFFSHORE PRODUCTION PLATFORM

Large structures with facilities to extract, store and process petroleum and natural gas which lie in rock formations beneath the seabed

About:

- Water depths up to 10,000ft (approx. 3,000m)
- Installation costs start from £150 million
- Example operation costs: £150k / day
—> £55 million / year

Problem setting can be transferred to other industrial domains



LOSS OF PRODUCTION

If machinery breaks: cost to replace + waiting time for replacement parts

Illustrative loss of production: £10M on repair and maintenance events

- £1M expected events
- £9M unexpected events





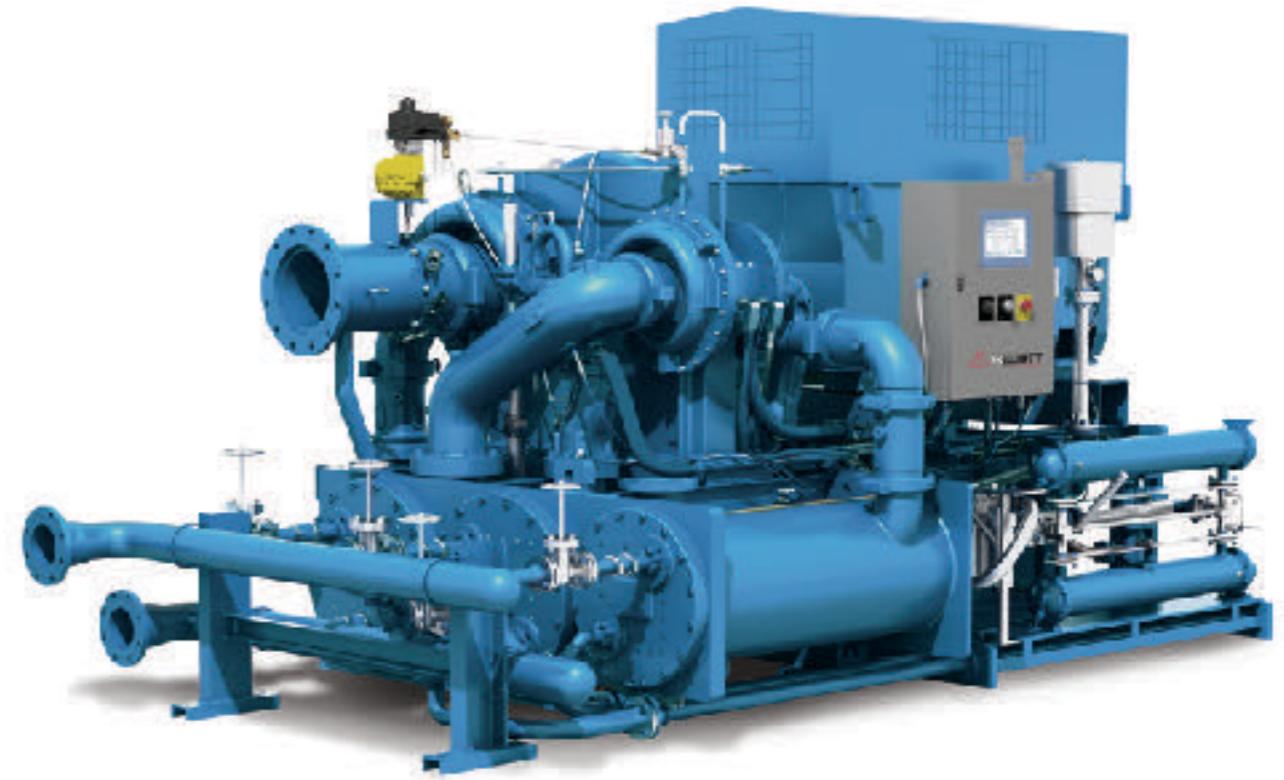
CENTRIFUGAL GAS COMPRESSOR

Two tasks:

- compress gas - for pipeline export
- re-injection - to support gas lift

Many components: seals, bearings, motor, ...

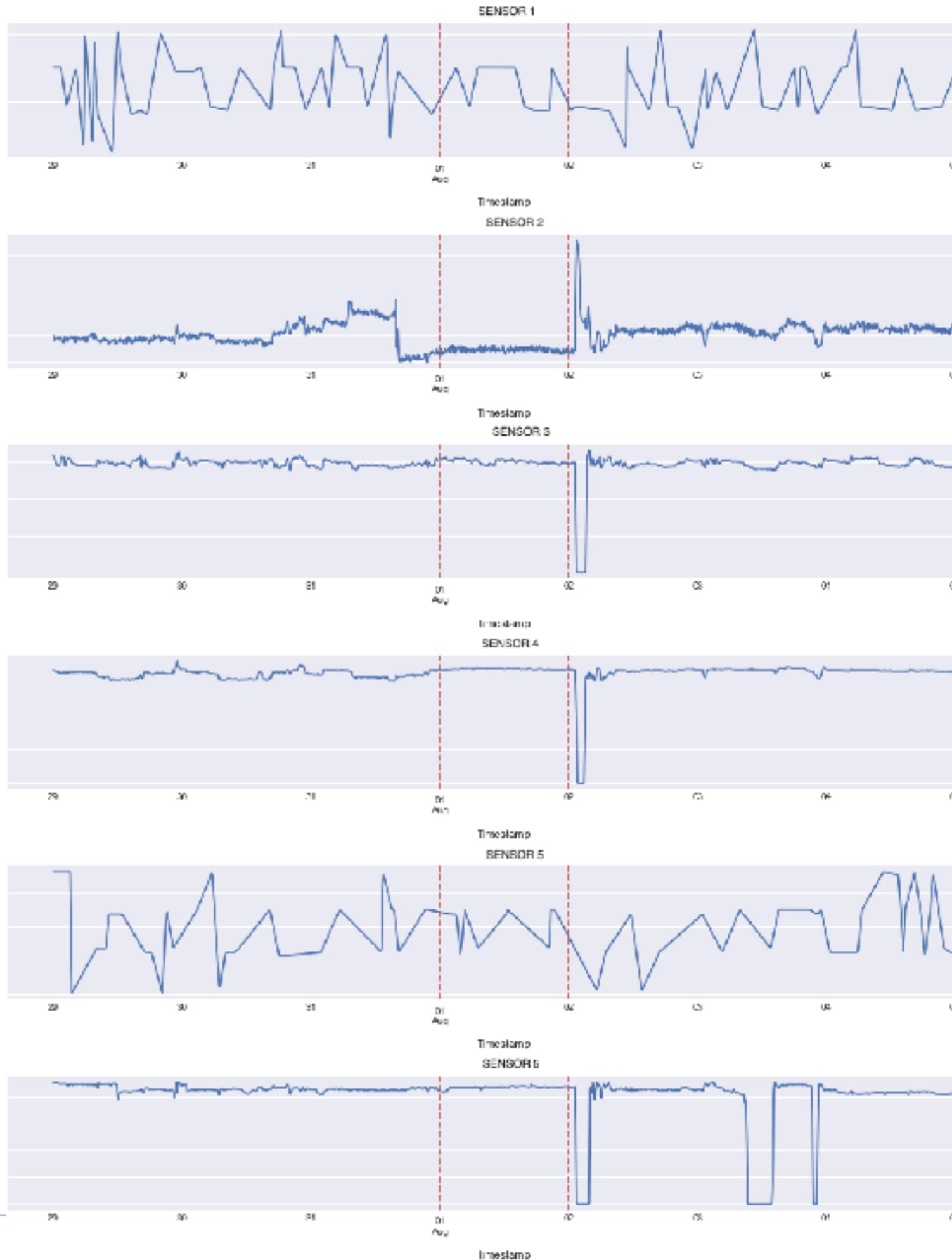
What to measure: uptime, downtime, vibration, throughput, ...



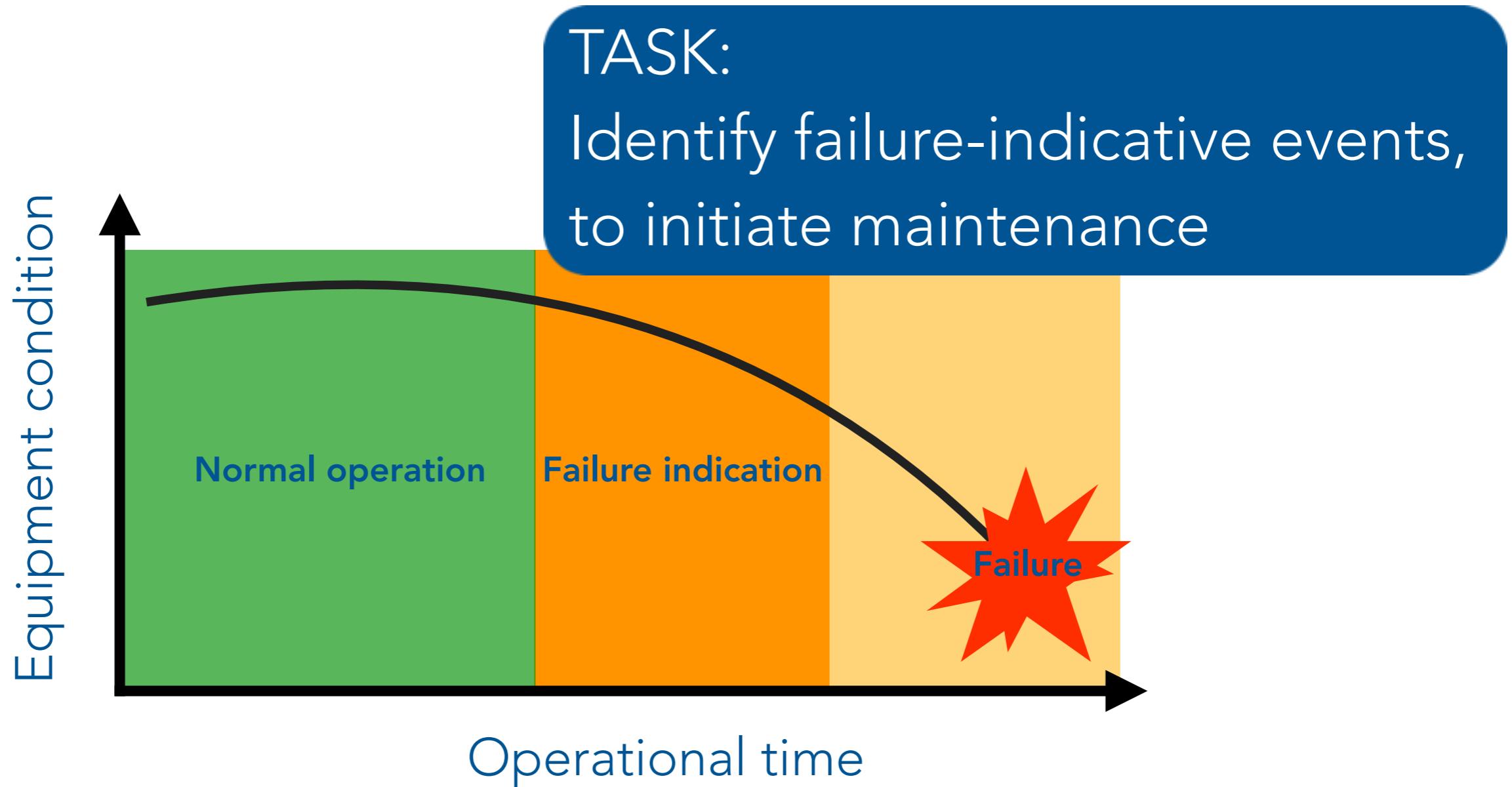
Source: <https://www.turbomachinerymag.com/cover-story-centrifugal-compressors/>

DATA

- Minute-wise sensor measurements
- Several years of data
- Meta-data (ranges, descriptions)
- Documented unexpected downtime with dates, descriptions and actions taken
- Work orders and planned system downtime

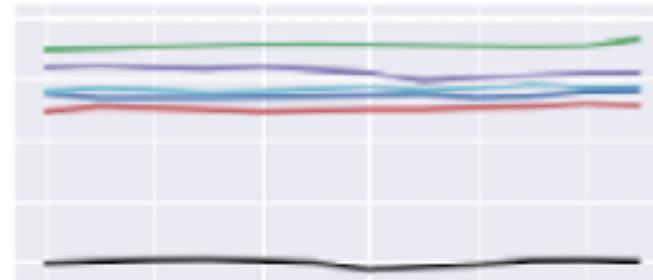


P-F CURVE (POINT OF DEFECT, FUNCTIONAL FAILURE)

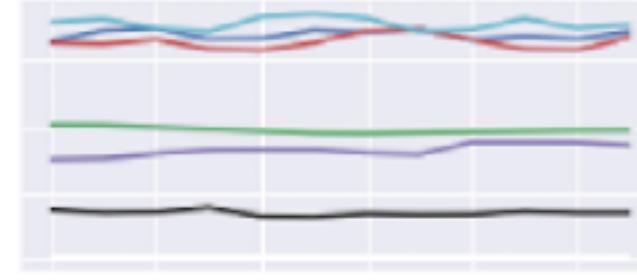


Illustrating equipment condition over time

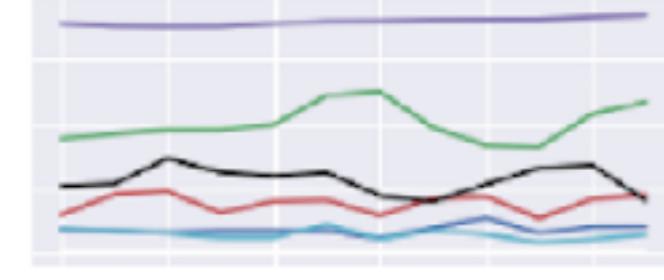
SUPERVISED MACHINE LEARNING



Normal



Normal



Failure-indicative

Supervised multivariate sequence classification problem

STEPS

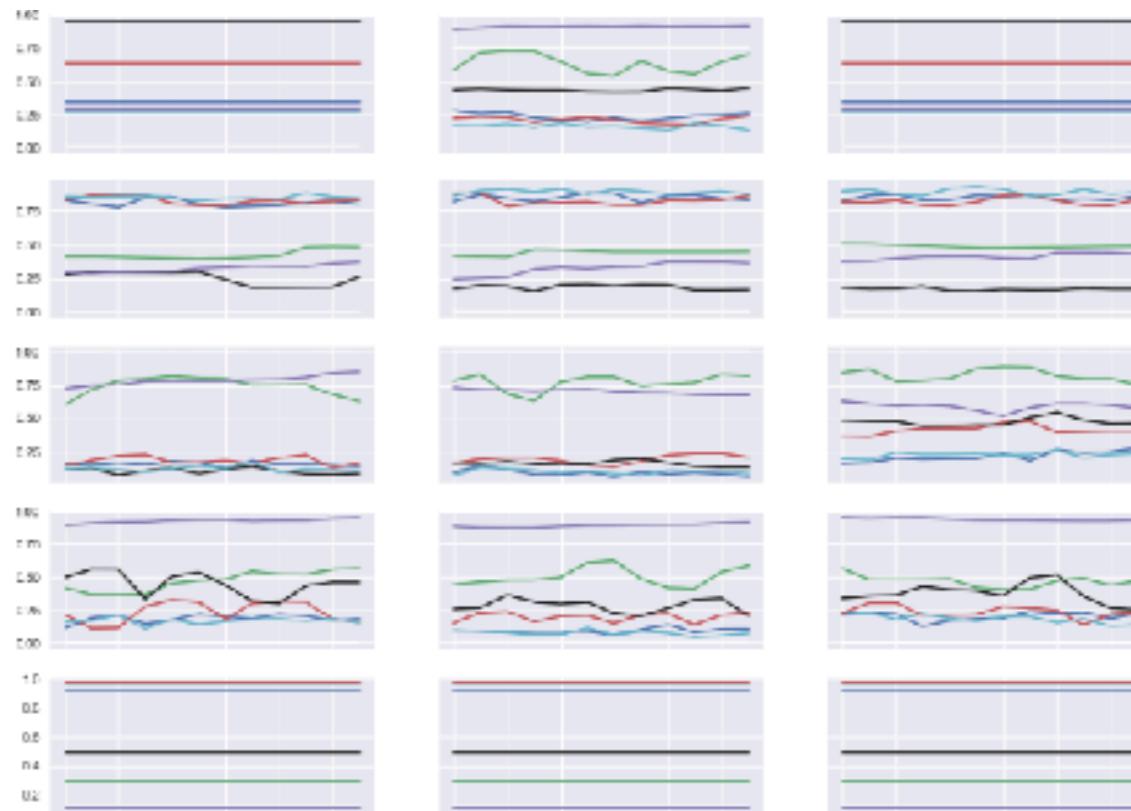
- Train a model to differentiate between time series data patterns in normal regions and in failure-indicative regions.
- Deploy model —> classify new sequences of data
- IF class == 'failure-indicative' —> create alert

LABELLING DATA

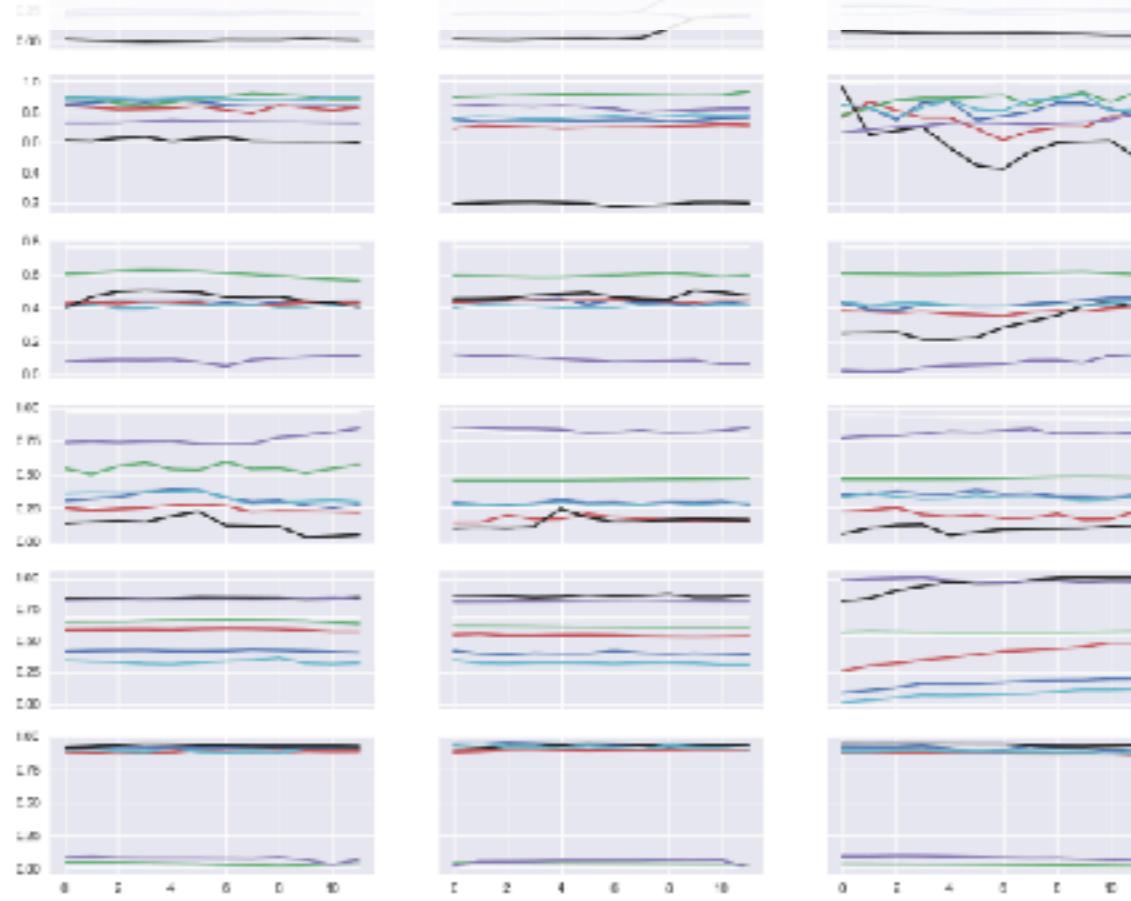
- Approach relies on having labelled data (normal vs. failure-indicative)
- Connect sensor measurements to technical events documentation







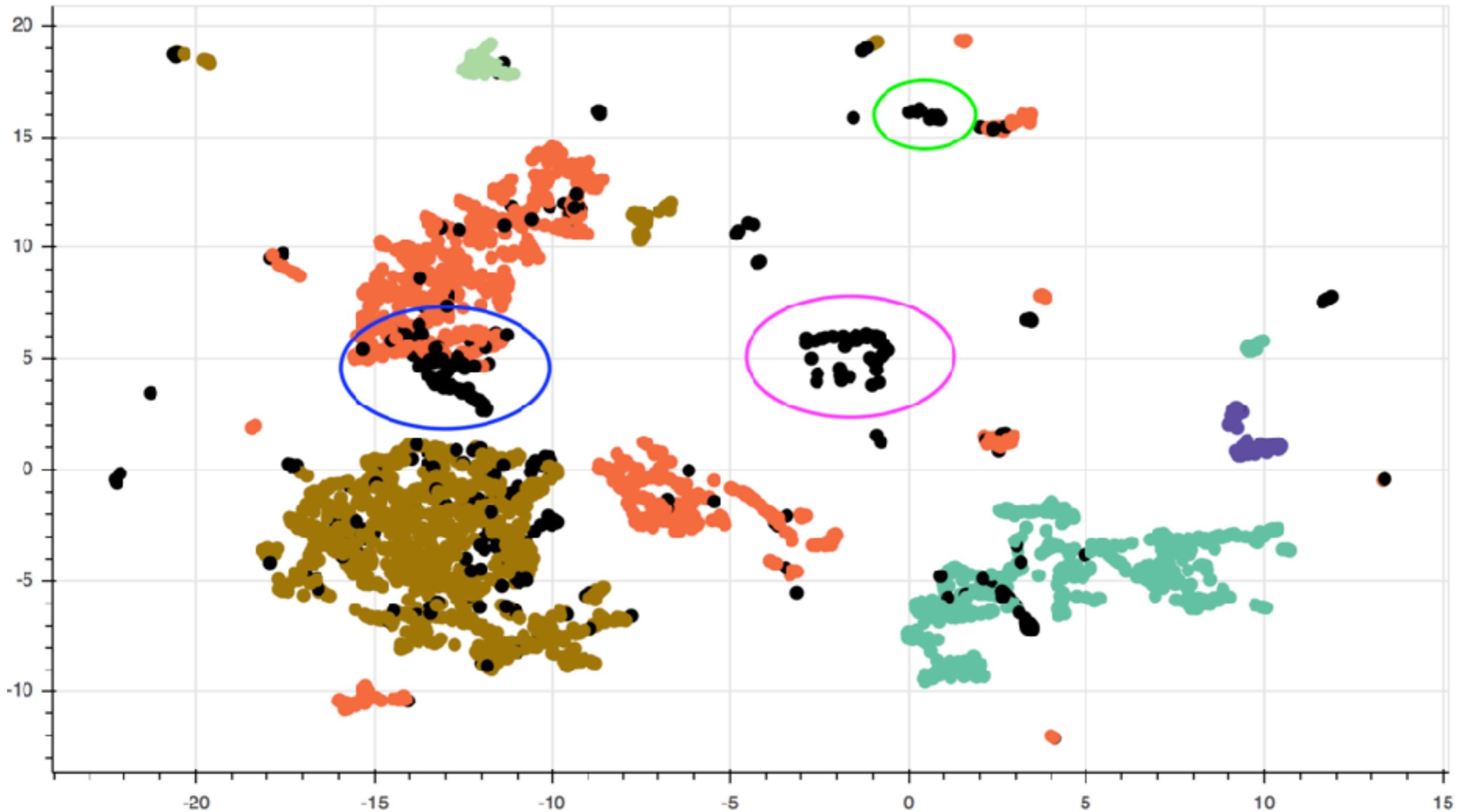
Which of those are 'failure-indicative'?



UNSUPERVISED APPROACH

- Cluster sub-sequences into similar groups
- Sub-sequences from the same mode of operation cluster together. Clusters representing different modes are far apart from each other.
- Failure modes cluster together, distinct from normal operation.

Interpretation of clusters confirmed by Subject Matter Experts



2-dim embedding of sub-sequence clustering results

PROJECT OUTCOME

- Presented clusters and outliers to Subject Matter Experts to classify failure mode behaviour
- Confirmed that we have indeed identified failure-indicative situations
- Clusters created during model training provide classification to a specific failure mode
- PREDICTIVE: Classify incoming sub-sequences, and alert when failure-indicative sequence detected
- PRESCRIPTIVE: Use past tech reports to suggest solution / maintenance for detected situation

SUMMARY

Journey:

- Labelling
- Supervised task: identify failure-predictive situations and apply to prevent future failure
- Unsupervised task with prescriptive component

A lot of experimentation:

- processing and preparation
- modelling and visualisation
- what the solution will be

Representative example of challenges in domains with industrial machinery and processes

J OBS AND CONTACT

We are hiring!

- Data Engineer
- Software Development Manager
- Senior Developer

<https://toumetis.bamboohr.co.uk/jobs/>

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REFERENCES

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- Definition: 'An Offshore Production Platform, also known as an offshore rig is an oil drilling rig that is installed in an offshore location. The offshore rig primarily consists of floating platforms which make up the drilling, production, storage and transporting units.' (09.2018 <https://www.petropedia.com/definition/7956/offshore-production-platform>)
- Definition: 'large structures with facilities for well drilling to explore, extract, store, process petroleum and natural gas which lies in rock formations beneath the seabed' (08.2018 https://en.wikipedia.org/wiki/Oil_platform)
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- "It can cost \$50 million just to map a potential reserve, and \$100 million to drill an exploratory well. The entire platform operation can cost up to a billion dollars to build and millions a day to operate. It's a big investment, but there's a potentially huge payoff. Oil is now selling for about \$75 a barrel; with economies of scale, it costs companies about \$5 a barrel to find, extract, and transport offshore oil. A major deposit, known in the trade as an "elephant," can produce up to 20,000 barrels a day for years. So a single rig can produce revenues of about \$550 million per year. But first, the companies have to find the oil." (05.2010) <http://theweek.com/articles/494480/oil-rigs-cities-sea>
- Investments and Operating costs - Exploration (2017) <https://www.norskpetroleum.no/en/economy/investments-operating-costs/#exploration-costs>
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