

CCT College Dublin

Assessment Cover Page

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Declaration

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Detection and Prediction Severe Slugging

Strategic Thinking Capstone Project

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Strategic Thinking Capstone Project

Higher Diploma in Science in Artificial Intelligence Applications
CCT College Dublin
Ireland
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1 Introduction

Introduction to be inserted here

1.1 Business Understanding

1.1.1 Hypothesis

Hypothesis here

1.1.2 General Goal

Goal here

1.1.3 Success criteria/indicators

Success criteria/indicators here

1.1.4 Selected Processes and Technologies

Libraries, Models and machine learning algorithms.

1.1.5 Accomplishments

- Extracted and prepared data from Petrobras 3W
- Two models with a very high accuracy (Random Forest and Decision Tree)

2 Data Understanding

Preprocessing a dataset through data characterisation involves summarising the features and characteristics present in the data using statistical measures and visualisations techniques such as bar charts and scatter plots. After this stage, it should be possible to identify biases, patterns, trends, and any missing or irrelevant data in the data set that may need to be addressed.

This dataset is composed by instances of eight types of undesirable events characterized by eight process variables from three different sources: real instances, simulated instances and hand-drawn instances. All real instances were taken from the plant information system that is used to monitor the industrial processes at an operational unit in Brazilian state of Espírito Santo. The simulated instances were all generated using <https://www.software.slb.com/products/olga>, a dynamic multiphase flow simulator that is widely used by oil companies worldwide (Andreolli, 2016). Finally, the hand-drawn instances were generated by a specific tool developed by Petrobras researchers for this dataset to incorporate undesirable events classified as rare.

Ultimately, only the data from the real instances were select for this project, as simulated data and hand-drawn instances did not present any record for two relevant features, namely Gas Lift Flow Rate and Pressure Variable Upstream Of the Gas Lift Choke.

2.1 Data Characterisation

The data consists of over 50 million observations, with 13 columns of data for each observation. The first column, label, indicates the event type for each observation. The second column, well, contains the name of the well the observation was taken from. Hand-drawn and simulated instances have fixed names for in this column, while real instances have names masked with incremental id. The third column, id, is an identifier for the observation and it is incremental for hand-drawn and simulated instances, while each real instance has an id generated from its first timestamp. The columns representing the process variables are:

- P-PDG: pressure variable at the Permanent Downhole Gauge (PDG) - installed on Christmas Tree;

- P-TPT: pressure variable at the Temperature and Pressure Transducer (TPT) - installed on Christmas Tree;
- T-TPT: temperature variable at the Temperature and Pressure Transducer (TPT);
- P-MON-CKP: pressure variable upstream of the production choke (CKP) - located on platform;
- T-JUS-CKP: temperature variable downstream of the production choke (CKP);
- P-JUS-CKGL: pressure variable upstream of the gas lift choke (CKGL);
- T-JUS-CKGL: temperature variable upstream of the gas lift choke (CKGL);
- QGL: gas lift flow rate;

The pressure features are measured in Pascal (Pa), the volumetric flow rate features are measured in standard cubic meters per second (SCM/s), and the temperature features are measured in degrees Celsius (°C).

Other information are also loaded into each pandas Dataframe:

- label: instance label (event type) - target variable;
- well: well name. Hand-drawn and simulated instances have fixed names (respectively, drawn and simulated. Real instances have names masked with incremental id;
- id: instance identifier. Hand-drawn and simulated instances have incremental id. Each real instance has an id generated from its first timestamp;
- class: Although it can be used to identify periods of normal operation, fault transients, and faulty steady states, which can help with diagnosis and maintenance, it is a category which results from label, which is our target here

The labels are:

- 0 - Normal Operation = Normal
- 1 - Abrupt Increase of BSW = AbrIncrBSW
- 2 - Spurious Closure of DHSV = SpurClosDHSW
- 3 - Severe Slugging = SevSlug
- 4 - Flow Instability = FlowInst
- 5 - Rapid Productivity Loss = RProdLoss
- 6 - Quick Restriction in PCK = QuiRestrPCK
- 7 - Scaling in PCK = ScalingPCK
- 8 - Hydrate in Production Line = HydrProdLine

In order to maintain the realistic aspects of the data, the dataset was built without preprocessing, including the presence of NaN values, frozen variables due to sensor or communication issues, instances with varying sizes, and outliers (R.E.V. Vargas, et al. 2019).

A concise summary of this data set generated by *pandas.DataFrame.info* method can be seen on Table 1.

2.2 Exploratory Data Analysis

A bar chart was generated displaying the percentage of present values in each column of the data frame - see Figure 1. It contained missing values in several columns, thus some columns and row were deleted in order to obtain accurate and reliable results.

Three boxplots were plotted to show how the data was distributed before any data cleaning - see Figure 2. They were divided according the feature measurement unit: the pressure features were measured in Pascal (Pa), the temperature features are measured in degrees Celsius (°C) and one feature about volumetric flow rate which was measured in standard cubic meters per second (SCM/s).

Column	pandas.Dtype
timestamp	datetime64[ns]
label	int64
well	object
id	int64
P-PDG	float64
P-TPT	float64
T-TPT	float64
P-MON-CKP	float64
T-JUS-CKP	float64
P-JUS-CKGL	float64
T-JUS-CKGL	float64
QGL	float64
class	float64
source	object

Table 1: Summary of the data set compiled from real instances

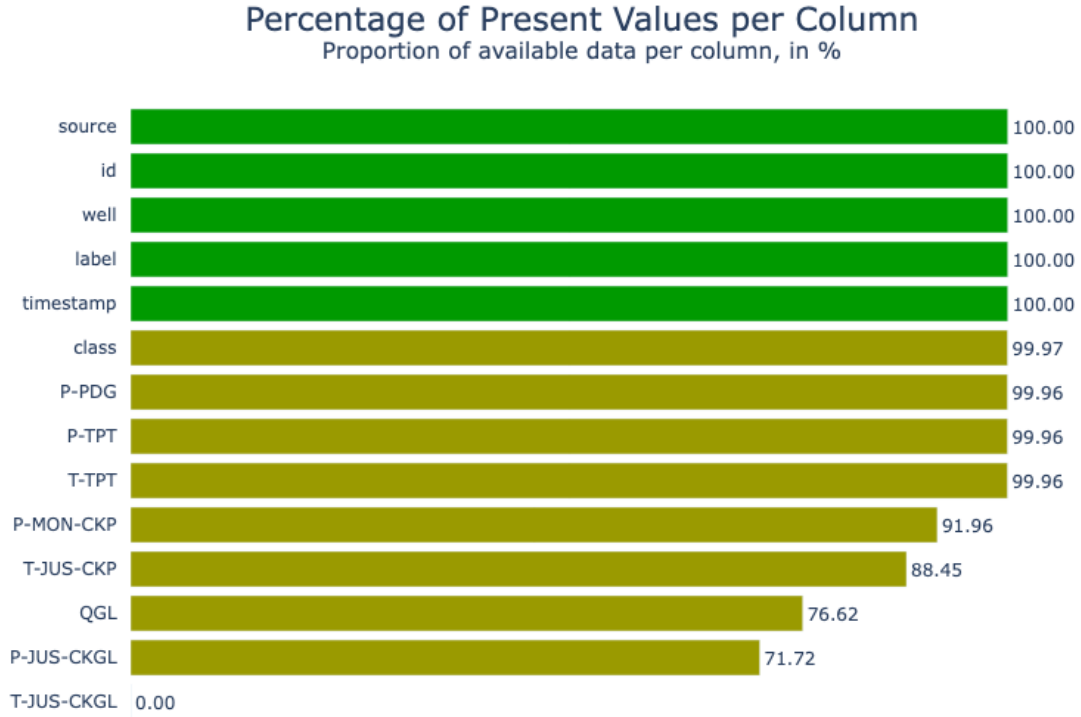


Figure 1: Proportion of available data per column, in %.

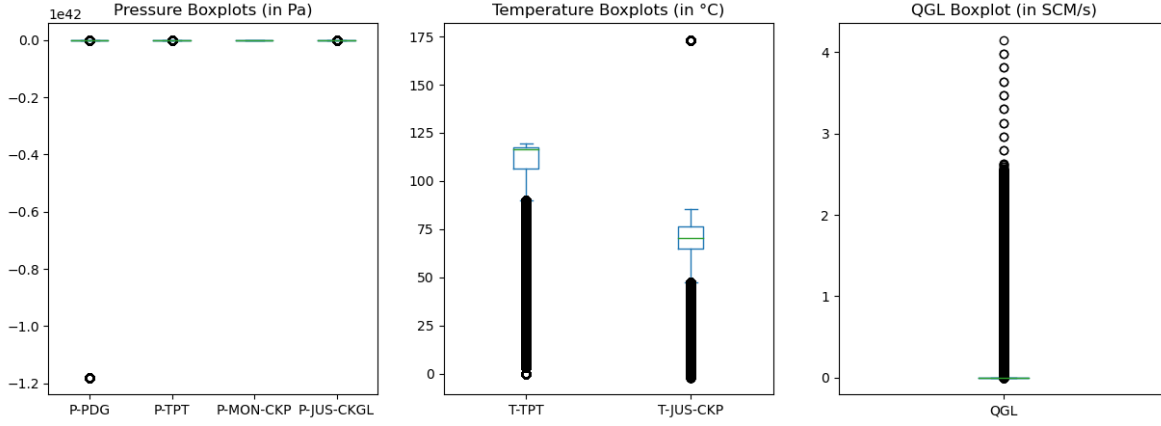


Figure 2: Boxplots showing the distribution of pressure, temperature, and QGL (SCM/s) data for a set of oil wells.

3 Data Preparation

Data preparation included Data Cleaning, Feature Engineering, Train/Test Splitting and Handling Imbalanced Data, Data Scaling, and an analysis of the chosen approach regarding dimensionality reduction for some models.

3.1 Data Cleaning

The missing data from the following columns were removed: class, P-PDG, P-TPT, T-JUS-CKP, P-MON-CKP, T-TPT, P-MON-CKP, QGL and P-JUS-CKGL. After this, the columns class, T-JUS-CKGL (an empty column), id, source were dropped. Column class is a column which brings more details about label. Consider that columns timestamp, label were kept at this stage. Finally all duplicates were removed.

```

1 # dropping rows with missing or null class column
2 df_clean = df.dropna(subset=[
3     'class', 'P-PDG', 'P-TPT', 'T-JUS-CKP', 'P-MON-CKP', 'T-TPT',
4     'P-MON-CKP', 'QGL', 'P-JUS-CKGL'
5 ])
6
7 # removing redundant columns
8 df_clean = df_clean.drop(['class', 'T-JUS-CKGL', 'id', 'source'], axis=1)
9
10 # checking duplicated rows after removing ids
11 df_clean = df_clean.drop_duplicates()
12
13 df_clean.info()

```

```

<class 'pandas.core.frame.DataFrame'>
Int64Index: 10003580 entries, 0 to 13952910
Data columns (total 10 columns):
#   Column      Dtype
---  -
0   timestamp   datetime64[ns]
1   label       int64
2   well        object
3   P-PDG       float64
4   P-TPT       float64
5   T-TPT       float64
6   P-MON-CKP   float64
7   T-JUS-CKP   float64
8   P-JUS-CKGL  float64

```

```
9    QGL          float64
dtypes: datetime64[ns](1), float64(7), int64(1), object(1)
memory usage: 839.5+ MB
```

3.2 Feature Engineering

3.3 Train/Test Splitting and Handling Imbalanced Data

3.4 Data Scaling

3.5 Dimensionality Reduction

4 Modeling

Modeling here

5 Evaluation

Evaluation here

6 Conclusion

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6.2 How to add Lists

You can make lists with automatic numbering ...

1. Like this,
2. and like this.

...or bullet points ...

- Like this,
- and like this.

6.3 How to write Mathematics

L^AT_EX is great at typesetting mathematics. Let X_1, X_2, \dots, X_n be a sequence of independent and identically distributed random variables with $E[X_i] = \mu$ and $\text{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \dots + X_n}{n} = \frac{1}{n} \sum_i^n X_i$$

denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.

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6.6 How to add Citations and a References List

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References

- [Gre93] George D. Greenwade. The Comprehensive Tex Archive Network (CTAN). *TUGBoat*, 14(3):342–351, 1993.