**Machine Breakdown Predictions**

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1. **Problem Statement and Background (15%)**

Our goal is to use a generated dataset to minimize costs and downtime of a business by predicting machine failures and finding the primary factors that contribute to those failures.

We found the initial dataset from Kaggle. The data includes rotational speed, air and process temp, torque of the machines, tool wear in minutes. There are 2 target variables, whether the machine fails and what specific failure type it is if it does fail. Our goal is to create a model of the data that can accurately predict when a machine is going to break before it does.

We believe that machine owners and operators would benefit from having a model like our intended one, as it would potentially reduce downtime and lost product due to misaligned, broken, or worn machine parts as we could better predict when the machine is to fail.

Should our work be successful, there could be practical application to the manufacturing industry as well as further incentive to collect accurate machine data to create a model like ours with real recorded data for specific machines and entire production lines.

As for related work, there have been several attempts to make predictive machine failure algorithms and of the ones we found, several were successful in predicting failures, giving us a basis to work from and potential future work in

1. **Data and Exploratory Analysis (15%)**

The dataset from Kaggle can be found [here](https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification/data). The dataset comes with a provided data dictionary, which can be found below:

The dataset consists of 10 000 data points stored as rows with 14 features in columns

* UID: unique identifier ranging from 1 to 10000
* productID: consisting of a letter L, M, or H for low (50% of all products), medium (30%), and high (20%) as product quality variants and a variant-specific serial number
* type: consisting of the letter prefix found in productID (L, M, H)
* air temperature [K]: generated using a random walk process later normalized to a standard deviation of 2 K around 300 K
* process temperature [K]: generated using a random walk process normalized to a standard deviation of 1 K, added to the air temperature plus 10 K.
* rotational speed [rpm]: calculated from powepower of 2860 W, overlaid with a normally distributed noise
* torque [Nm]: torque values are normally distributed around 40 Nm with an Ïƒ = 10 Nm and no negative values.
* tool wear [min]: The quality variants H/M/L add 5/3/2 minutes of tool wear to the used tool in the process. and a  
  'machine failure' label that indicates whether the machine has failed in this particular data point for any of the following failure modes are true.

Targets:

* Target: Failure or Not
* Failure Type: Type of Failure

We have potentially unnecessary columns, the UID and product ID which allow the algorithm to learn which items in the training set always fail, as such we removed them from the dataset for training and testing purposes. These could potentially lead to data leakage in which the model could find a pattern within the ID system to predict failures. UID is redundant for the same reason, as well as because of the *type* feature that already contains the relevant information – the product quality – that could be extracted from it. We also are not going to use failure type, as our focus is predicting whether the machine will fail or not regardless of type. Our focus at the start is binary classification, failure or not. There is no missing data, tool wear has a large amount of variance but is standardized. As for issues with the data, we examined the data thoroughly and searched for outliers, anomalies, and missing data by plotting all combinations of relations between numeric features and analyzing each one, all of which came up with no issues. The visualization for that can be seen below:

A screenshot of a computer

Description automatically generated

For the specific code, we removed these unnecessary rows by creating a new dataset – a subset of the original data – that omitted these rows.

updated <- subset(master, select = -c(UDI, Product.ID, Failure.Type))

Comments:

* Nice Problem Statement
* Data and EDA
  + Where is the data source/URL?
  + How did you know those were unnecessary?
  + How did you "thoroughly" do that?
  + Considering adding some visualizations and maybe a data dictionary

1. **Methods (10%)**

*[Describe the methods you explored (usually algorithms, or data cleaning or data wrangling approaches). Justify your methods in terms of the problem statement. What did you consider but \*not\* use? In particular, be sure to include every method you tried, even if it didn't "work". When describing methods that didn't work, make clear how they failed and any evaluation metrics you used to decide so.]*

Our initial approach to the problem statement involved building a scatterplot matrix to determine correlation between individual numerical variables, then using the gghighlight library to find initial trends in data when comparing 2 attributes against each other and finding patterns whether the machine breaks or not.

An issue we ran into was our data still has a categorical attribute in it alongside the rest of the numeric attributes, that being the machine type. Initially we discussed splitting the data into 3 types, one for each machine type, but we decided instead to convert from a categorical to a numeric, with L becoming 0, M becoming 1, and H becoming 2.

We initially explored using linear or logistic regression for our model, however since we are using several attributes rather than a smaller number we feel using a decision tree would be the superior approach to dealing with multiple attributes at once and finding the weights of each attribute on the machine failing.

In the end we decided that our best method to approach our problem statement would be a classification based decision tree, as it more flexible with nonlinear data than a regression model and can interpret several features at once into its decision matrix.

1. **Tools (10%)**

*[Describe the tools that you used and the reasons for their choice. Justify them in terms of the problem itself and the methods you want to use. Tools will probably include machine learning, and possibly data wrangling and visualization. Please discuss all of them. How did you employ them? What features worked well and what didn't? What could be improved? Describe any tools that you tried and ended up not using. What was the problem?]*

For our initial approach we used gghighlight and ggplot2 in order to get a cursory visualization of the data so we could see positive, neutral, or negative trends in the data while we discussed the potential uses of linear regression versus decision trees to solve our problem. We decided to go with decision trees as our approach to a solution of our problem statement for the benefits mentioned in the methods section. Initially we were going to use regressive decision trees on each of the three split segments of our data, but since we are trying to find a categorical value we decided to use decision tree classifiers instead, as they can more accurately represent whether a machine fails or not.

***INSERT HOW WE EMPLOYED DECISION TREES, WHAT FEATURES WORKED, AND WHAT CAN BE IMPROVED***

Tools used: gghighlight

pairs(updated[, c(2,3:7)]) – variable\_scatterplot\_initial\_relations

- gghighlight/ggplot

- either logistic or linear regression?

- If all else fails, decision tree.

1. **Results (35%)**

*[Give a detailed summary of the results of your work. Here is where you specify the exact performance measures you used. Usually there will be some kind of accuracy or quality measure. There may also be a performance (runtime or throughput) measure. Please use visualizations whenever possible. Include links to interactive visualizations if you built them. You should attempt to evaluate a primary model and in addition a "baseline" model. The baseline is typically the simplest model that's applicable to that data problem, e.g. Naive Bayes for classification, or K-means on raw feature data for clustering. If there isn't a plausible automatic baseline model, you can e.g. compare with human performance by having someone hand-solve your problem on a small subset of data. You won’t expect to achieve this level of performance, but it establishes a scale by which to measure your project's performance. Compare the performance of your baseline model and primary model and explain the differences.]*

1. **Summary and Conclusions (10%)**

*[In this section give a high-level summary of your results. If the reader only reads one section of the report, this one should be it, and it should be self-contained. You can refer back to the "Results" section for elaborations. This section should be less than a page. In particular, emphasize any results that were surprising.]*

1. **Appendix (5%)**

Include the link to your github/gitlab repository (that I can access) containing your R programs/scripts, and link to the data.