Testing Without Testing

Predicting Engine Failure Using Virtual Quality Gates


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Sponsor Organizations: Nissan Motor Co. Ltd., MIT MIMO, and MIT Device Realization Lab Faculty Advisors: Dr. Brian Anthony & Jim Butler PhD Mentors: Russel Bradley & Kimberly Carballo

Motivation

Nissan has faced recurrent engine issues:

2.1M
Engines recalled in 2010 due to faulty control system

700K
Rogue SUVs recalled in 2023 due to engine shut-off issues

Why Care?

Engine recalls are costly both to Nissan and drivers

Reduced Driver Safety
Faulty engines directly impact driving experience

Brand Reputation Damage
Quality concerns have killed car brands before

Monetary Impact
- Reduced production throughput
- Increased maintenance costs
- Increased retesting costs

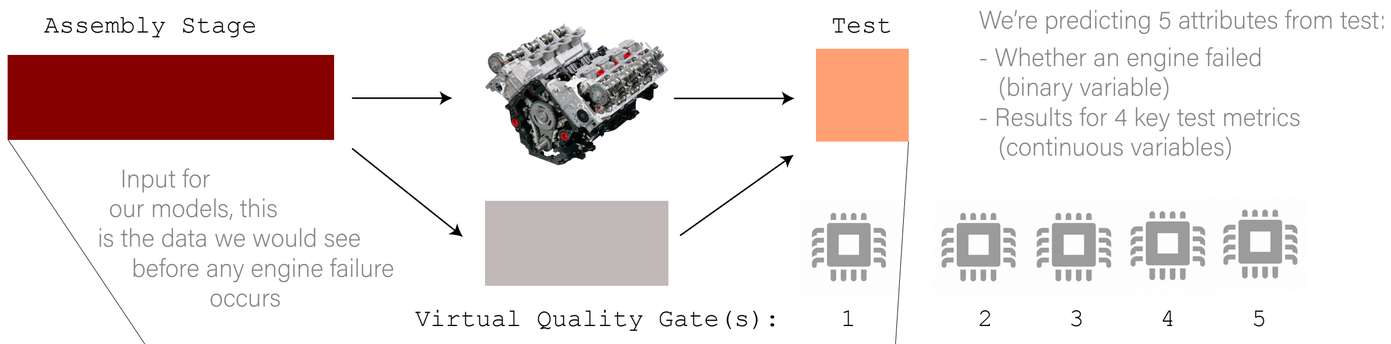
MIT Machine Intelligence for Manufacturing & Operations (MIMO) deploys machine intelligence to manufacturing problems.

MIT's Device Realization Lab, directed by Dr. Brian Anthony, designs instruments and techniques to sense and control physical systems.

Nissan is a large Japan-based automobile manufacturer

Problem Statement

Given data from an engine's assembly, can we predict its quality test results and whether it will fail?



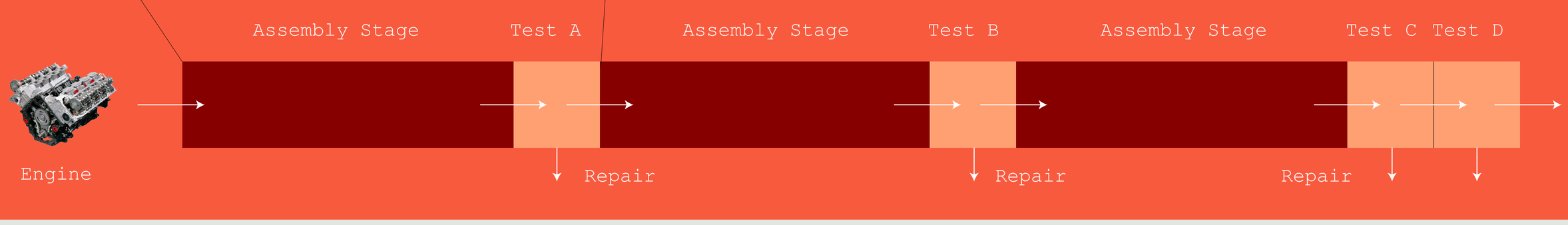
We're predicting 5 attributes from test:
- Whether an engine failed (binary variable)
- Results for 4 key test metrics (continuous variables)

Dataset

Production data from Nissan's Tennessee facility for VCR engine for the time period February 2022- March 2023. Contains over 11,000 engines

Assembly Data
Individual operation level data for all engines produced

Test Results Data
Functional engine testing data from test processes A, B, C, D



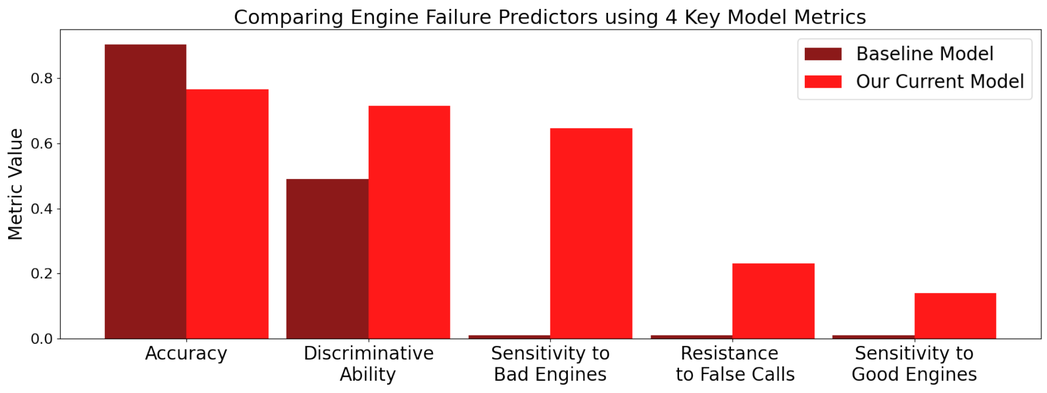
Aproach 1: Predicting Engine Failure

Engine Failure: If an engine was taken off the manufacturing line for an hour or more

Baseline Model: Simplest trainable classifier can't detect bad engines

Our Model: Modified logistic regression achieves far better detection rates

Technical specs: summary statistic training data, class weighting, LASSO regularization



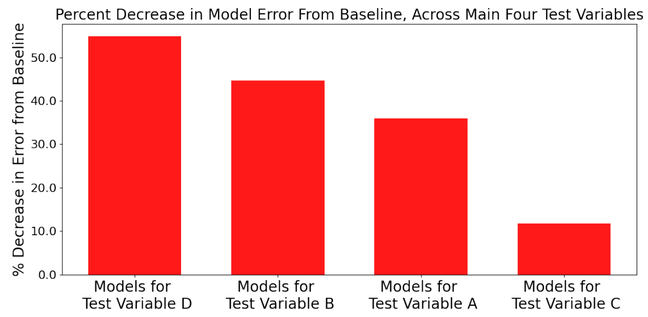
Approach 2: Predicting Test Results

Test Results: Measures of engine quality recorded at testing--we focus on four

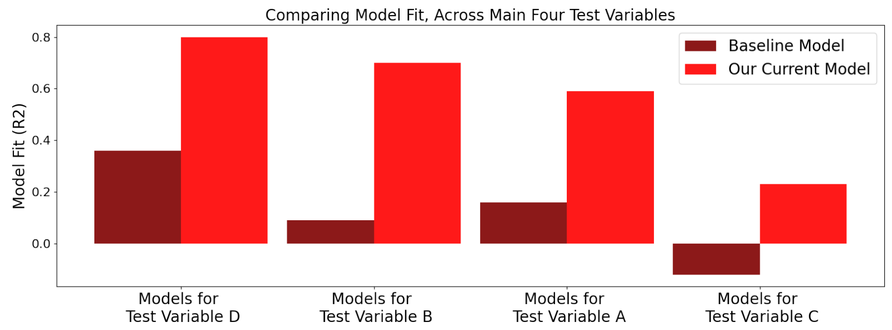
Baseline Model: Simplest trainable classifier has relatively low model fit

Our Model: Gradient boosting achieves a breakthrough in predictive power

Technical specs: XGBoost with cross-validated max_depth



For Context:
Previous modeling has be unable to beat the baseline when predicting many of the test variables



Business Impact

Our models help our client detect faulty engines, potentially saving 400K engines annually

1.4M
Engines recalled by client in 2023

Our model catches 77% of engine failures

1M
Engine failures are detectable with our model

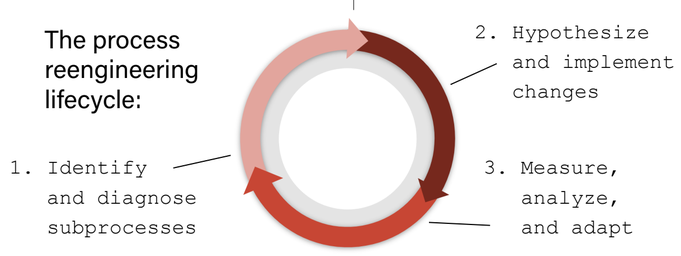
If 40% of flagged engines are reengineered (fixed):

400K
Engines become salvagable as a final result

Leveraging our models for growth

Understanding how assembly data affects test data allows Nissan to reengineer their engine production

The process reengineering lifecycle:



Future Work & Project Vision

We envision an integrated pipeline that provides more holistic value to Nissan

Raw Assembly Data	Data Preprocessing	Anomaly Detection	Testing Result Prediction
Real time production data flows into model	Adjust for data drift present in manufacturing sensors	Flag engines with obvious deviations for closer inspection, remove them from dataset	Using cleaned data, predict testing results and whether repair is needed

Handoff:
This research is ongoing, and we will deliver our code to MIT and Nissan as a foundation for future researchers to produce more value from.