MathWorks
AUTOMOTIVE CONFERENCE 2023
India

Predictive Maintenance As Vehicles Become More Software-Defined’

Aditya Jain, TCS

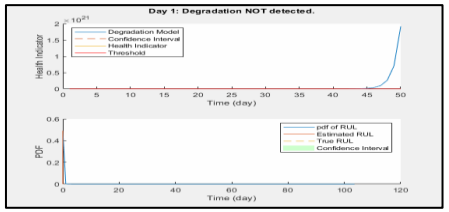
Koustubh Shirke, MathWorks

MathWorks

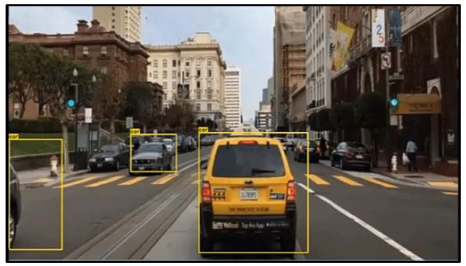
AI Role in SDVs

Predictive Maintenance

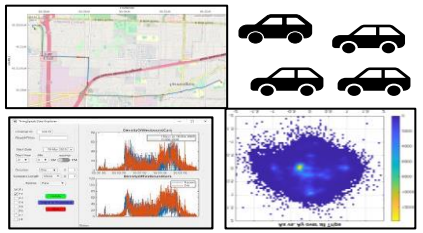
Remaining useful life estimation



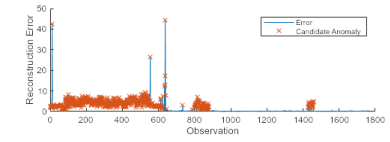
Object Detection with Deep Learning

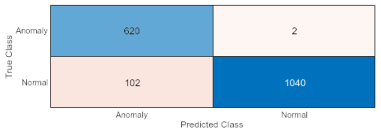


Fleet Data Analytics

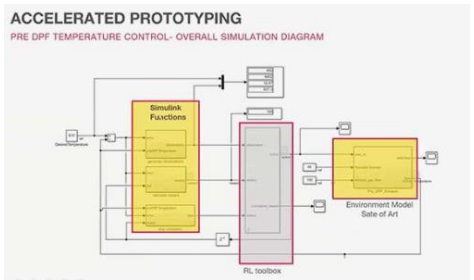


Intrusion Detection System

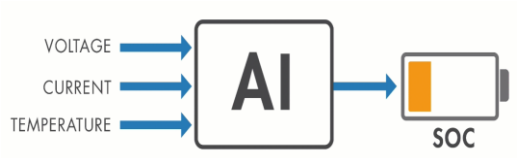




Reinforcement Learning

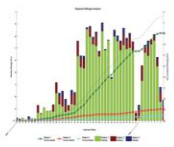


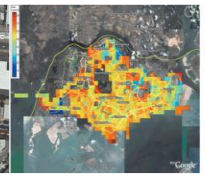
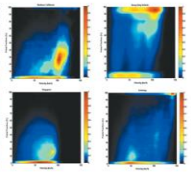
Virtual Sensor Modelling



MATLAB for AI in the Automotive Industry

Deep Dive into the Daimler's Fleet user story

Data Collection & Labelling

- Test Fleet of 100+ hydrogen fuel vehicles
- Telematics system to capture: GPS coordinates, fuel tank level, velocity, gas pedal position
- Diverse dataset with various driving conditions & climates
- Data transmitted to a central database
- **Database Toolbox** to query relevant data from the database

Data Visualization & Pre-processing

- MATLAB script to filter anomalous data, e.g. zero points reported by the GPS system and non-drive files
- **Mapping toolbox** used to reconstruct any trip taken in a test vehicle – integration with Google Earth

Statistical Analyses

- MATLAB scripts enabling engineers to link real-world location to vehicle performance, simplifying remote diagnostics analyses on the worldwide fleet.
- Engineers can use these results to determine how fuel depletion rates are affected by the driving environment.
- **Plan Hydrogen refueling** – spatial histogram
- **Analyze driving patterns,** e.g. pedal position analysis

Deployment

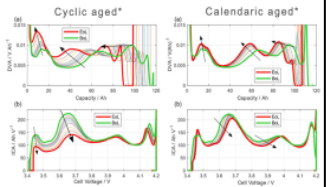
- **Automated Reports**
- **Web Applications**

Developing Onboard SOH Estimation Using DVA and ICA for LFP Batteries

Gotion

Challenge

Li-on Batteries suffer from a variety of degradation mechanisms that lead to either capacity fade or power fade. Techniques like Incremental Capacity Analysis and Differential Voltage Analysis can be used to estimate DQ and DV curves but inferring battery State of Health (SOH) from these curves still requires domain expertise.



Solution

Gotion used MATLAB to develop feature extraction methods that detect the most important features in DQ and DV curves, then trained a linear regression model that correlates these features with capacity fade. This regression model was then used alongside temperature data in a 2-D look-up table that estimates SOH. The solution was implemented in Simulink for testing, requirements validation, and certification.

Benefits of using MATLAB and Simulink

- Easy data analysis for visualization and identification of key trends in battery aging
- Built-in tools to extract meaningful features from differential voltage curves (peak detection)
- V-diagram workflow support including requirements management, automatic code generation, and ISO 26262/IEC 61508 certification

Link to MathWorks Automotive Conference slides
Link to MathWorks Automotive Conference recording

BMW Uses Machine Learning to Detect Oversteering

Challenge

Develop automated software for detecting oversteering, an unsafe condition in which rear tires lose their grip during a turn

Solution

Use MATLAB to develop, train, and evaluate a variety of supervised machine learning classifier types, including KNN, SVM, and decision trees

Results

- Oversteering identified with greater than 98% accuracy
- Multiple machine learning classifiers trained automatically
- Code generated and deployed to an ECU for real-time, in-vehicle testing

A BMW M4 oversteering on a test track.

"Working in MATLAB, we developed a supervised machine learning model as a proof of concept. Despite having little previous experience with machine learning, in just three weeks we completed a working ECU prototype capable of detecting oversteering with over 98% accuracy."
- Tobias Freudling, BMW Group

Renault Uses Deep Learning Networks to Estimate NO_X Emissions

Challenge

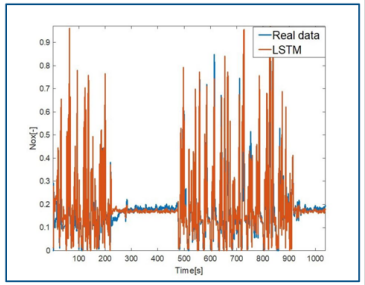
Design, simulate, and improve aftertreatment systems to reduce oxides of nitrogen (NO_X) emissions

Solution

Use MATLAB and Deep Learning Toolbox to model engine-out NO_X emissions using a long short-term memory (LSTM) network

Results

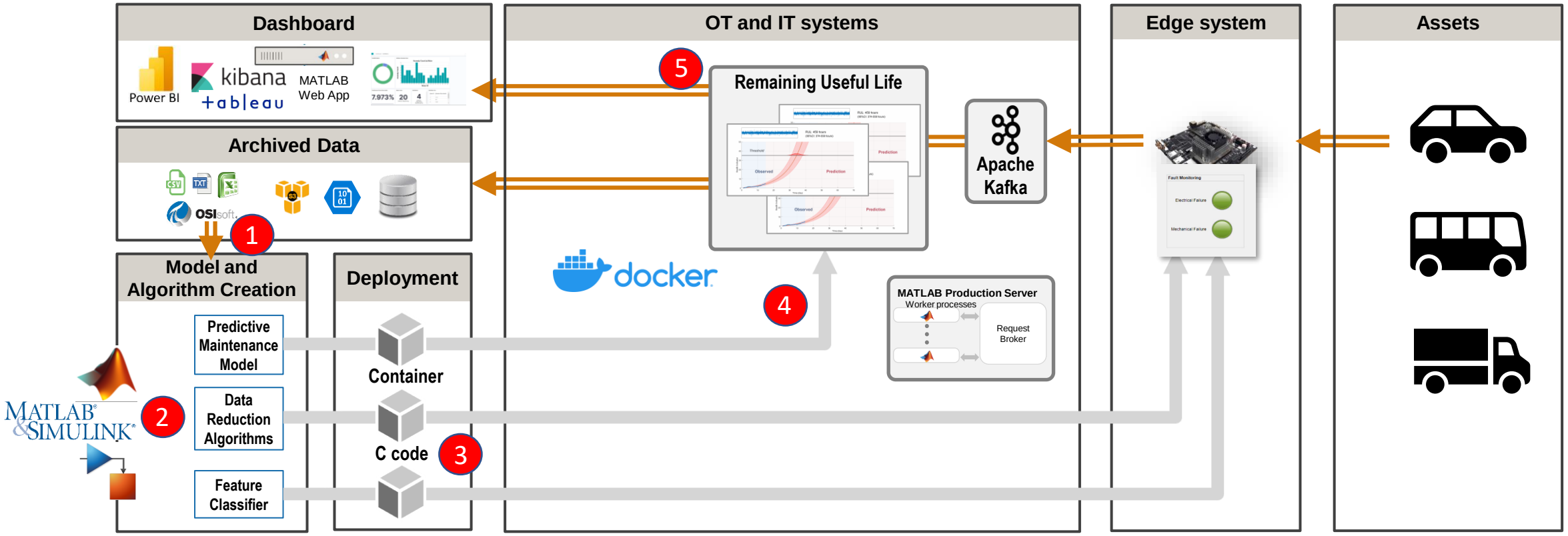
- NO_X emissions predicted with close to 90% accuracy
- LSTM network incorporated into aftertreatment simulation model
- Code generated directly from network for ECU deployment



Measured NO_X emissions from an actual engine and modeled NO_X emissions from the LSTM network.

"Even though we are not specialists in deep learning, using MATLAB and Deep Learning Toolbox we were able to create and train a network that predicts NO_X emissions with almost 90% accuracy."
- Nicoleta-Alexandra Stroe, Renault

Operationalizing AI Models at Edge and in Cloud



1. Interactively access data sources
2. Create AI models, feature classifiers, and data reduction algorithms
3. Automatically generate code
4. Automatically create Docker containers for streaming or batch operations
5. Enable data-driven decision-making with dashboards
6. Verify edge/cloud algorithms with digital twin simulations of equipment

Case Study: Anomaly Detection for Air Intake System

6. Conformation of Anomaly & Time to Failure Appointment booking at nearest dealership

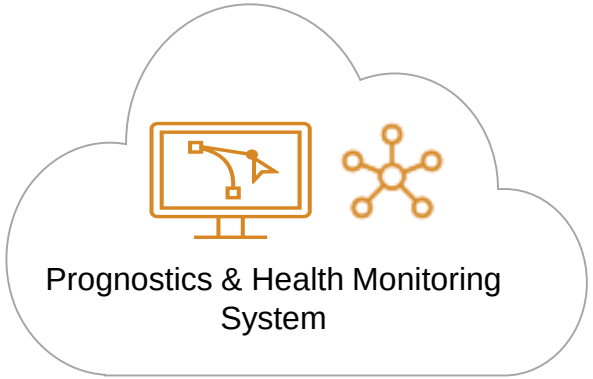
1. Model Deployment on Edge

5. Relevant Data Sharing

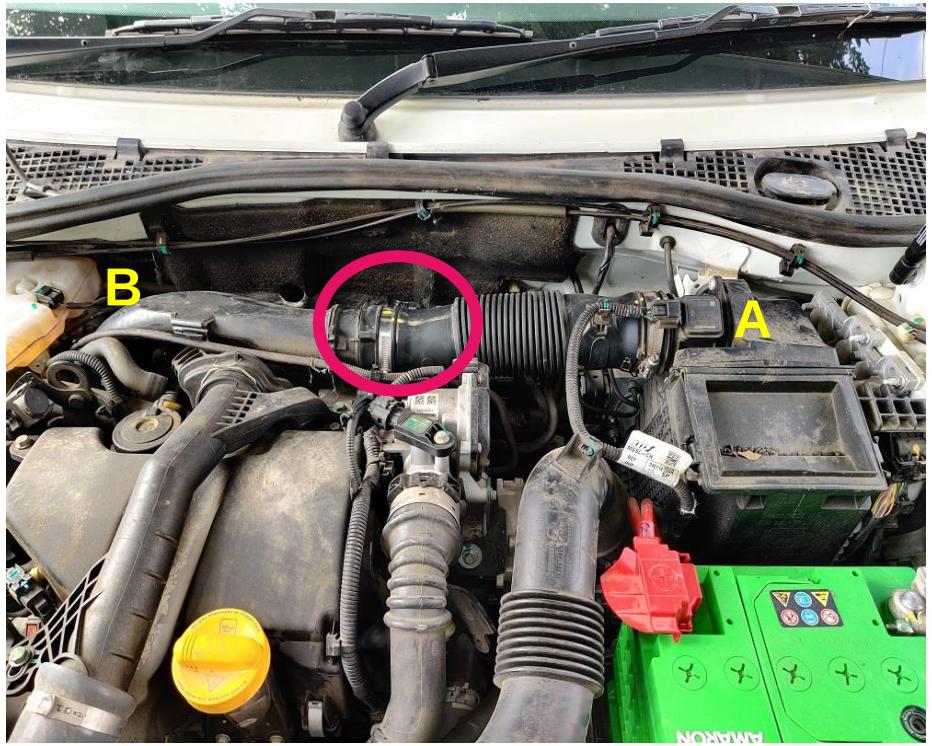
2. Periodic Vehicle Health Update

4. Permission to Fetch data

3. Vehicle Heath Alert Identifying potential anomaly in Air-Intake system



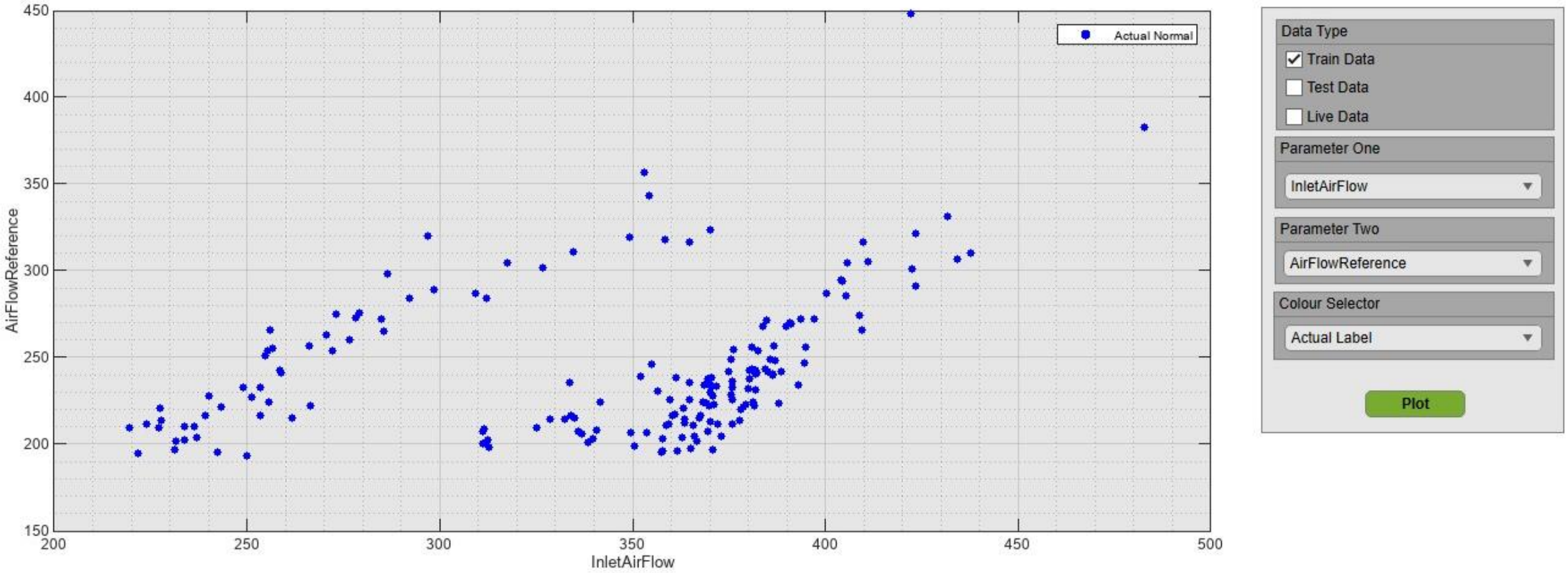
- SDV Car with an Odometer reading of 70K kilometer
- Car experiencing loss of power. Hard acceleration required
- No DTC code or MIL light seen
- Health alert indicating some anomaly in Air-Intake



TATA CONSULTANCY SERVICES Analytics Dashboard

Anomaly Prediction | Data Exploration | Anomaly Detection

Data Exploration

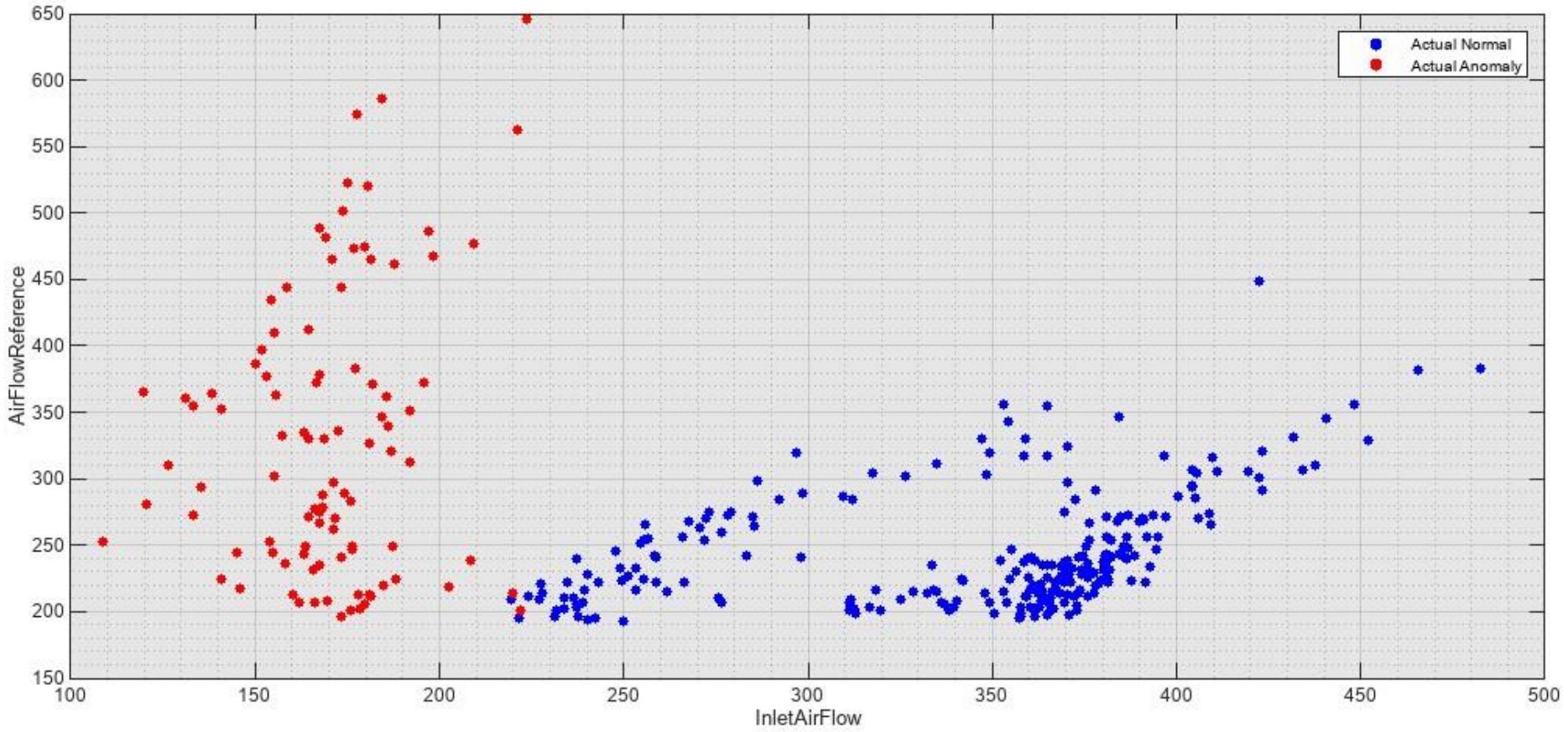


Show Log

TATA CONSULTANCY SERVICES Analytics Dashboard

Anomaly Prediction | Data Exploration | Anomaly Detection

Data Exploration



Data Type
- [x] Train Data
- [x] Test Data
- [ ] Live Data

Parameter One: InletAirFlow

Parameter Two: AirFlowReference

Colour Selector: Actual Label

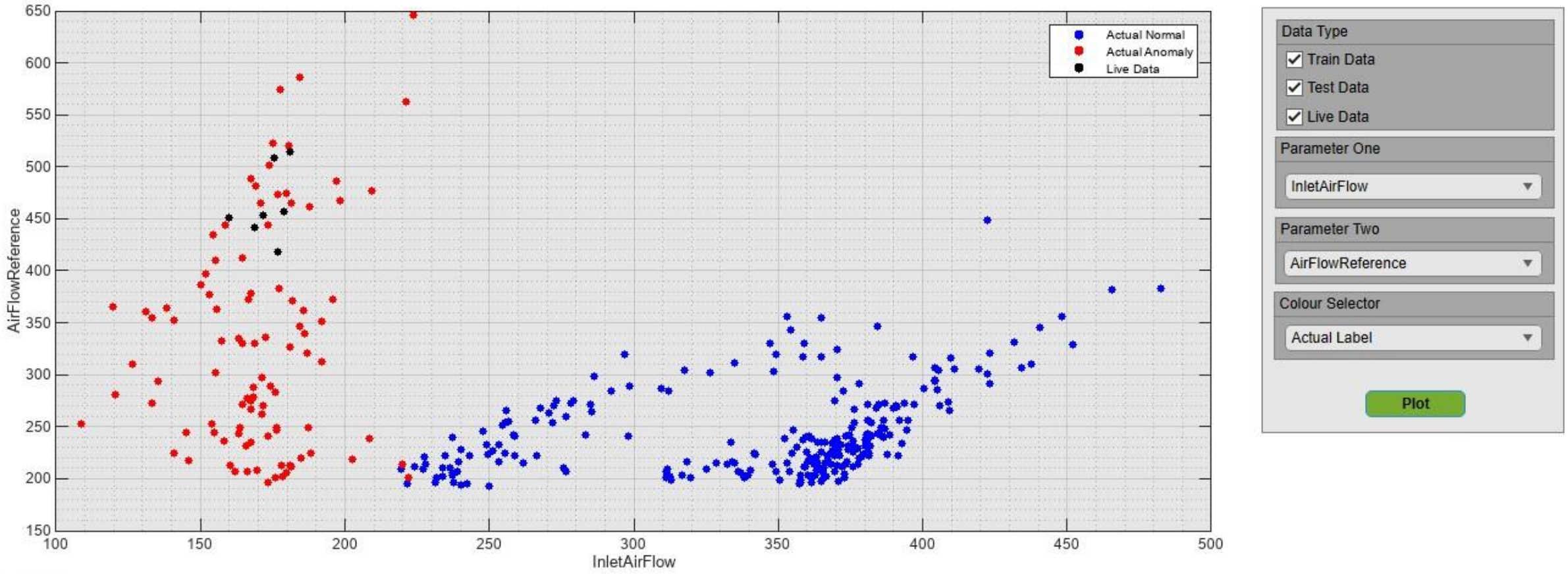
Plot

Show Log

TATA CONSULTANCY SERVICES Analytics Dashboard

Anomaly Prediction | Data Exploration | Anomaly Detection

Data Exploration



Data Type
- Train Data
- Test Data
- Live Data

Parameter One: InletAirFlow

Parameter Two: AirFlowReference

Colour Selector: Actual Label

Plot

Show Log

Analytics Workflow

1 Access and Explore Data

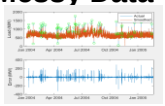
Files

Databases

Sensors

2 Preprocess Data

Working with Messy Data



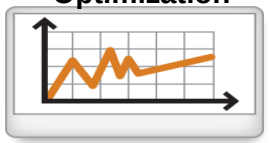
Data Reduction/ Transformation

Feature Extraction

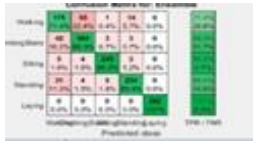
3 Modeling & Insights

Model Creation e.g. Machine Learning

Parameter Optimization

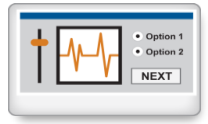


Model Validation



4 Deploy

Desktop Apps

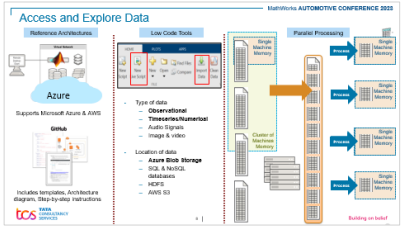


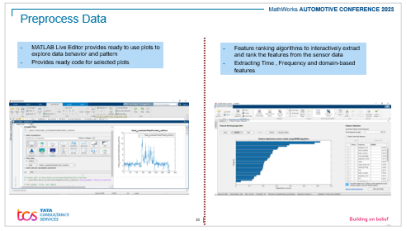
Enterprise Scale Systems

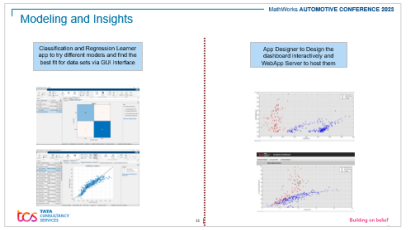
MATLAB Excel .NET C/C++ .exe Java .dll

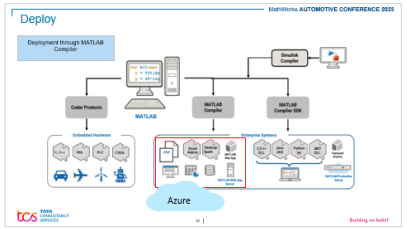
Embedded Devices and Hardware

Delivered through Matlab









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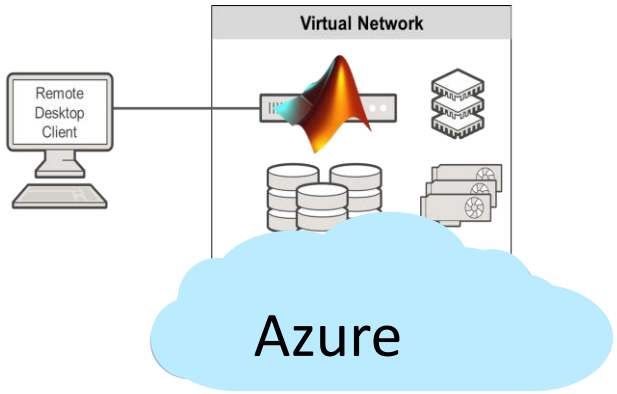
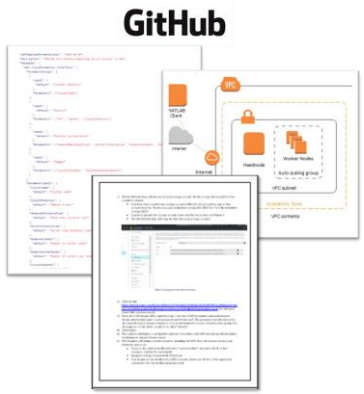
Building on belief

Access and Explore Data

Reference Architectures

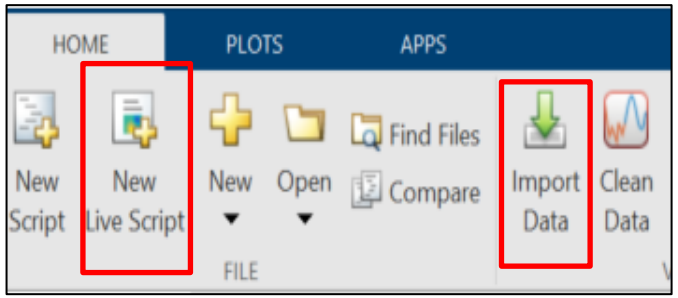


Supports Microsoft Azure & AWS



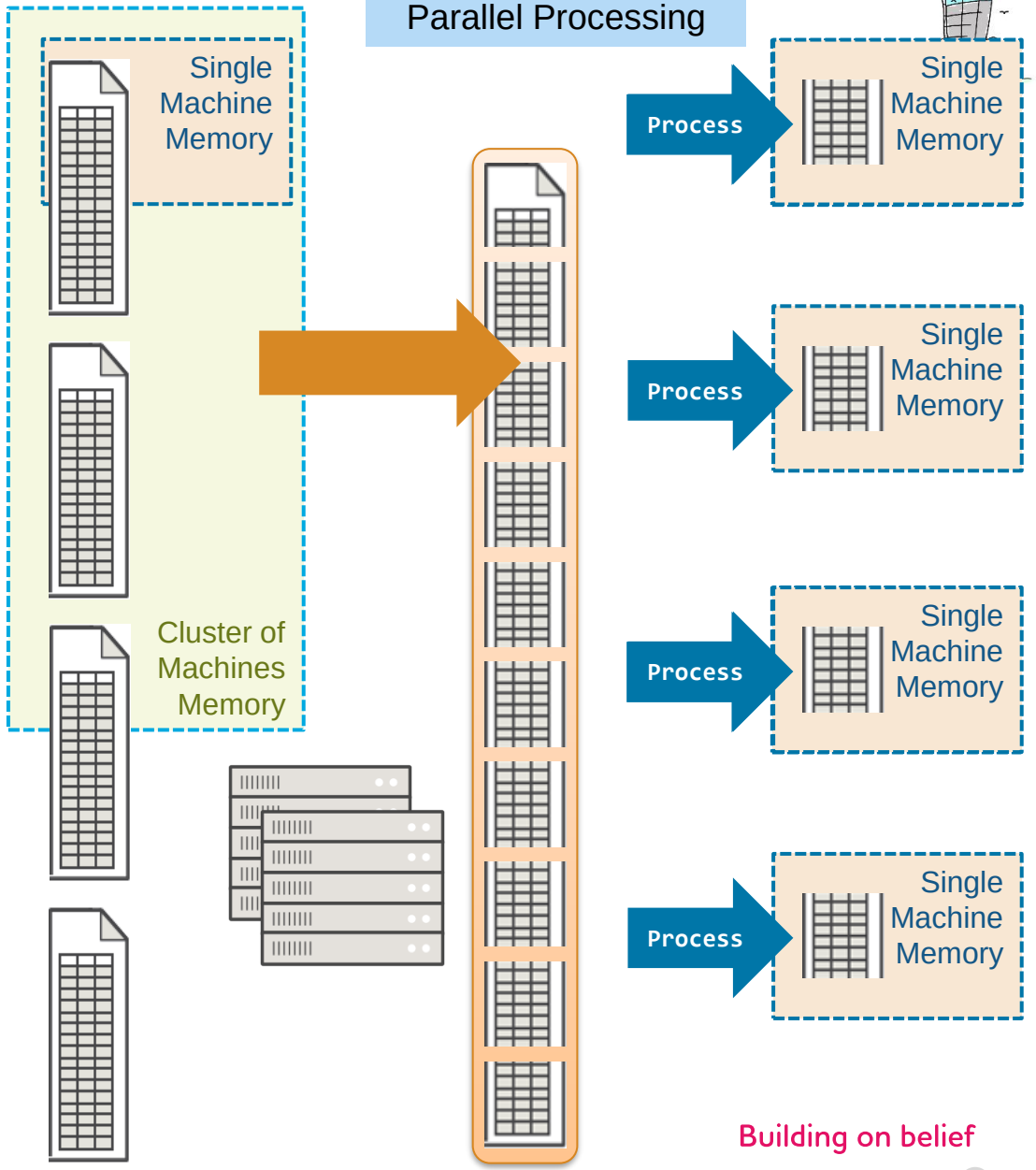
Includes templates, Architecture diagram, Step-by-step instructions

Low Code Tools



- Type of data
  - **Observational**
  - **Timeseries/Numerical**
  - Audio Signals
  - Image & video
- Location of data
  - **Azure Blob Storage**
  - SQL & NoSQL databases
  - HDFS
  - AWS S3

Parallel Processing



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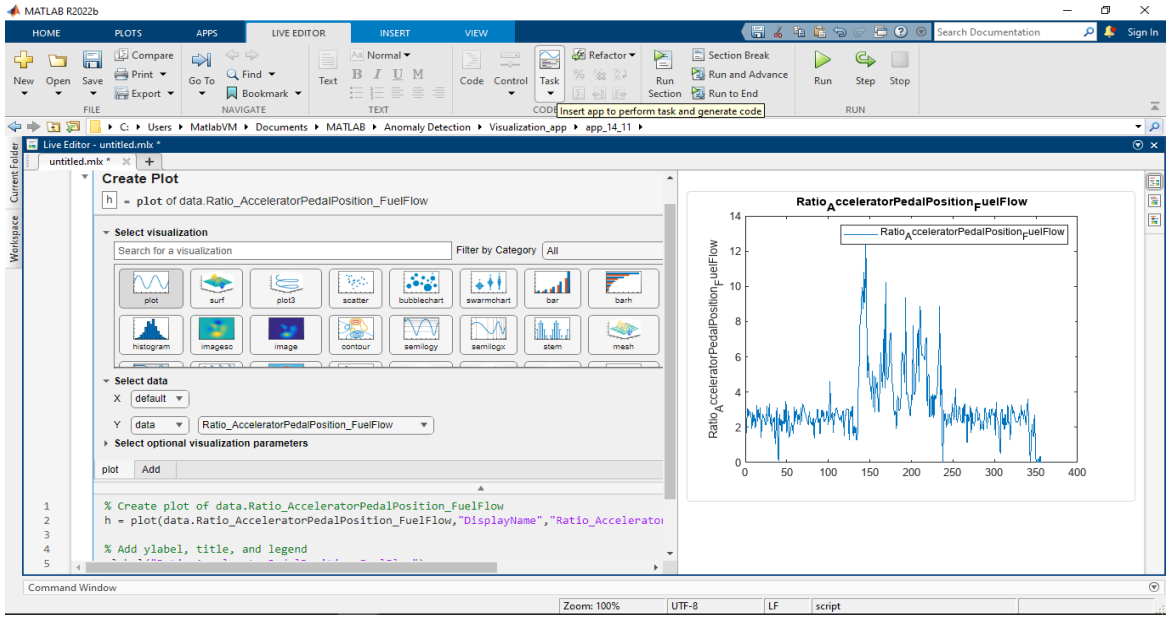
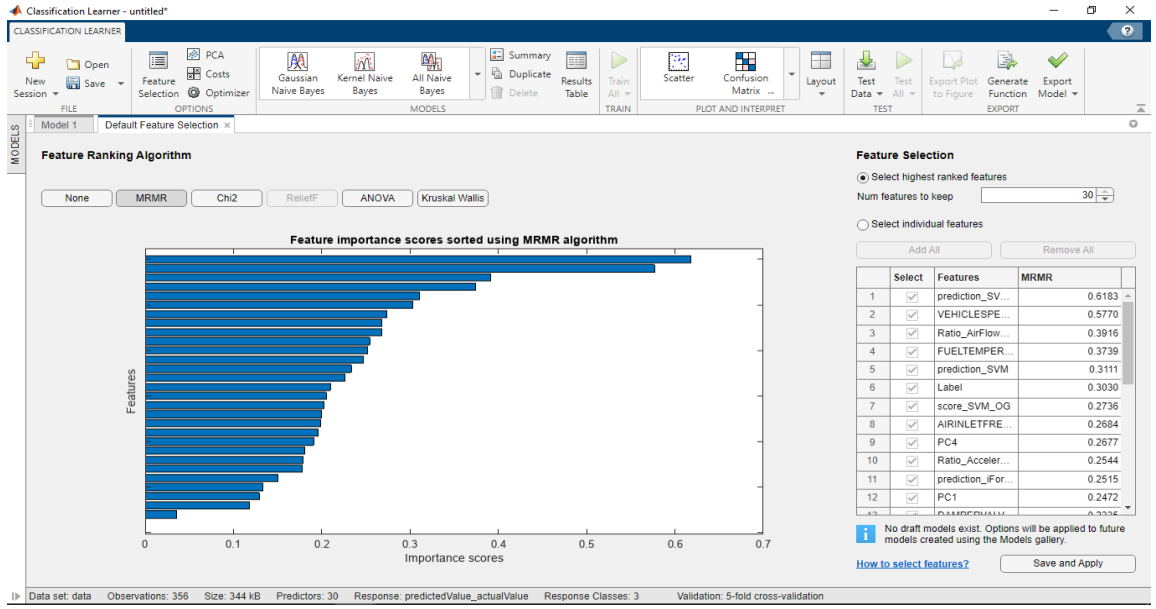
Building on belief

Preprocess Data

- MATLAB Live Editor provides ready to use plots to explore data behavior and pattern
- Provides ready code for selected plots



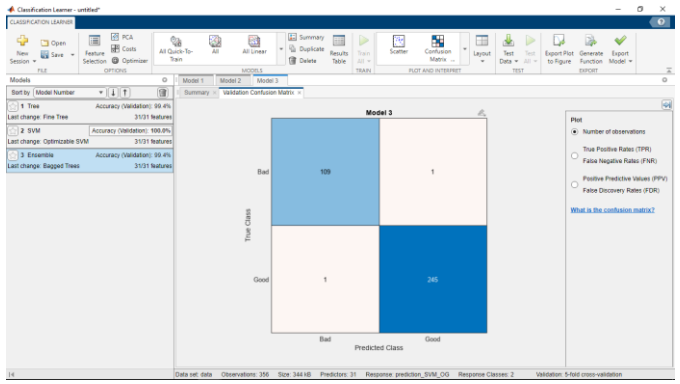
- Feature ranking algorithms to interactively extract and rank the features from the sensor data
- Extracting Time , Frequency and domain-based features

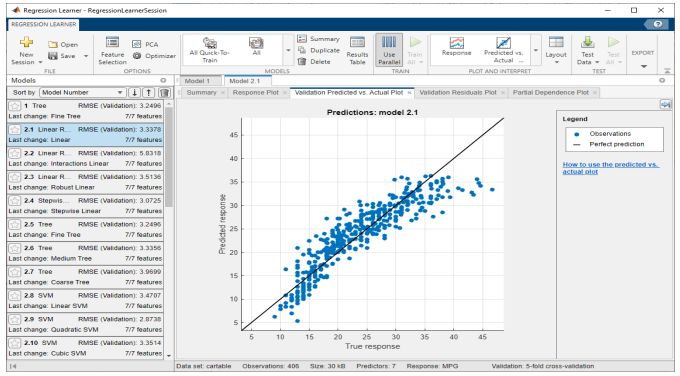


Building on belief

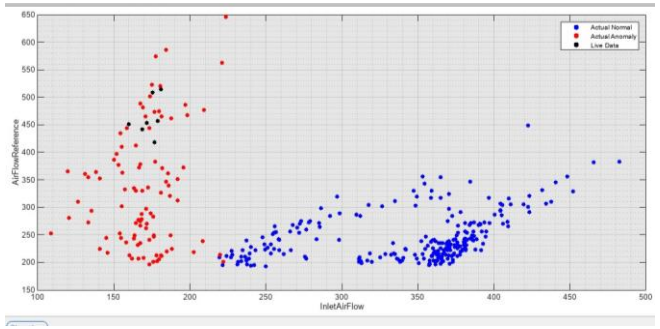
Modeling and Insights

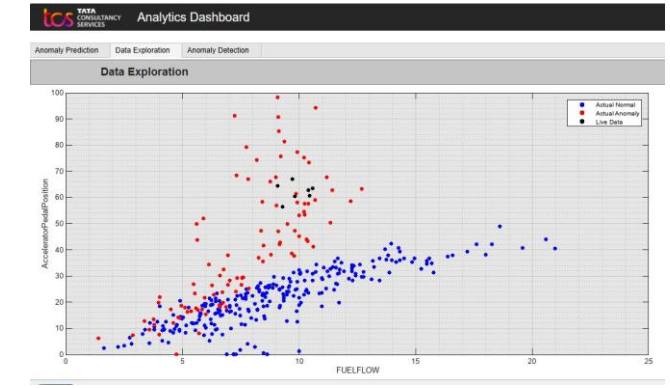
Classification and Regression Learner app to try different models and find the best fit for data sets via GUI Interface





App Designer to Design the dashboard interactively and WebApp Server to host them

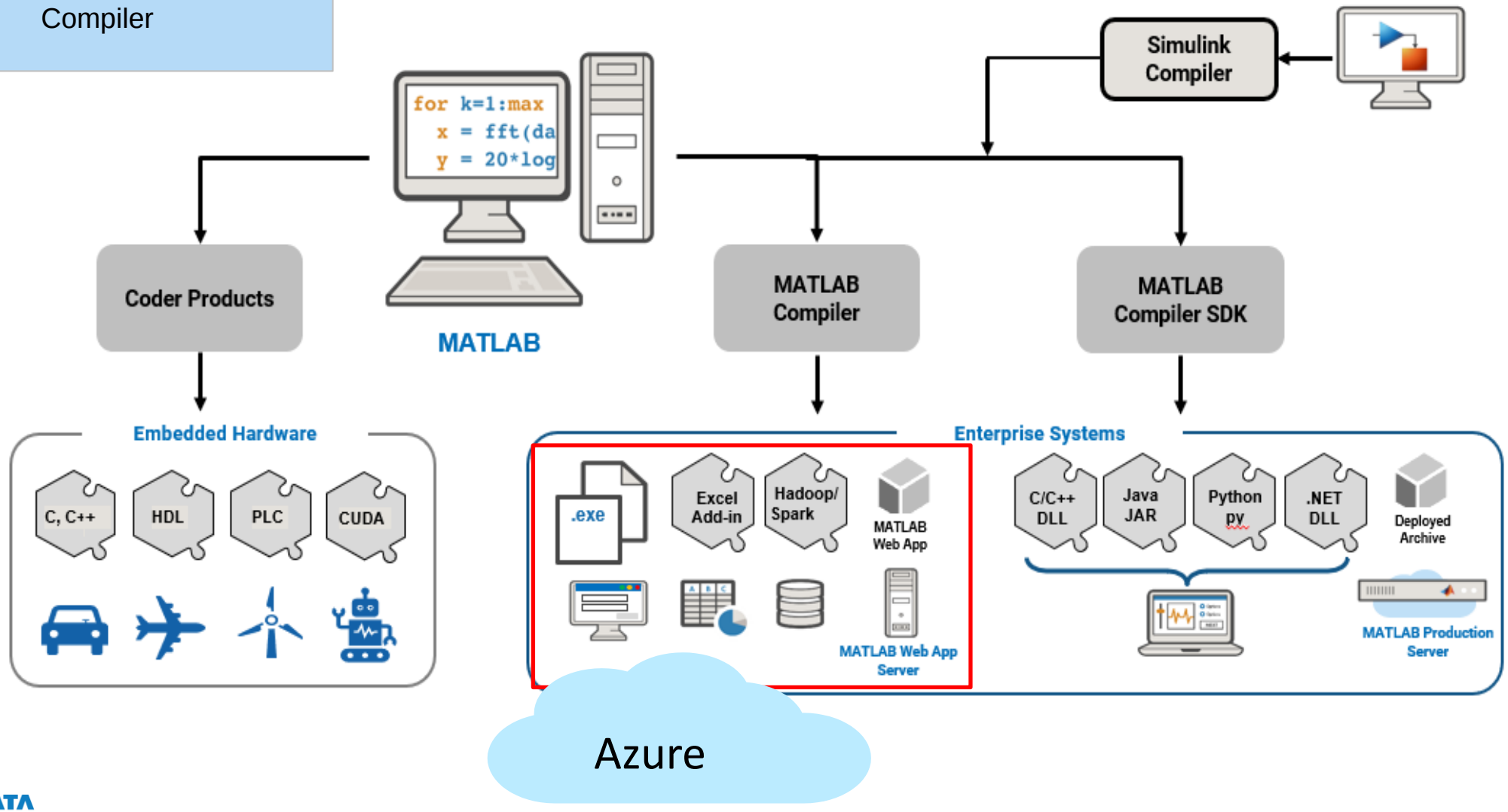




Building on belief

Deploy

Deployment through MATLAB Compiler



Summary

Role of AI in SDV

- Across Domains
- ADAS, Cyber Security, Diagnostics

Predictive Maintenance

- SDV Data
- High Computing Power

Architecture for Predictive Maintenance

- Distributed
- Offboard and Onboard

MATLAB Tool Chain

Robust
Work with Business and Engineering Data

MathWorks

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Country

Thank you