License Metric

Driving Test Feedback System

GITHUB_LINK | DRIVE_LINK | DEMO_LINK | DATASETS

College: Indraprastha Institute of Information Technology Delhi

Faculty Advisor: Dr. Anuj Grover

Team Members:

Abhishek Jha

Harsh Kumar

Aryan Jain

Angadjeet Singh

PROBLEM DESCRIPTION

Driving tests traditionally rely on subjective human observation to evaluate a driver's proficiency. This methodology often introduces inconsistency and potential bias in the assessment process. Our project addresses this challenge by developing an objective, data-driven system to monitor and analyse driving patterns in real time.

We can capture precise movement data from vehicles by leveraging the accelerometer and gyroscope sensors available on STMicroelectronics microcontroller boards. This allows for quantitative measurement of driving behaviours such as acceleration, turning, braking, and stability. The system aims to provide driving instructors with concrete metrics to supplement their observations, resulting in more fair and comprehensive driver evaluations.

Our proposed solution can identify specific driving patterns, including straight driving at various speeds, turning manoeuvres, braking behaviour, and stability during minor road disturbances. This objective data helps instructors identify areas where student drivers need improvement and can serve as valuable feedback for the learners.

RESEARCH METHODOLOGY

Hardware Selection

We selected the STEVAL-MKBOXPRO (SensorTile.box PRO) as our primary development platform. This ready-to-use programmable wireless box kit is designed for developing IoT applications based on remote data gathering and evaluation. It leverages both motion and environmental data sensing, along with a digital microphone, to enhance connectivity and smartness in various environments.

The STEVAL-MKBOXPRO integrates multiple sensors, including:

- **LSM6DSV16X:** A high-performance, low-power 6-axis inertial measurement unit (IMU) featuring a 3-axis digital accelerometer and a 3-axis digital gyroscope. This sensor offers a triple-channel architecture for processing acceleration and angular rate data on three channels (user interface, OIS, and EIS) with dedicated configuration, processing, and filtering.

The board also features wireless connectivity options, including Bluetooth Low Energy (BLE), facilitating seamless data transmission to external devices.

Data Collection Approach

We designed a controlled experiment to build a comprehensive dataset involving a test vehicle performing predefined manoeuvres. The STEVAL-MKBOXPRO was securely mounted within the vehicle to ensure consistent and accurate data acquisition. During each test run, the board's sensors continuously recorded motion data, which was transmitted wirelessly to our data collection system.

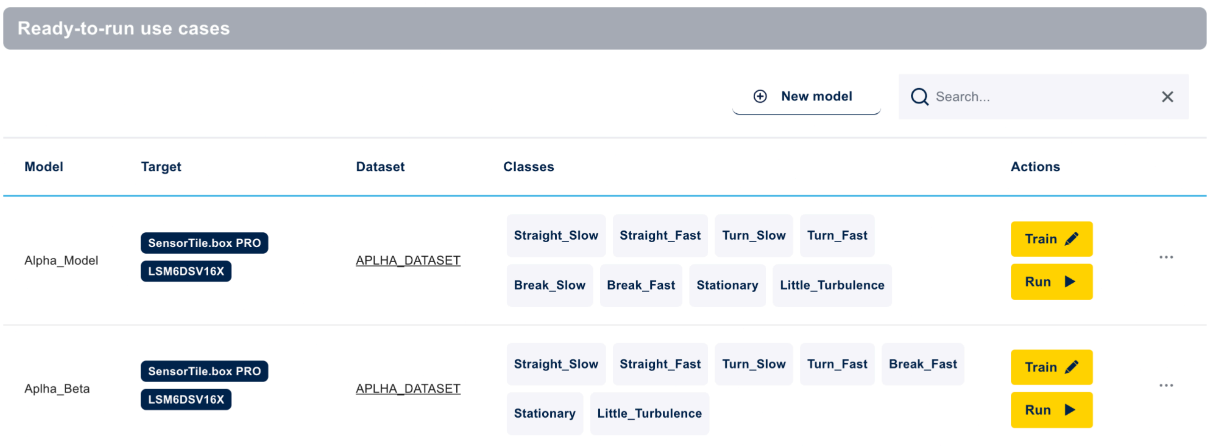
We collected data corresponding to the following labelled driving patterns:

- **Straight_Slow:** Vehicle moving in a straight line at low speed.
- **Straight_Fast:** Vehicle moving in a straight line at high speed.
- **Turn_Slow:** Vehicle executing left and right turns at low speed.
- **Turn_Fast:** Vehicle executing left and right turns at high speed.
- **Brake_Fast:** Sudden braking or reverse command applied to a moving vehicle.
- **Stationary:** Vehicle at complete rest.

- **Little_Turbulence:** Vehicle experiencing minor bumps and road disturbances.

Multiple test runs were conducted for each pattern to ensure sufficient data volume and variety, allowing us to capture various driving conditions.

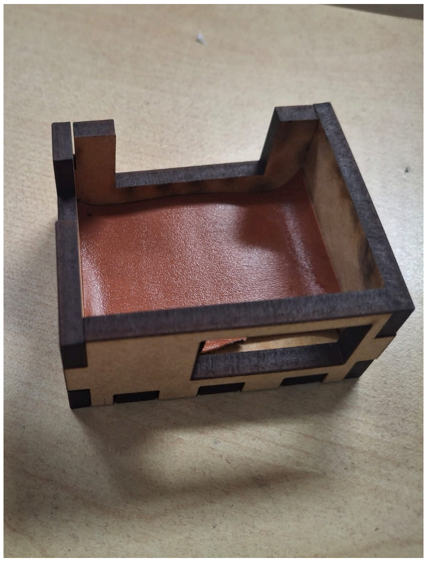
Dataset Preparation



The raw sensor data was collected using the ST AIoT Craft tool, automatically time stamped and organized the data streams. We segmented the continuous data into labelled samples corresponding to each driving pattern. Care was taken to ensure a balanced representation across all pattern categories to prevent bias in subsequent model training.

Data Collection Apparatus

To validate our proof of concept and ensure the safety of the evaluation equipment, we employed a robot car model as our test platform. We designed a custom enclosure using Autodesk Fusion 360 to enhance accuracy and protect the evaluation hardware. This approach allowed us to conduct controlled experiments while safeguarding sensitive components.



How ST AIoT Craft Tool Enhanced Project Efficiency

The ST AIoT Craft tool significantly streamlined our project workflow, offering features that reduced development time and complexity:

Wireless Data Collection

ST AIoT Craft's wireless data collection capabilities eliminated the need for physical connections between the vehicle-mounted microcontroller and our data logging system. This facilitated more natural driving behavior during tests and simplified the experimental setup.

Intuitive Data Visualization

The tool provided real-time visualisation of sensor data streams, allowing us to monitor data quality during collection. This immediate feedback enabled prompt identification and resolution of sensor mounting issues or data anomalies.

Custom AI Model Training

A notable advantage was ST AIoT Craft's built-in AI model training functionality. Without requiring deep expertise in machine learning frameworks, we were able to:

- Import our labelled dataset directly.
- Configure and train a classification model.
- Evaluate model performance.
- Export the trained model for deployment.

This no-code/low-code approach democratised the AI implementation process, allowing team members without specialised ML knowledge to contribute to model development. The integrated training pipeline automatically handled data preprocessing, feature extraction, model selection, and hyperparameter tuning.

Detailed Solution Description

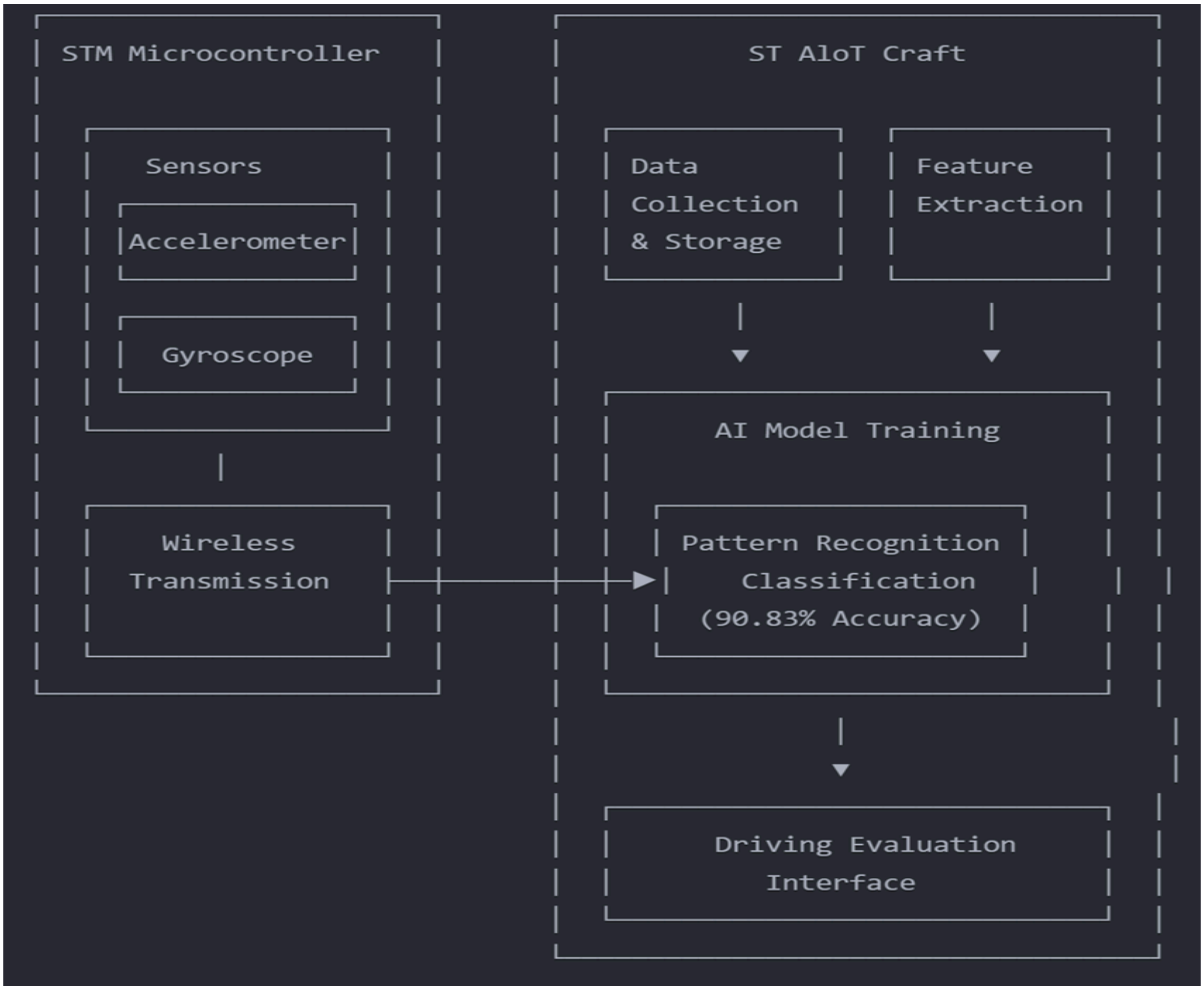
System Architecture

Our driving pattern analysis system comprises the following key components:

- **Sensing Layer:** STEVAL-MKBOXPRO with integrated LSM6DSV16X accelerometer and gyroscope sensors.
- **Data Transmission Layer:** Wireless communication between the board and the data collection system.

- **Data Processing Layer:** Signal processing and feature extraction.
- **Classification Layer:** Trained AI model for pattern recognition.
- **Feedback Interface:** Results visualization for driving instructors.

Block Diagram:



Data Processing Pipeline

1. **Sensor Data Acquisition:** Raw accelerometer and gyroscope readings are collected at a sampling rate of 240 Hz, suitable for capturing vehicle dynamics.

2. **Signal Preprocessing:** The raw sensor data undergoes labeling to account for different permutations of sensor data, car orientation, and car speed.

3. **Pattern Classification:** Our trained model analyzes the extracted features to classify the driving pattern into one of the predefined categories:
    - Straight_Slow
    - Straight_Fast
    - Turn_Slow
    - Turn_Fast
    - Brake_Fast
    - Stationary
    - Little_Turbulence

4. **Result Aggregation:** Multiple classifications over time are aggregated to provide a real-time driving behaviour assessment via simulations.

Model Performance

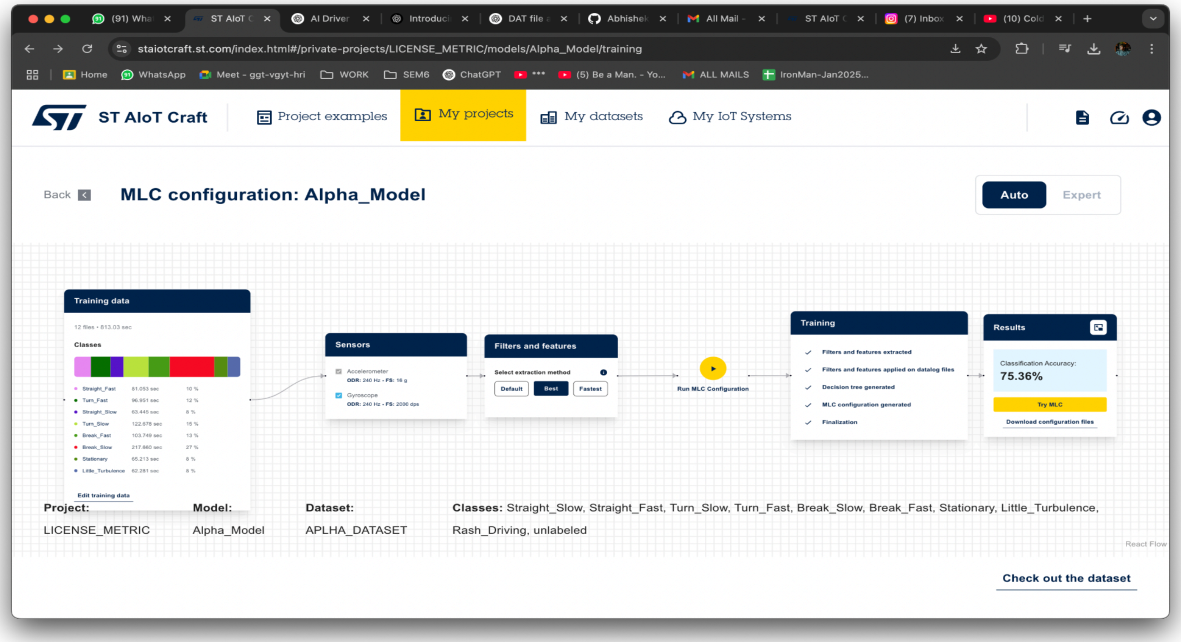


Figure 1.1: Initial Dataset and MLC

Through a series of methodical refinements in our dataset and labeling strategies, we observed a significant enhancement in our model's classification accuracy, culminating in near-perfect performance. The progression is as follows:

1. **Initial Model (Alpha):** Incorporated all labels, including "Brake_Slow," resulting in a maximum accuracy of 75.36%. The frequent misclassification of "Brake_Slow" adversely affected overall performance.

2. **Refined Model (Alpha_Beta):** By excluding the problematic "Brake_Slow" label and re-recording major faulty labels, the average accuracy improved to 89.48%, with a peak at 90.83%.

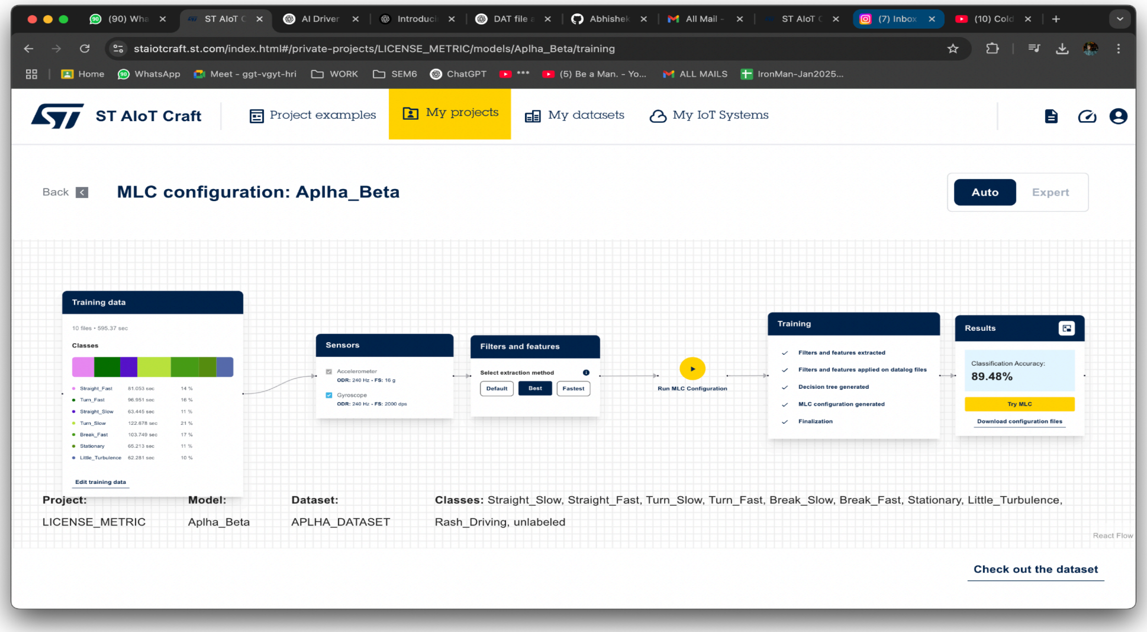
3. **Enhanced Dataset:** Further data refinement and augmentation led to an accuracy range between 99% and 100%.

Inferences:

- **Impact of Label Optimization:** The removal of ambiguous labels like "Brake_Slow" minimized confusion during classification, highlighting the importance of clear and distinct labeling in supervised learning.

- **Data Quality and Quantity:** Augmenting the dataset with refined and representative samples provided the model with a more comprehensive understanding of driving patterns, leading to substantial accuracy improvements.

- **Iterative Enhancement:** The systematic approach of identifying issues, refining data, and reassessing performance underscores the effectiveness of iterative processes in machine learning projects.



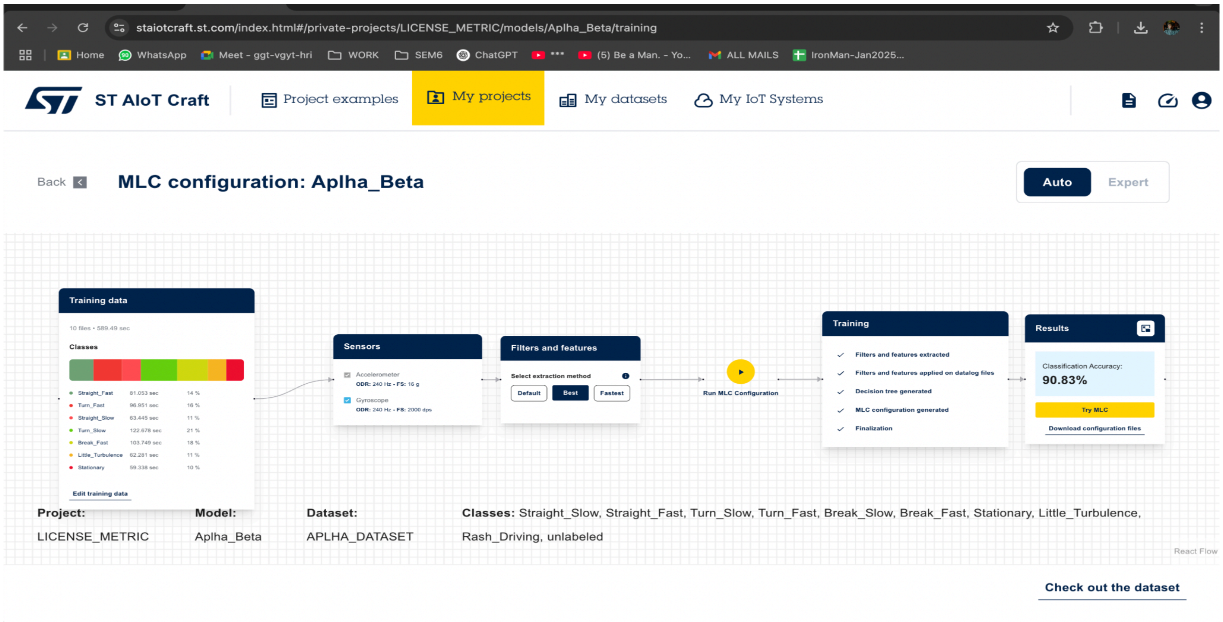
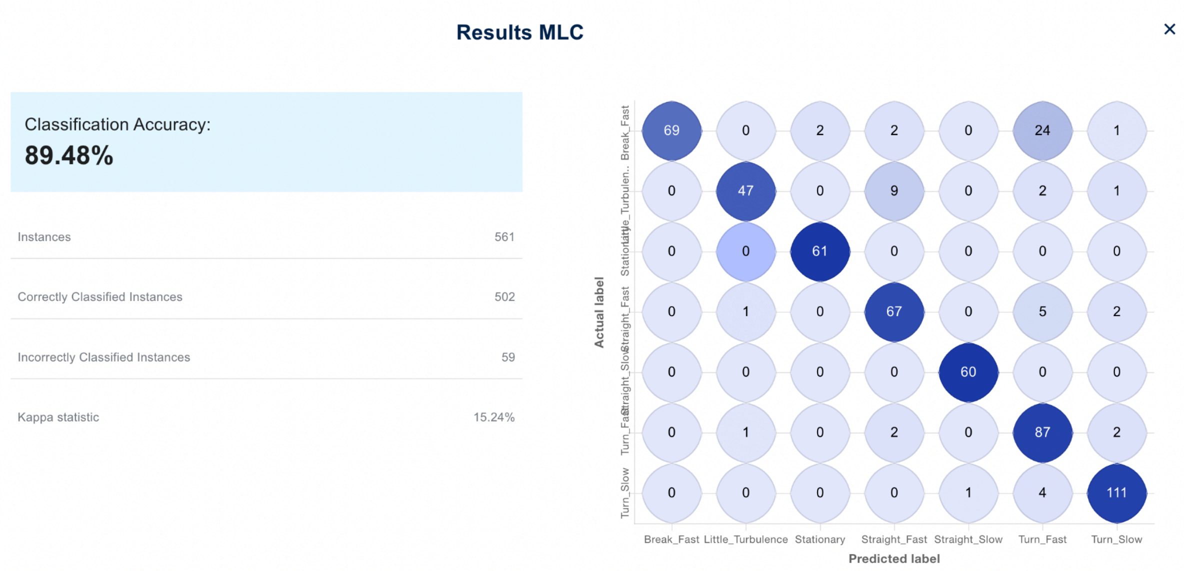


Figure 1.2: Filtered Dataset



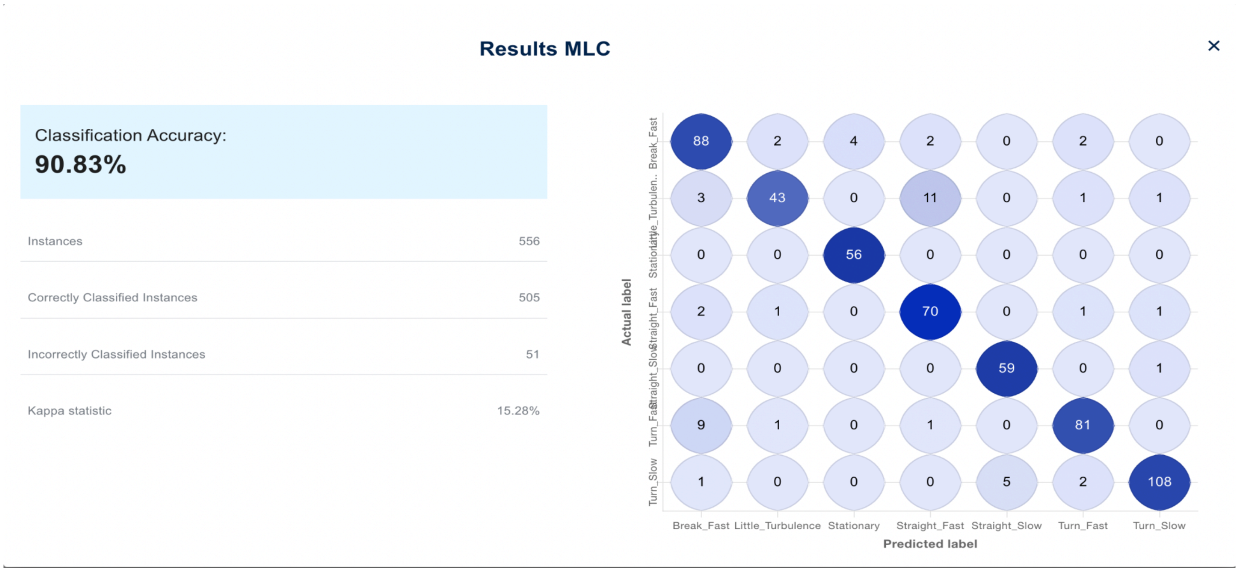
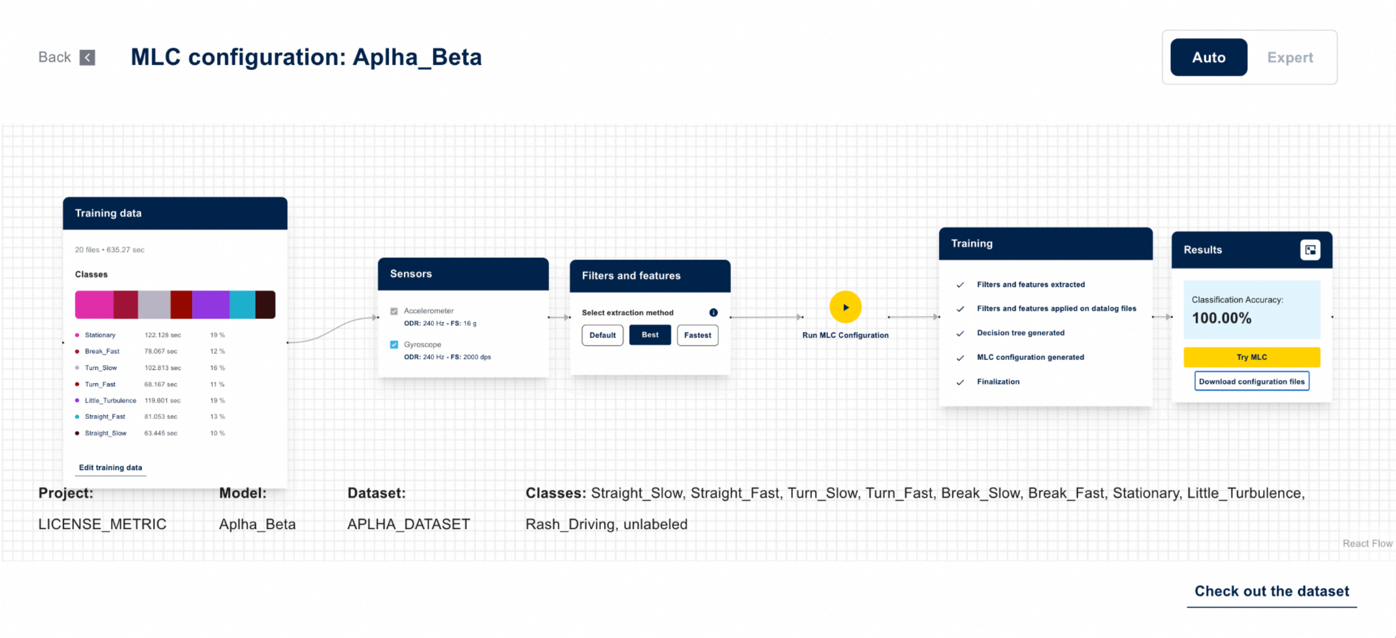


Figure 1.3: MLC Results on Filtered Dataset



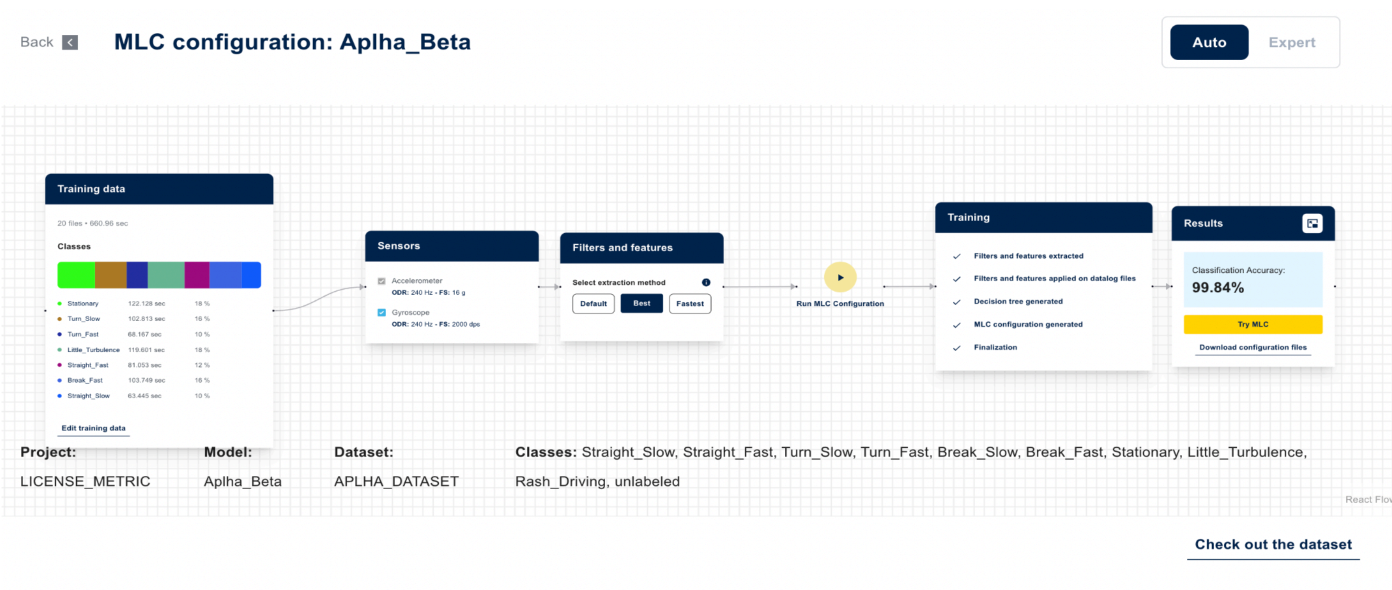


Figure 1.4 : MLC Results on FINAL DATASET(99% - 100 % accuracy)

Implementation Considerations

- The system can be extended to identify additional driving patterns or more nuanced behaviours.
- Real-time feedback could be incorporated to provide immediate guidance to student drivers.
- Long-term data collection could enable personalised tracking of driver improvement over time.

Limitations and Future Work

While our current implementation shows promising results, several areas for future enhancement include:

- Incorporating additional sensor types (e.g., GPS, vehicle CAN bus data) to improve classification accuracy.
- Expanding the training dataset to include more diverse driving conditions and vehicle types.
- Developing a more granular classification system to evaluate specific driving skills rather than general patterns.
- Creating a more user-friendly interface for driving instructors to interpret the results.(Website_Files)

TRACK FOR DEMONSTRATION

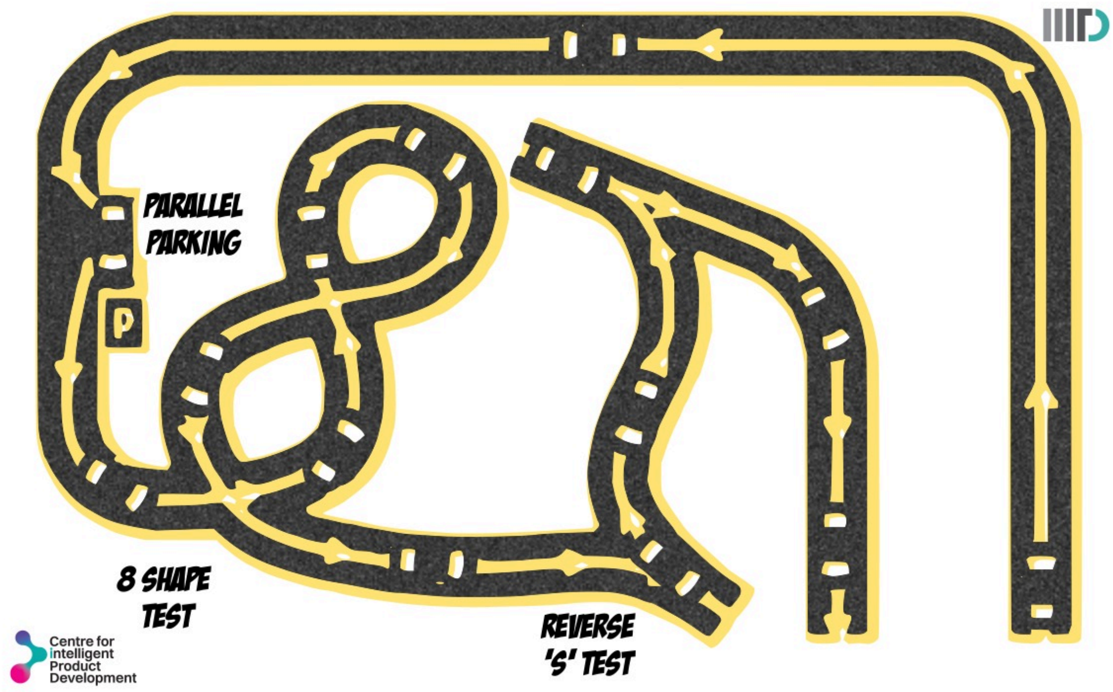


Figure : Track used by Delhi Driving Test Organisations.
Scaled Size : 10 ft x 17 ft

Conclusion

Our Smart Driving Pattern Analysis System demonstrates how embedded sensors, wireless connectivity, and AI-powered classification can transform traditional driving assessment. By providing objective, data-driven insights into driving behaviour, this system has the potential to enhance driver training programs and improve road safety. Using the ST AIoT Craft tool was instrumental in rapidly developing this solution without requiring specialised expertise in machine learning, showcasing how modern development tools can accelerate innovation in applied IoT projects.