

License Metric

Driving Test Feedback System

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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

Ready-to-run use cases					
Model	Target	Dataset	Classes	Actions	
Alpha_Model	SensorTile.box PRO LSM6DSV16X	APIHA_DATASET	Straight_Slow Straight_Fast Turn_Slow Turn_Fast Break_Slow Break_Fast Stationary Little_Turbulence	Train  Run 	...
Alpha_Beta	SensorTile.box PRO LSM6DSV16X	APIHA_DATASET	Straight_Slow Straight_Fast Turn_Slow Turn_Fast Break_Fast Stationary Little_Turbulence	Train  Run 	...

The raw sensor data was collected using the ST AIoT Craft tool, automatically timestamped 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.

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 visualization 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 labeled dataset directly.
- Configure and train a classification model.
- Evaluate model performance.
- Export the trained model for deployment.

This no-code/low-code approach democratized the AI implementation process, allowing team members without specialized 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

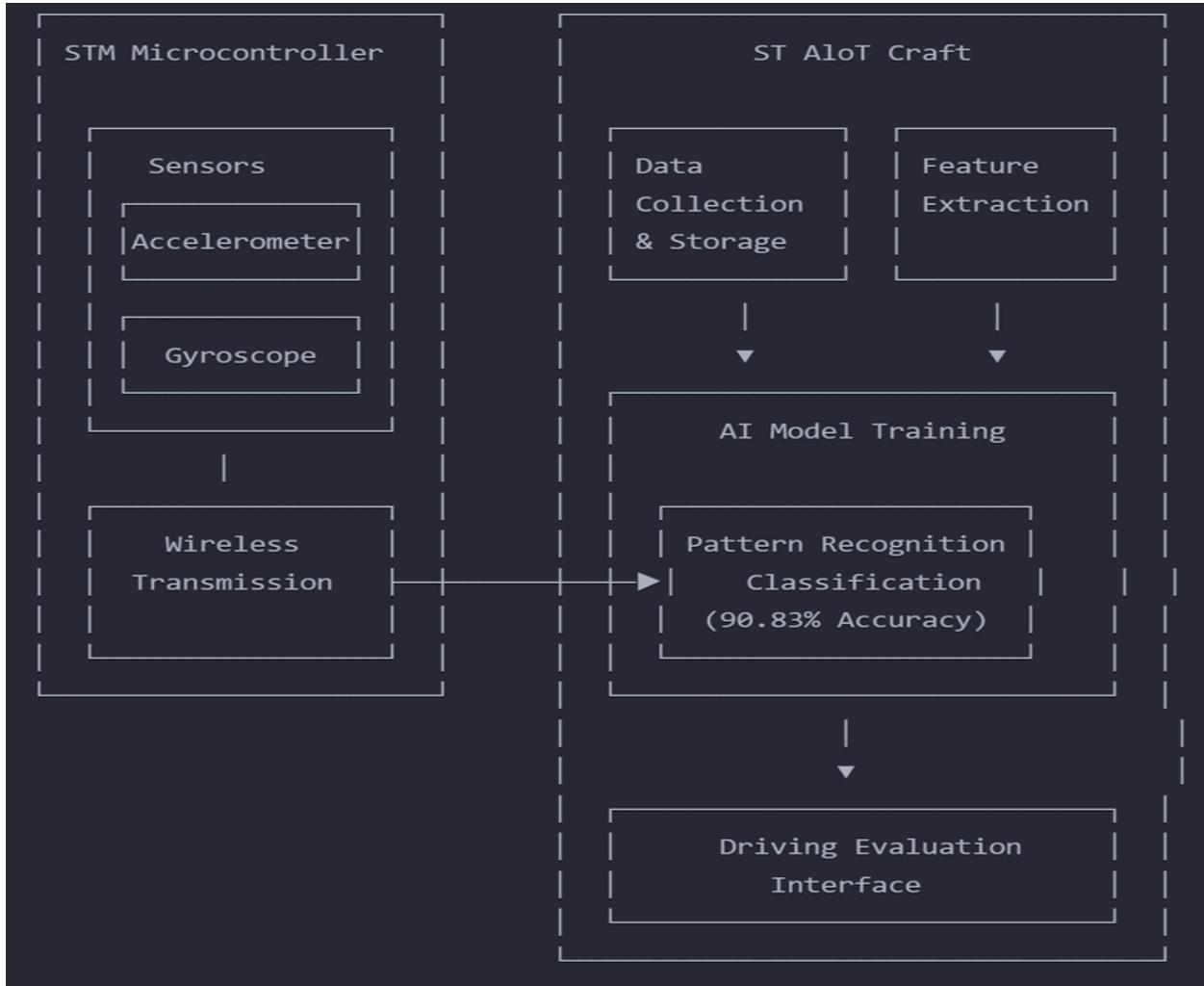
System Architecture

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

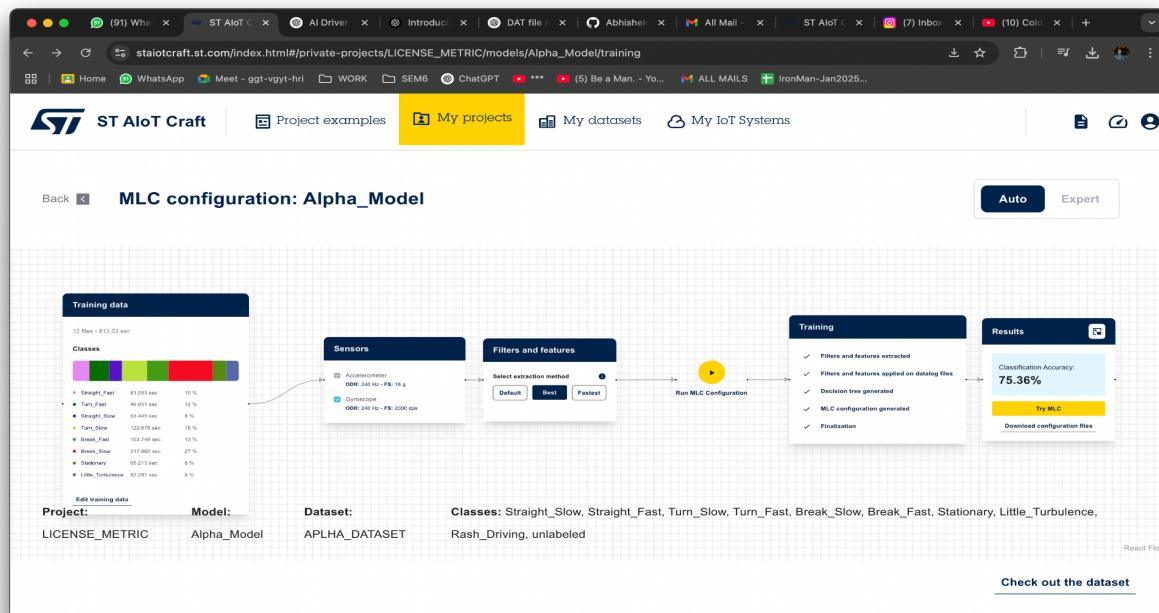




Figure 1.1: Initial Dataset and MLC

We initially utilized the **Alpha model** with all labels in the dataset. However, significant accuracy issues arose due to the "brake slow" label appearing frequently in both actual and predicted classifications. As a result, the model achieved a maximum classification accuracy of **75.36%**.

We then modified the dataset to **Alpha_Beta** and re-recorded the major faulty labels. Ultimately, we decided to exclude the "Brake_Slow" label, as it frequently caused confusion with other labels. **This adjustment led to an improved average accuracy of 89.48%, with a best-case accuracy of 90.83%.**

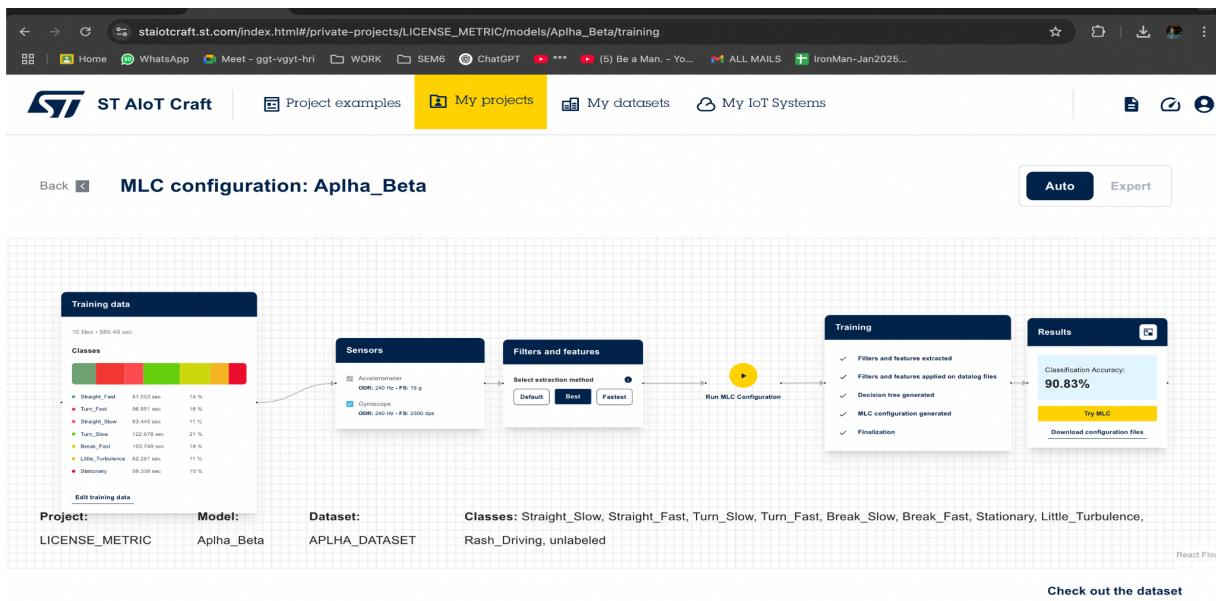
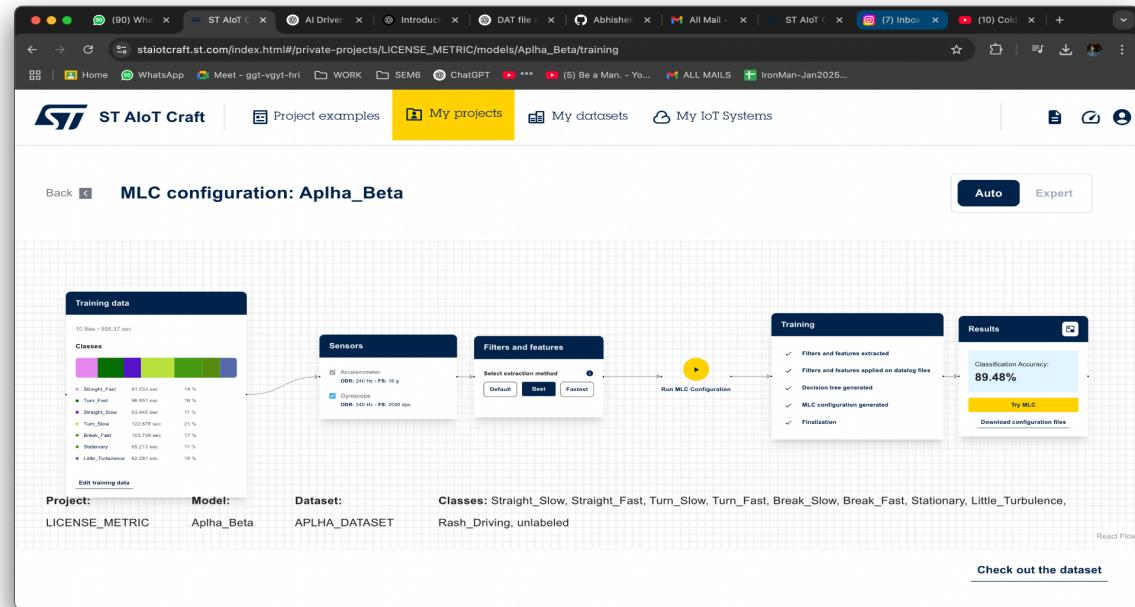
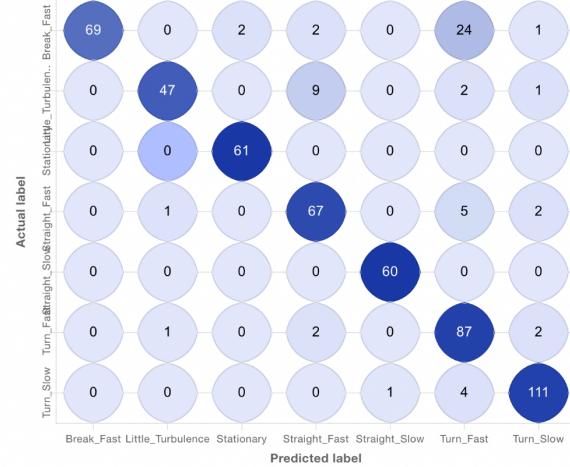


Figure 1.2: Filtered Dataset

Classification Accuracy:
89.48%

Instances	561
Correctly Classified Instances	502
Incorrectly Classified Instances	59
Kappa statistic	15.24%



Classification Accuracy:
90.83%

Instances	556
Correctly Classified Instances	505
Incorrectly Classified Instances	51
Kappa statistic	15.28%

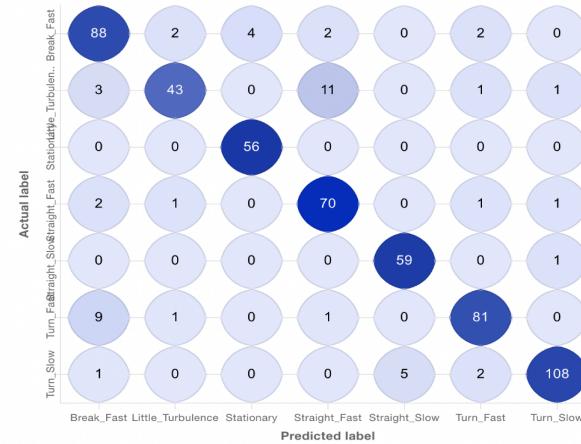


Figure 1.3: MLC Results on Filtered Dataset

Inference:

The AI model trained using the ST IoT Craft tool achieved a training accuracy of 90.83%. This high accuracy demonstrates the system's ability to distinguish between different driving patterns reliably. The model was trained on balanced datasets representing each driving pattern to ensure robust performance across all categories.

Implementation Considerations

- The system can be extended to identify additional driving patterns or more nuanced behaviors.
- Real-time feedback could be incorporated to provide immediate guidance to student drivers.
- Long-term data collection could enable personalized 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](#))

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 AloT 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.