MathWorks
AUTOMOTIVE CONFERENCE 2023
Europe

Deploying AI for on-board mission profile classification of construction equipment vehicles

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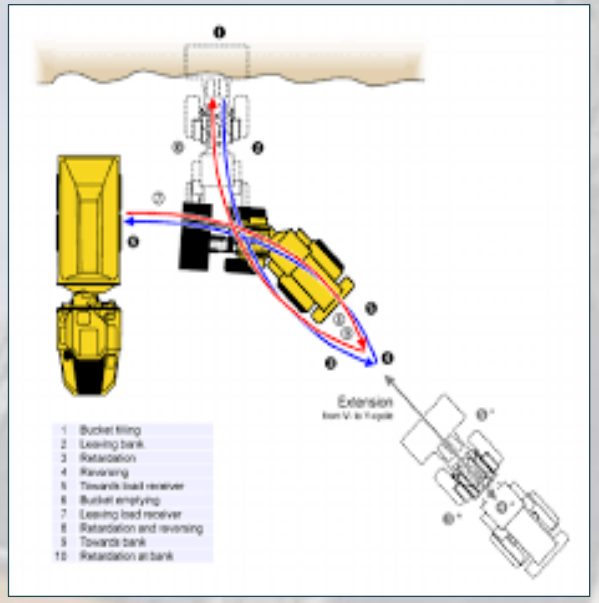
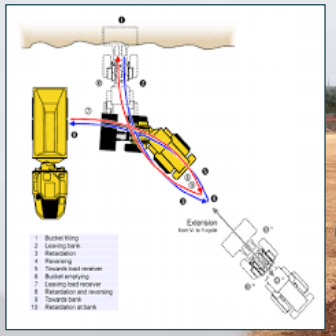
Agenda



- Background – Wheel Loader and Mission Profile
- What we are trying to solve
- Solution & Use Cases - AI for Mission Profile Recognition
- Deployment
- Results
- Next Steps

Wheel Loader and Mission Profile

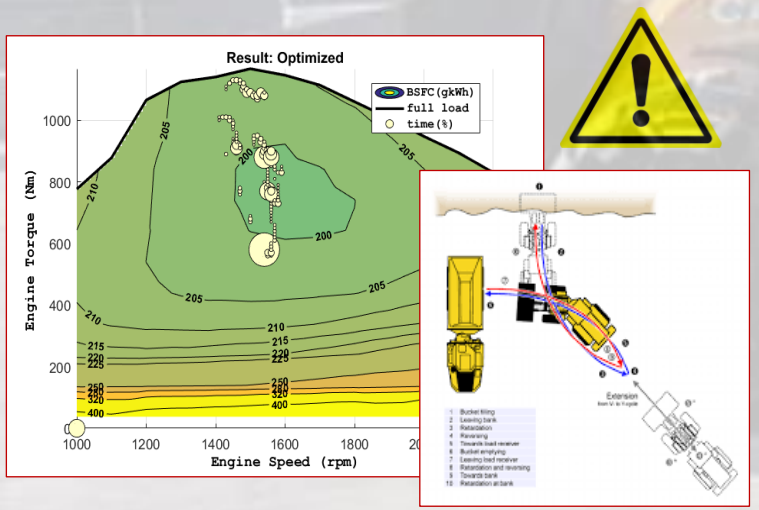
Mission: Scope of the usage of the vehicle corresponding to cyclical execution of a sequence of movements.
Different missions can include similar movements but with different execution speeds and/or arm positioning.



Background - What we are trying to solve

Quality & Product Design

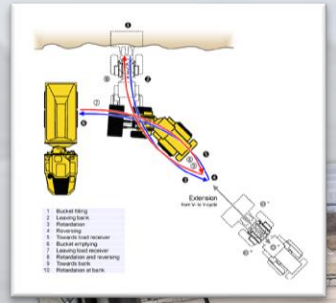
- Poor understanding of vehicle **performances** (Efficiency, Thermal, Aftertreatment) in relation to **vehicle missions**.
- Poor understanding of **Customer Behaviors** in correlation with **system failures**.



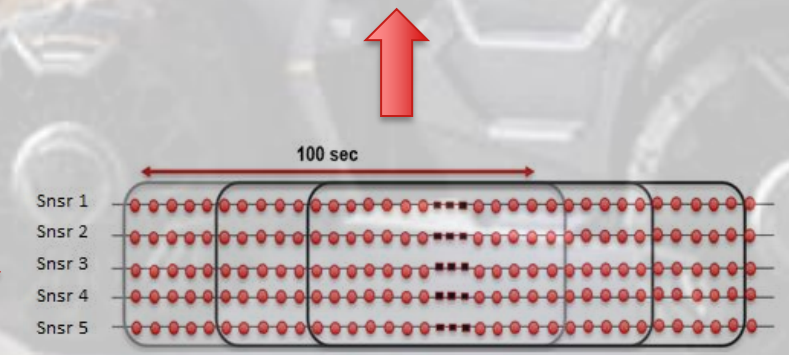
Customer Experience

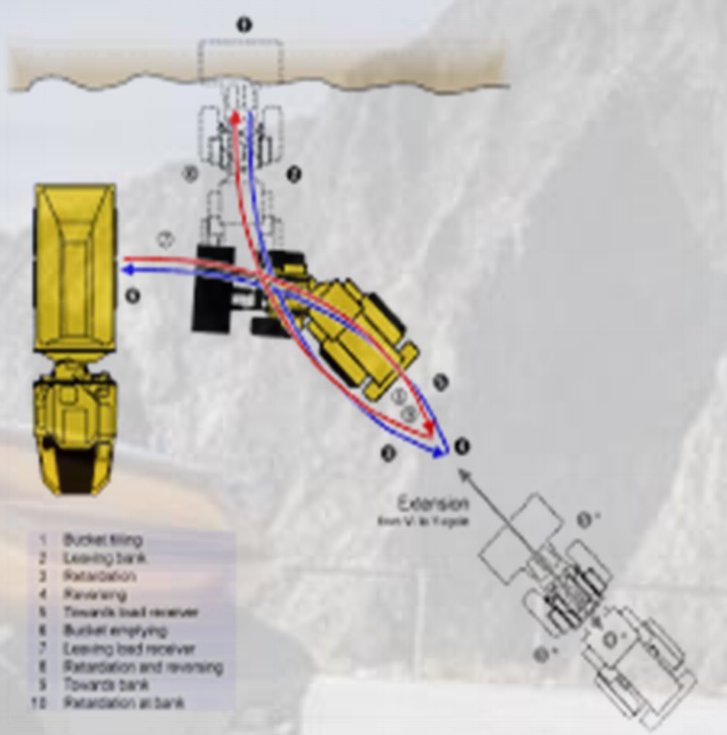
- **Operator not always knows all modes/functions** available on the vehicle and do not use them in the proper way, **based on application**, with an **impact on Productivity and Efficiency**
- **Young or Unexpert operator** usually **misuse** the vehicle

Solution: AI for Mission Profile Recognition



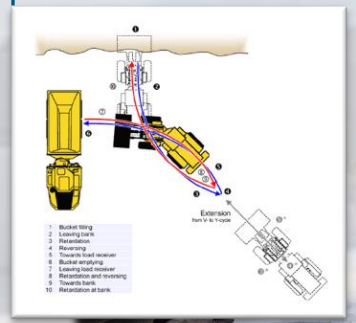
On-Board



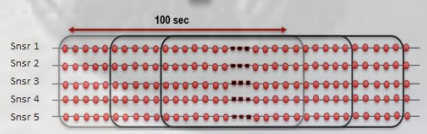


Use Cases – Advanced Dashboard & Predictive Maintenance

Development of an **Advanced Dashboard** for the **Real Time Monitoring** of **fleet KPI** with **respect** to the **overall Missions** for the identification of outliers.

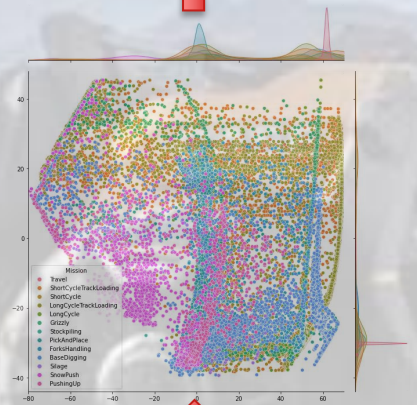


1 - Operator drives the vehicle



2 - Real Time Data are collected On Board

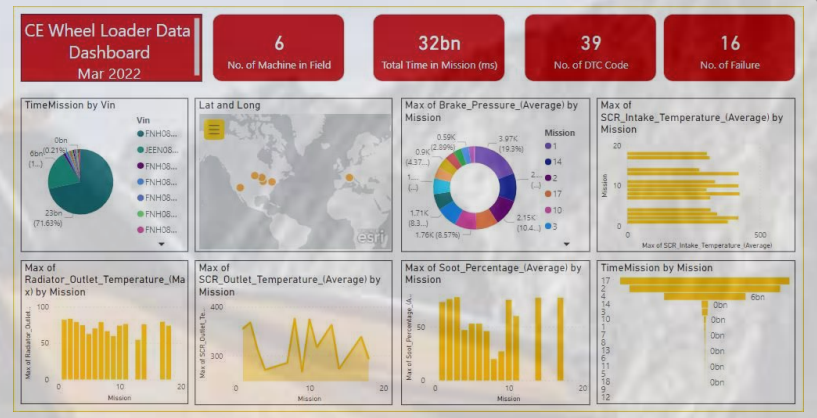
3- AI Algorithm



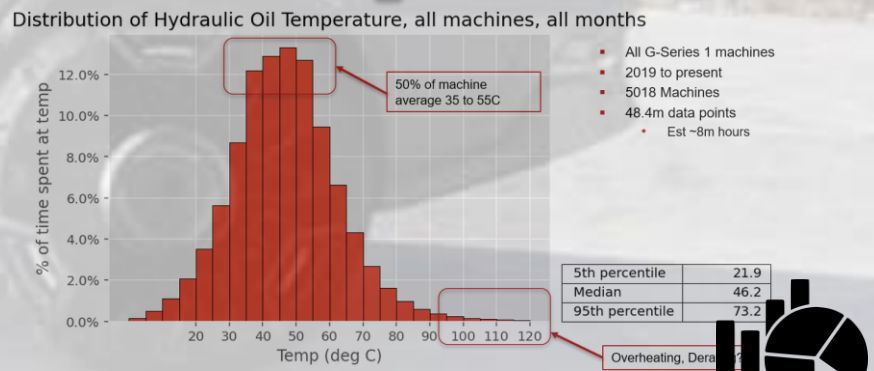
4 - Mission Recognized

On-Board

Off-Board

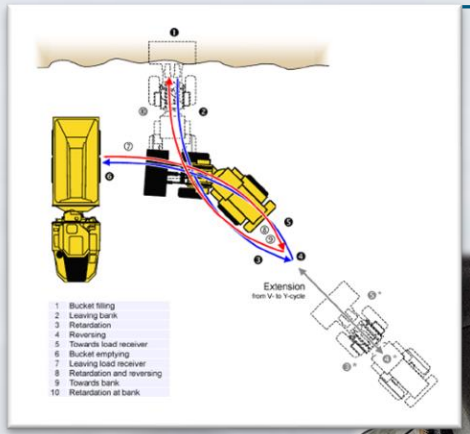


5b - Advanced Dashboard



5a - Standard Statistics

Use Cases – Virtual Assistant

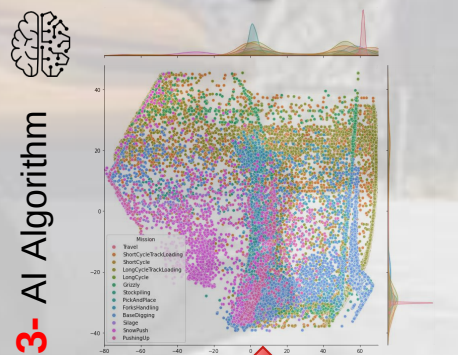


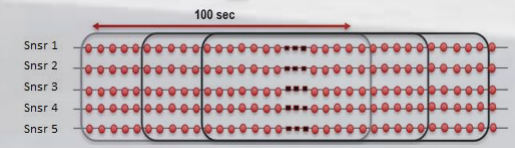
Artificial Intelligence System able to **suggest** operative **modes** and **parameters setting** on top of the automatic recognition of the mission performed.

5 – Vehicle provides suggestion

4 - Mission Recognized

3- AI Algorithm





1 - Operator drives the vehicle

2 - Real Time Data are collected On Board

System Architecture

Sensors

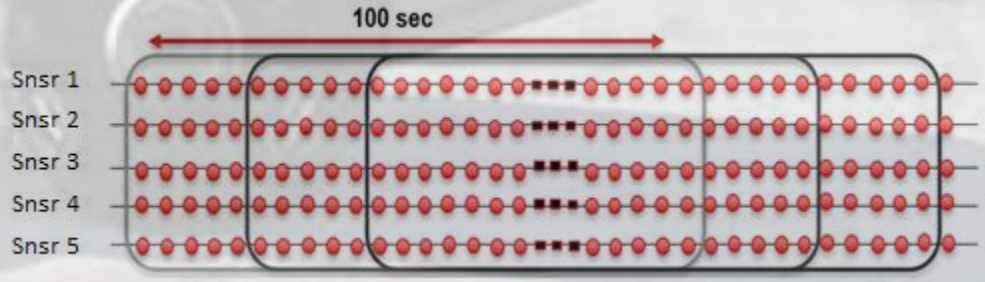
Display Controller

Engine Controller

Transmission Controller

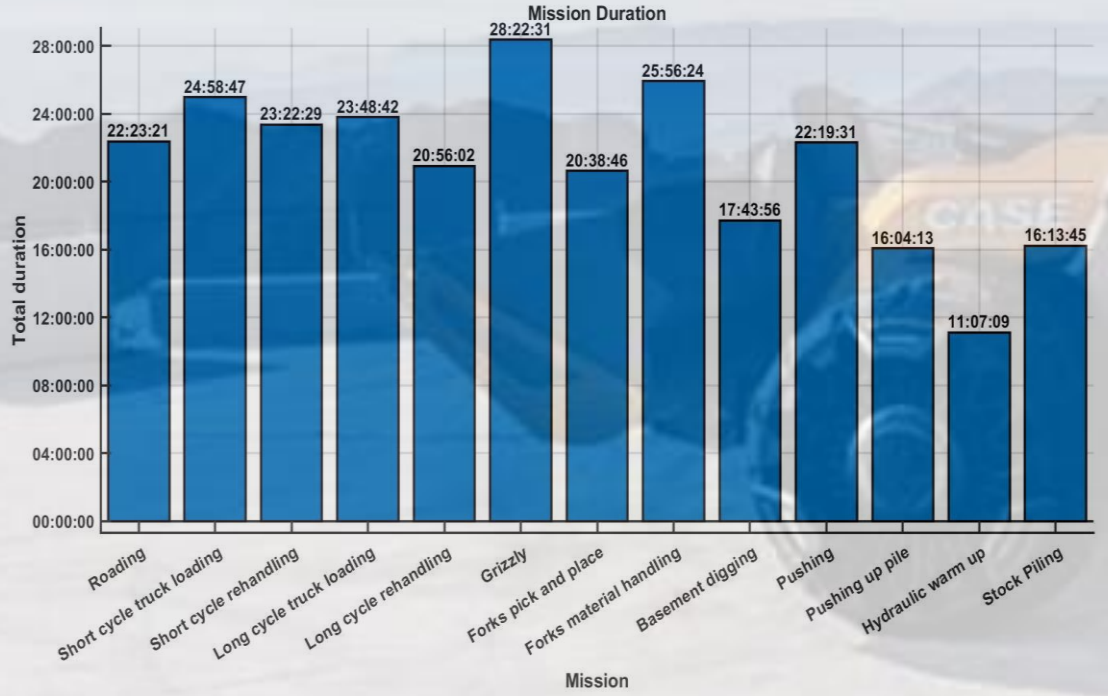
CAN BUS

Vehicle Controllers



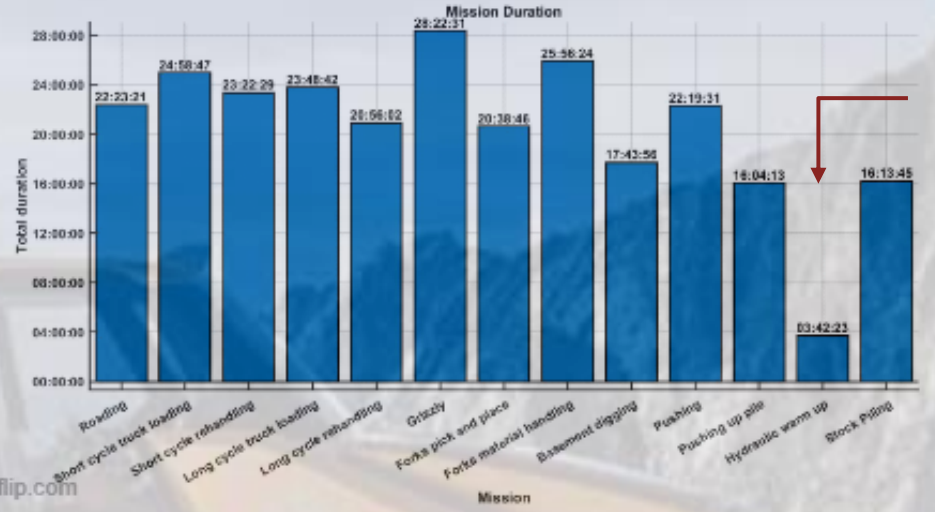
Data Collection/Labeling

Number of Missions:13
Training set duration: 273.9 hours

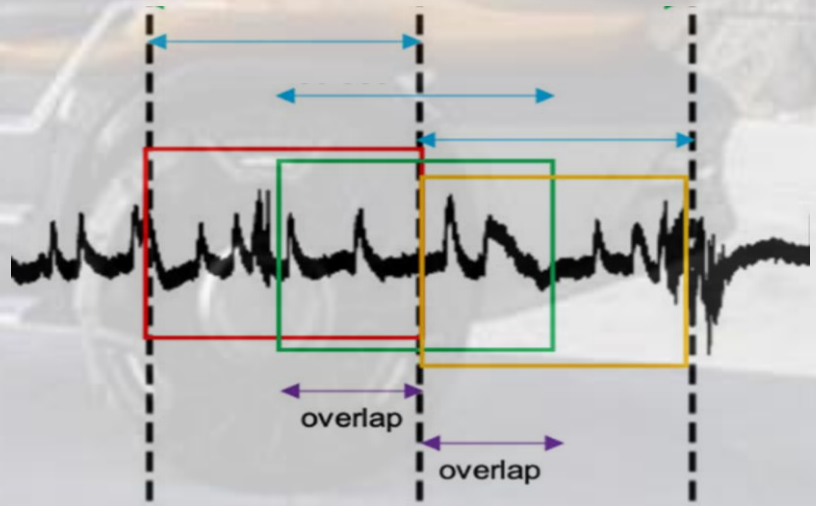


Dataset Manipulation

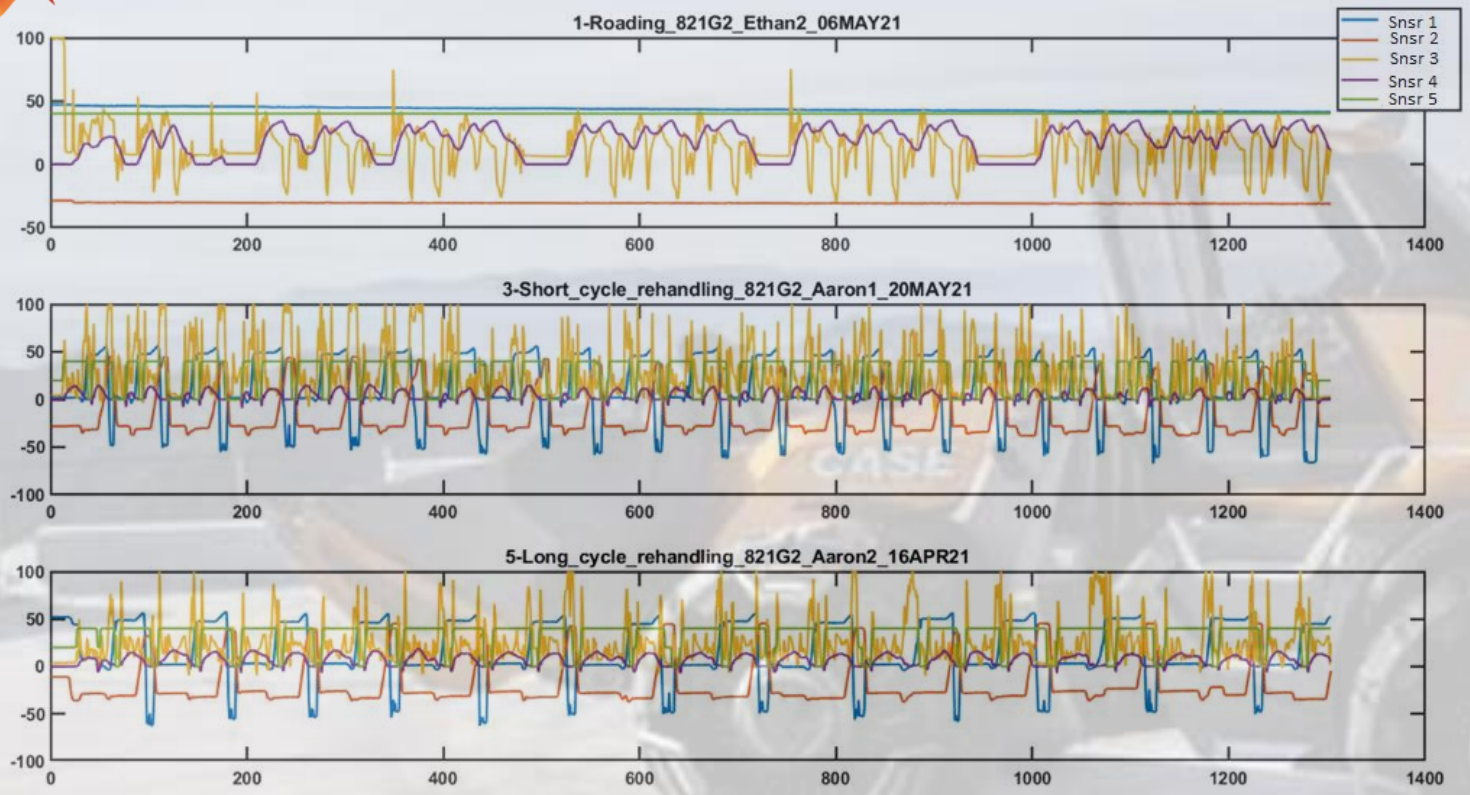
- **Data Augmentation:** Hydraulic Warmap is a short duration activity. Data augmentation, varying boom, bucket ans vehicle speed range, is a good solution to get more data.

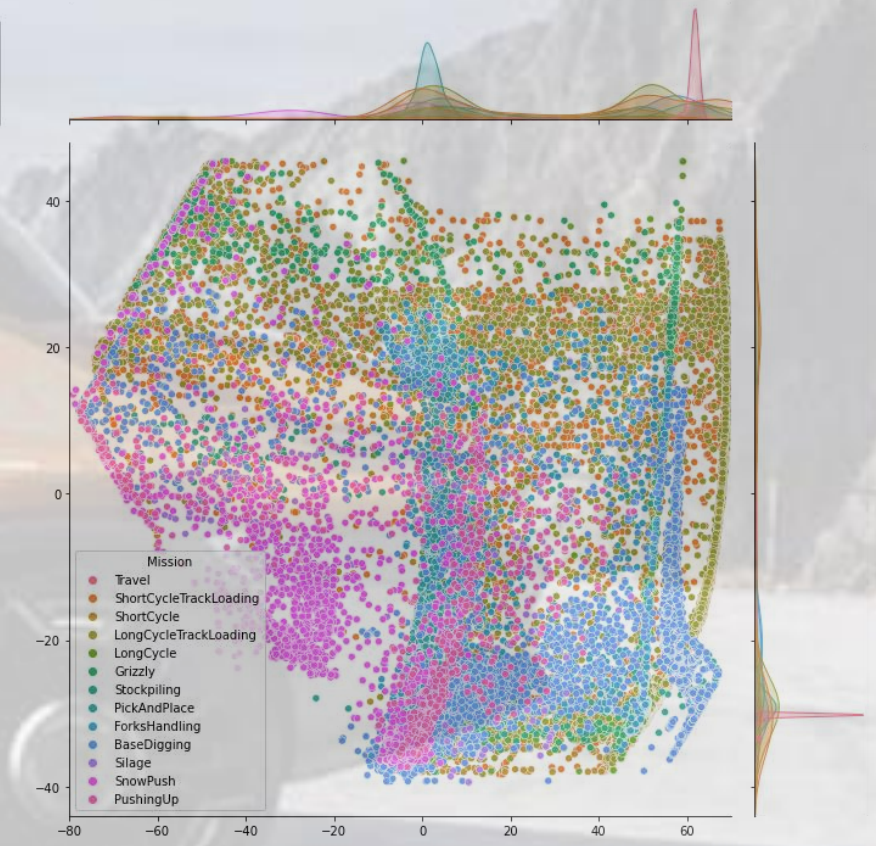


- **Dataset Balancing:** To get the same number of windows among missions, since they have different time duration, a GA was used to calculate the ad-hoc overlap to be applied at each mission

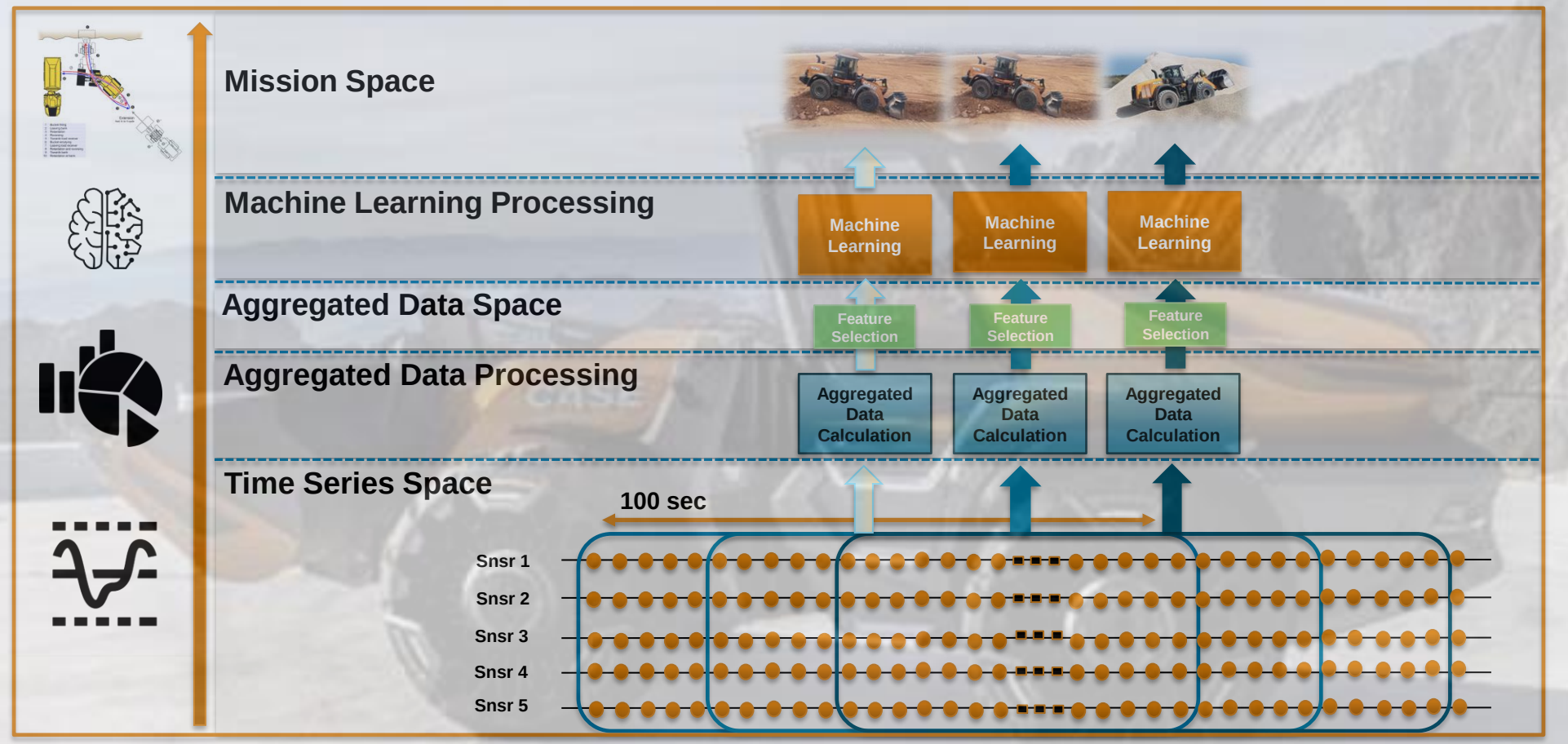


Data Exploration

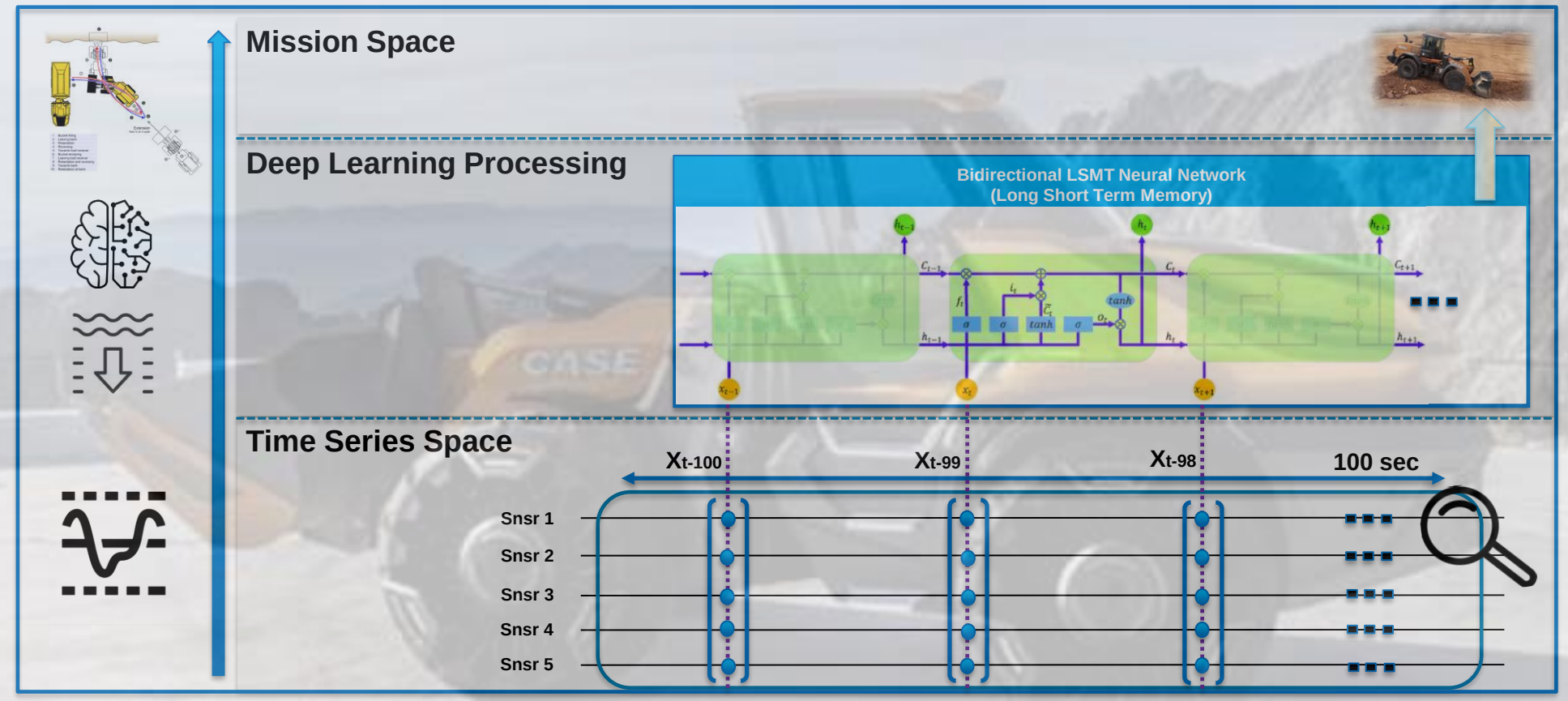




Machine Learning Versus Deep Learning

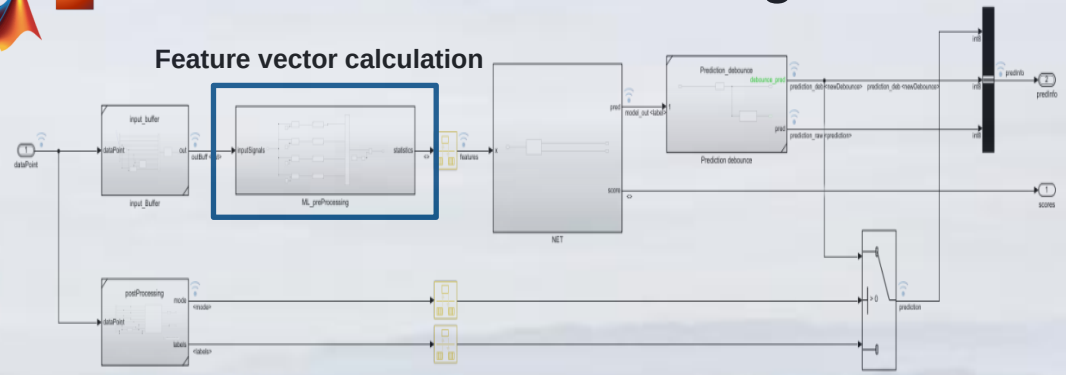


Machine Learning Versus **Deep Learning**



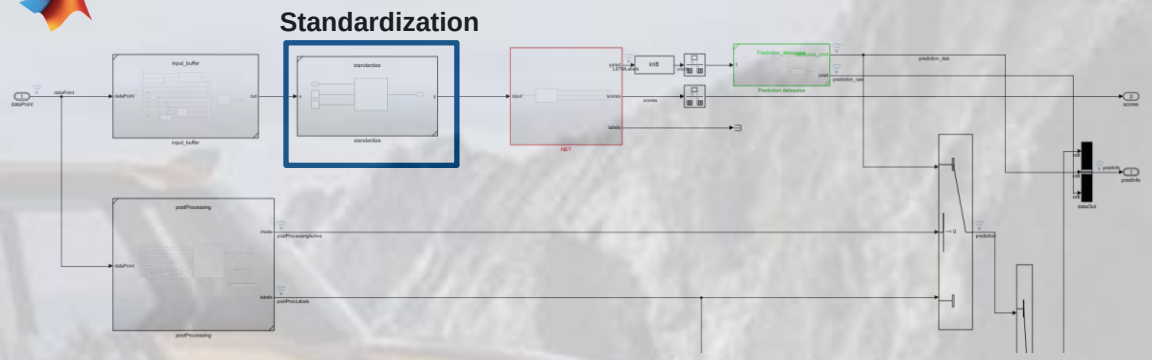
Machine Learning Versus Deep Learning: Deployment

Machine Learning

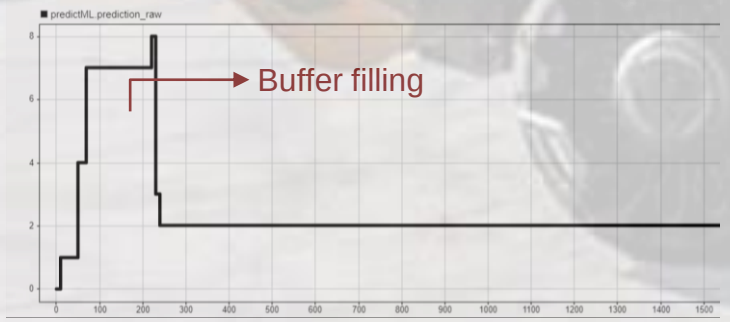


- Feature extraction and selection for feature vector creation as ML input;
- Slower training process;
- More stable prediction;
- Higher test set accuracy (91%).

Deep Learning

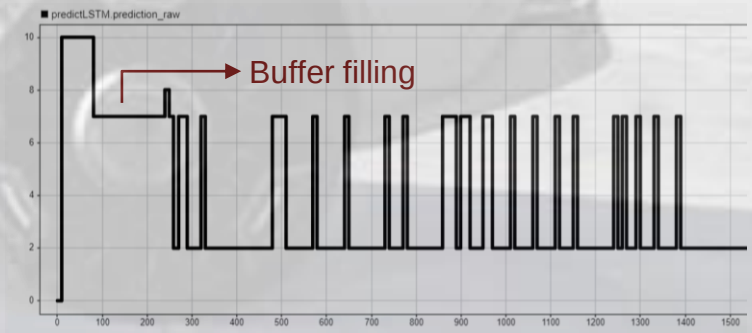


- Time domain standardized signal as LSTM input;
- Faster training process;
- Less stable prediction;
- Lower test set accuracy (88%).

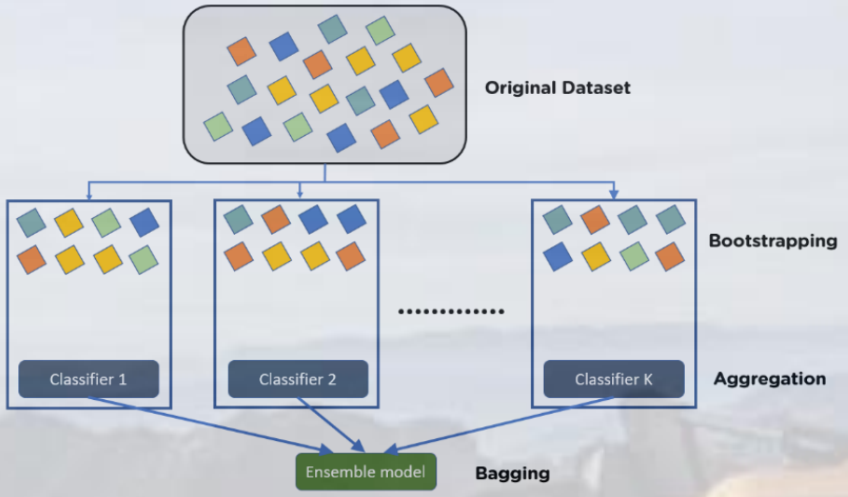


Prediction

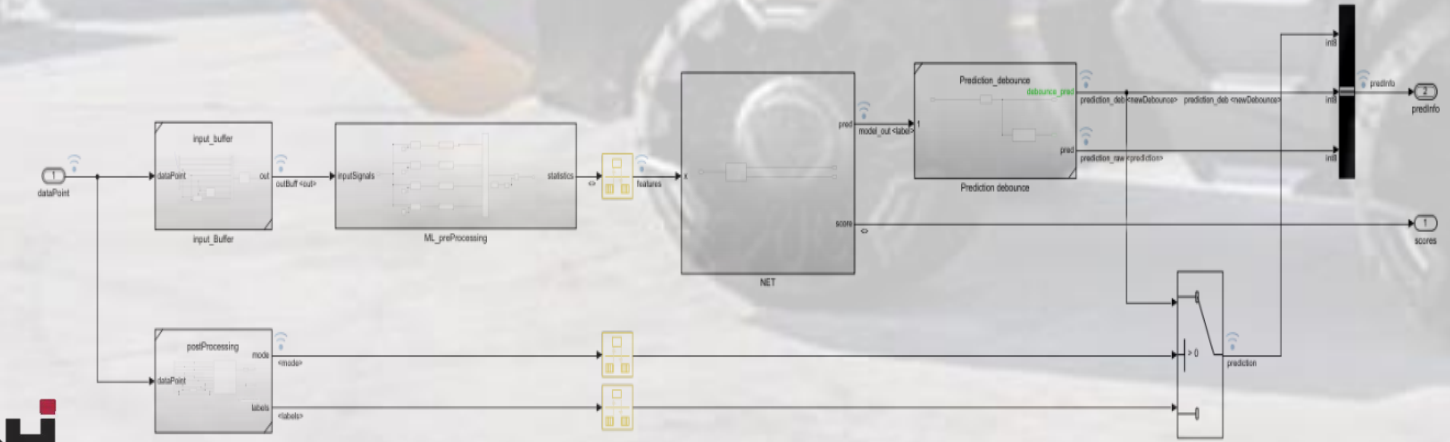
Mission 2



Software Deployment



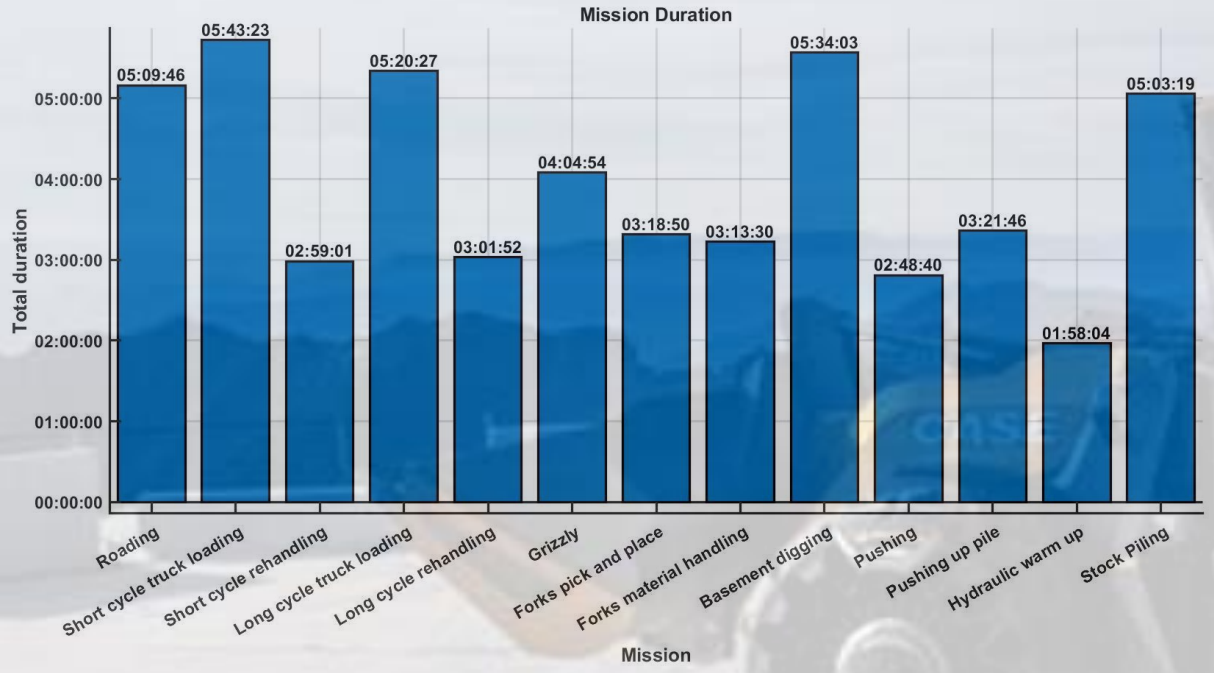
- **ML algorithm trained in Matlab** using *Classification Learner App*
- ML algorithm is based on **Classification Trees** (*Ensemble Bag* technique)
  - Bagging **minimizes the overfitting** of data (Reduce the variance)
  - It **improves** the model's **accuracy**

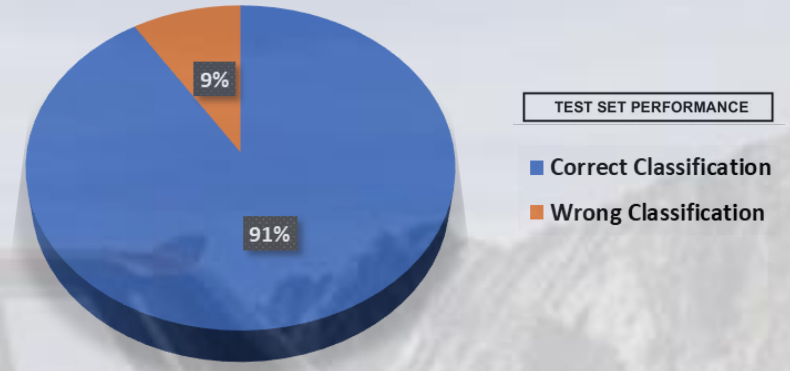


- Model developed in *Simulink*
- C++ code generated with *Embedded Coder*
- Used HW: ARM, 4Core, Linux

Results/Performances

Test set duration:51.6 hours





Missclassifications happen principally between similar missions such as in forks case (Mission 7-8)

TEST SET PERFORMANCE

True Class \ Predicted Class	1	2	3	4	5	6	7	8	9	10	11	12	13	
1	1820													100.0%
2		1912	53	15				2						96.5% 3.5%
3		1	981		5		3	6	17	1	2			96.6% 3.4%
4	1			1689	45	21	2	77				1	9	91.5% 8.5%
5	6	5		27	896		77	21		13			7	85.2% 14.8%
6				99		1310		2						92.8% 7.2%
7							886	248						78.1% 21.9%
8							128	975						88.4% 11.6%
9			93						1873					95.3% 4.7%
10	2		21		39			1		883	27			90.8% 9.2%
11			32	2			2	1	2	185	909			80.2% 19.8%
12		23	1	5			7	26	1			371		85.5% 14.5%
13					10	121		96	1				1553	87.2% 12.8%
	99.5%	98.5%	83.1%	91.9%	90.1%	90.2%	80.2%	67.0%	98.9%	81.6%	96.9%	99.7%	99.0%	
	0.5%	1.5%	16.9%	8.1%	9.9%	9.8%	19.8%	33.0%	1.1%	18.4%	3.1%	0.3%	1.0%	
	1	2	3	4	5	6	7	8	9	10	11	12	13	

Predicted Class

Mathworks Collaboration

FINE TUNED MODEL

Final model developed and fine tuned to recognize all missions.

PROTO UNIT

Integration of model in Vehicle controller for Real Time Mission Recognition

Modeling

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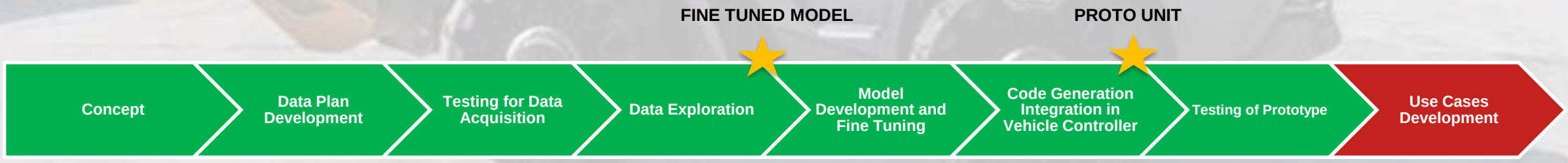
Code Generation



Next Step

- Transition to LSTM with more data
- Development of Use Cases
- System to get labeled data from customer

Thank you for the attention!