

Development of an Edge Device and Cloud Environment for Replica Vehicle Implementation

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Establishing vehicle durability targets requires suspension load and wheel force data obtained under actual driving conditions. Collecting these data from a large number of vehicles, however, is costly and time-consuming because suspension load cells, wheel force transducers (WFTs), instrumented vehicles, and specialized test personnel are required. Replica vehicle technology addresses this limitation by combining a small number of sensors with surrogate models to estimate suspension loads and wheel forces without extensive vehicle instrumentation. This study developed an onboard and cloud framework for applying previously developed AI-based suspension load and wheel force prediction models to production vehicles.

The onboard system integrates the NVIDIA Jetson AGX Orin platform with a commercial ReXGen Air data logger. The resulting edge device acquires raw vehicle CAN data, six-axis inertial measurement unit data, global navigation satellite system data, and measurements received from an external data acquisition system. Four CAN FD ports accommodate both vehicle network signals and additional CAN-based instrumentation, while an LTE/5G modem supports communication with a remote server. This configuration reduces the number of separate devices required for installation and avoids the cost associated with developing a dedicated hardware platform.

The Robot Operating System (ROS) provides the software framework for data processing, model training, and inference. CAN frames received through the Linux SocketCAN interface are decoded using the signal definitions in a DBC file and converted into ROS topics. The topics are recorded as training data, together with measured load data used as training targets. Previously developed recurrent neural network (RNN) models were retrained on the Jetson AGX Orin platform. The trained models are stored on the server and can be deployed in either the onboard or cloud environment. The edge device also supports inference using locally stored measurements or data downloaded from the server.

RViz was adopted for onboard visualization. Steering angle, wheel speed, inertial measurements, suspension spring displacement, measured loads, and model outputs can be displayed through a real-time vehicle representation. This function allows users to review vehicle dynamics and prediction results during vehicle operation without relying on separate visualization equipment.

For remote data management, measurements recorded by ReXGen Air are uploaded via LTE/5G networks and stored in Amazon Web Services S3 buckets. Server-side functions support RNN model training and inference, while a web-based dashboard provides access to training results, prediction outputs, and continuously uploaded raw CAN data. Thus, the same dataset and trained model can be used across the onboard and cloud environments.

The developed framework supports both direct load measurement and virtual-sensor-based load estimation using a common device architecture. The framework is intended for large-scale acquisition and estimation of suspension loads and wheel forces across vehicle fleets with minimal instrumentation. Such fleet-scale data can contribute to durability test modes that better represent customer usage and may also support vehicle diagnostic, supervisory, and monitoring systems. Ongoing work focuses on scenario-route design and driving-pattern development to improve the model training process and the accuracy of replica vehicle models.

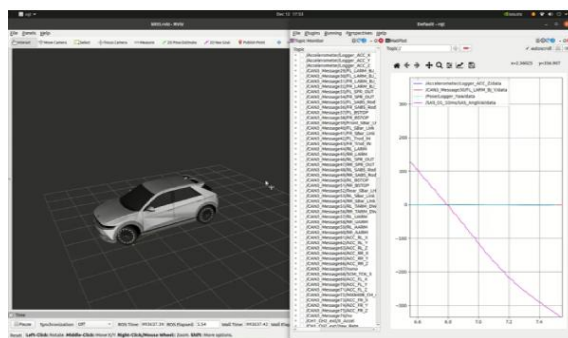


Fig.1 Visualization of vehicle motion data using RViz



Fig.2 Web browser-based dashboard