Demo: Telematics Data Collection from BeamNG with Openpilot Integration

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Abstract

We present a framework that integrates BeamNG.tech's high-fidelity vehicle simulation environment with Comma.ai's Openpilot autonomous driving system. This framework provides an accessible platform for automotive security researchers to collect realistic telematics data, simulate in-vehicle networks, and develop security solutions without requiring access to specialized hardware. Our system bridges the gap between simplified simulations and real-world vehicle behavior, enabling a wide range of research applications in automotive as well as broader research areas such as transportation, environment and emissions related fields.

1 Introduction

Vehicle security research spans multiple areas, including cybersecurity, transportation safety, and autonomous driving technologies. However, researchers often face significant barriers when attempting to collect realistic vehicle data: physical test vehicles are expensive and modifications can be destructive; collecting large amounts of data takes significant time and resources; incorporating vehicle diversity is difficult with physical vehicles; and simple simulations lack fidelity of physical properties for realistic telematics data. Our work addresses these challenges by developing a framework integrating BeamNG.tech's research-oriented vehicle simulator [1] with autonomous driving systems. We demonstrate the framework through the integration of the comma.ai Openpilot autonomous driving system [2]. This combination creates a research platform that balances realism with accessibility, providing high-quality telematics data suitable for security research without the associated costs of hardware-based approaches.

2 Simulation Platform Comparison

We compared several popular vehicle simulation environments before selecting BeamNG.tech. When comparing BeamNG.tech [1], CARLA [3], and MetaDrive [4], BeamNG.tech offers the most advanced and realistic vehicle physical modeling with its soft-body simulation, while CARLA provides a good physical model but focuses more on the overall autonomous driving ecosystem, and MetaDrive prioritizes lightweight performance and compositionality over absolute realism. For target use cases, MetaDrive focuses on reinforcement learning research and generalization testing; CARLA serves as a comprehensive platform for autonomous driving research and development; and BeamNG.tech excels in vehicle dynamics, crash testing, and detailed physics-based simulations. Regarding visual fidelity, CARLA offers the most photorealistic rendering, BeamNG.tech has good visuals with exceptional physical detail, and MetaDrive sacrifices some visual fidelity for performance. All three offer good customizability but in different ways: MetaDrive excels at procedural generation of diverse scenarios, CARLA has a rich ecosystem of tools and assets, and BeamNG.tech offers unmatched vehicle physics customization. For our research purposes, BeamNG.tech's superior physics simulation was the determining factor, as accurate vehicle dynamics are essential for generating realistic telematics data.

3 BeamNG.tech Platform

Based on our comparison, we selected BeamNG.tech for our research. The BeamNG.tech platform features soft-body physics for realistic vehicle dynamics simulation, a comprehensive Python API for programmatic control and data collection, fine-grained access to control different sensors (Camera, Lidar, IMU, Electrics), rich telematics data generation including sensor readings typically found in modern vehicles, and a detailed physics model accounting for suspension geometry, tire friction, drivetrain behavior, and other vehicle properties.

4 Openpilot Integration

Our primary contribution is a bidirectional interface between BeamNG.tech and Openpilot. Using BeamNG's Python API, we implemented a virtual camera that captures the driver's perspective (dashcam) and streams this feed to Openpilot's vision processing pipeline.The framework streams control signals (throttle, brake, steering angle) from Openpilot's control algorithms to BeamNG, while simultaneously returning vehicle state feedback (speed, actual steering angle) back to Openpilot.

The system captures comprehensive telematics data in standardized formats suitable for security research, including:

- Engine metrics: RPM, thermal readings, torque measurements (40+ features)
- Input controls: Gas, brake, clutch positions
- General vehicle state: Speed, yaw, air speed, position (20+ features)
- Powertrain parameters
- Wheel-specific data: Individual wheel speeds, per-wheel brake status, tire volume (40+ features)
- Custom sensor data: Camera streams, LiDAR point clouds, IMU readings, electrical system parameters

For our implementation, BeamNG runs on Windows while Openpilot operates in Ubuntu through Windows Subsystem for Linux (WSL).

5 Demonstration

During the conference, we will present a poster and demonstrate a vehicle in BeamNG controlled by Openpilot. Attendees will have the opportunity to interact with the system and change the vehicle type, map, cruise speed etc.

6 Results and Challenges

Our framework enables the generation of telematic datasets for research purposes with several advantages: diverse set of vehicles, large scale data generation without human supervision, and fine-grained data with hundreds of features. We faced challenges in figuring out the ideal steering angle ratio for each vehicle and dealing with platform differences (BeamNG:Windows and Openpilot:Linux) that made camera streaming slow. BeamNG supports camera streaming using shared memory but only within the same operating system. Without shared memory, streaming camera frames through network sockets was not very efficient. BeamNG on Linux is "experimental" and Openpilot only works in Linux. So we had to use Windows with WSL.

7 Applications

7.1 Automotive Security Research

The platform supports CAN Bus data generation. This synthetic CAN Bus data allows researchers to develop and test intrusion detection systems without specialized hardware. It enables Anomaly Detection testing against various attack scenarios in vehicle telematics data streams, and Attack Vector Exploration where researchers can safely explore potential attack vectors in advanced driver assistance systems.

7.2 Additional Research Areas

Additional applications include Insurance and Risk Management through simulation of driver behaviors for risk profiling and premium calculations; Environmental Impact analysis of driving patterns and their effects on emissions and fuel efficiency; and Driver Behavior Modeling for the development of models to identify unsafe driving behaviors.

8 Future Work

Our ongoing development focuses on bug fixes and seamless environment setup by solving the camera communication bottleneck. We will release the data collected through in PIVOT project [5]. In the future, we want to implement a complete CAN Bus simulation with attack vector injection. So instead of integrating BeamNG directly with Openpilot, we could add a simulated CAN Bus layer in between. This would allow us to simulate attacks.

9 Conclusion

The integration of advanced telematics data collection and Openpilot with BeamNG creates a powerful research environment for vehicle security investigations. This platform reduces barriers to entry for automotive security research while maintaining high fidelity to real-world vehicle systems.

References

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