DIGITAL TWIN OF AN ELECTRIC VEHICLE

Authors: GHERMAN Antonio

MICHICIUC Viviana Gabriela Veronica

MOISE Roxana Teodora

DUMITRAȘCU Luca Georgian

FLORESCU Alin Constantin

# TASK 1: Identify the System, Its Form and Function

# TASK 2: Identify the entities of the system, their form and function and the system boundary and context

# Task 3: Identify the Relationships among the Entities

# Task 4: Predicting Emergence

4.Unintended emergence refers to **unexpected or** 2 Unintended emergence:

Unintended emergence **intended outcomes** that occur as a result of the complex interactions between the physical and digital systems in the car.

These outcomes may not have been anticipated during the design of the digital twin and could include: battery degradation over time, increased demand on the electrical grid, and the generation of electronic waste.

Battery Degradation: Over time, the repeated charging and discharging cycles can reduce the battery's capacity and efficiency, leading to shorter driving ranges and the need for costly replacements.

Increased Grid Load: As the number of EVs increases, the demand on the electrical grid could surge, especially during peak charging times. This may result in grid instability or require significant infrastructure upgrades.

Electronic Waste: The production and disposal of batteries and electronic components could lead to environmental issues if not managed properly, creating new challenges in terms of recycling and waste management.

These unintended emergences highlight the need for continued innovation and infrastructure development to fully realize the potential benefits of electric vehicles without significant negative consequences.

4.3 F**unction + functional interaction description**

Performance Optimization

The digital twin continuously collects and analyzes data from the physical vehicle’s systems (battery, motor, drivetrain) to enhance vehicle performance. Through simulations, it optimizes energy usage, adjusts regenerative braking, and improves motor efficiency based on real-world driving conditions. This enables the vehicle to operate in the most efficient manner possible under various scenarios.

The digital twin interacts with real-time data streams from the vehicle’s sensors, which monitor parameters like speed, temperature, power consumption, and battery status. This data is fed back into the virtual model to simulate different optimization strategies, which are then sent back to the vehicle for real-time adjustments.

For example, the twin might detect that a specific driving pattern leads to higher battery drain. Based on this, it could suggest more energy-efficient driving behaviors or adjust vehicle settings (like regenerative braking) to maximize efficiency

Predictive Maintenance

The digital twin is used to anticipate failures before they occur. By monitoring component wear (e.g., battery degradation, motor efficiency), the twin predicts when parts will need maintenance or replacement. This prevents unplanned downtime and ensures the vehicle remains operational for longer periods.

Sensors embedded in the vehicle continuously feed data to the digital twin, which tracks the status of critical components. If an anomaly is detected, like excessive heat in the motor or irregular charging behavior, the twin can analyze the data and predict when a failure is likely to occur. This information is then shared with the maintenance system or service provider, enabling timely repairs or part replacements before actual breakdowns

For instance, in a fleet of electric vehicles, the digital twin could identify which vehicles need maintenance and prioritize them, ensuring that vehicles are serviced before critical failures happen.

Customization and Personalization

The digital twin allows for personalized adjustments to the vehicle’s software and settings based on the driver’s behavior and preferences. It creates a unique model of how each driver operates the vehicle, helping to optimize energy consumption and vehicle response based on individual patterns.

As the vehicle is driven, the digital twin learns the driver’s habits—such as acceleration patterns, braking tendencies, and preferred routes. It uses this information to recommend or automatically apply customized settings, such as adjusting throttle response for smoother acceleration or increasing regenerative braking in urban driving environments to improve battery life. This creates a seamless interaction between the driver and vehicle, enhancing both comfort and efficiency

These functions illustrate the intended emergence of digital twin technology in electric vehicles, where the **goal-driven interactions** between real-world data, simulations, and digital models lead to optimized performance, reduced maintenance costs, and enhanced personalization.