DIGITAL TWIN OF AN ELECTRIC VEHICLE

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What are Digital twins?

- The concept of digital twins emerged around 20 years ago, having been developed and improved as technologies for simulation, sensor hardware, and real-time data transmission have advanced.
- This concept represents a faithful copy of a physical process, system, or object, with the copy being virtual, created by providing real and as concise data as possible related to the physical model.
- With the help of such a virtual model, you can simulate, monitor, or optimize the performance of an existing physical model. This concept helps in the better development of the physical model without causing damage or destroying the physical model in any way. Thus, the virtual model is powered by data collected from the physical model's sensors, allowing various scenarios to be simulated or specific data to be better analyzed to make decisions related to the physical model.
- This concept is used in industry and manufacturing, in product design and development, in the medical field, in energy, and many other sectors.
- This concept is also used in car manufacturing, especially for electric vehicles. Data from a specific physical model is provided, creating a virtual prototype, a digital twin, which is an almost 1:1 replica of the physical model. By using this, various usage scenarios, the performance of the physical model, and how it can be improved can be tested, as well as studying existing data to prevent potential risks that may arise from using the physical model.

TASK 1: Identify the System, Its Form and Function

System	Form	Function	
		Process	Operand
Electric Car	The Electric Car	Provide Transportation	Electricity

Figure 1 – System form & function table

The Form of the electric car system is the electric car itself and the function of this system is to provide transportation as a process and using electricity as an operand.

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

System	Entity Function	Entity Form	Form
Electric Vehicle	Converts electrical energy into mechanical energy	Electric Motor	The Electric Vehicle
	Stores electrical energy	Battery Pack	
	Connects to an electricity source	Charging Connector	
	Transfers mechanical power	Transmission	
	Steering	Steering system	
	Signal & Energy transfer	Wires	
	Storing	Trunk	
	Providing Structural resistance	Chassis	
	Providing Protection & Aerodynamics	Body	
	Accommodates people	Cabin	
	Provides Control to different systems	Controls & Display	
	Provide traction and support	Wheels	

Figure 2 – System's entities

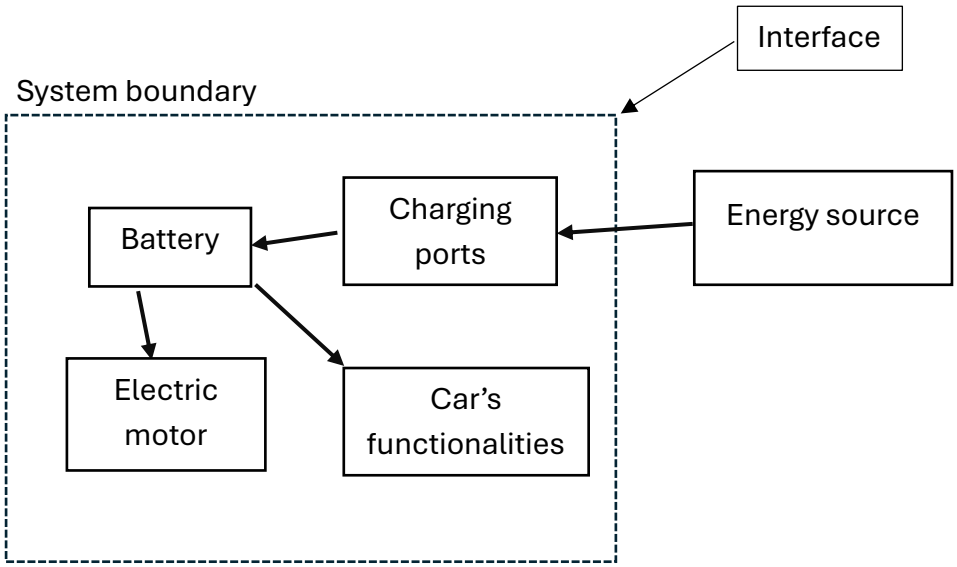

Figure 3 – System's boundaries

Task 3: Identify the Relationships among the Entities

Interfaces define how system components communicate and work together, ensuring that the system as a whole works properly.

These interfaces are divided into two categories:

1. FUNCTIONAL RELATIONSHIPS (DYNAMIC)

The **dynamic relationship** between components describe how entities flow through different parts of the system.

a) Electricity

Electricity is the only operand present in the system and it is used by the car in order to function, almost all the components utilize this operand in different ways. For instance, the electric motor draws energy from the battery to power the car. This example shows the way in which energy is conducted through the wires. Another example can be the charging station and the charging socket of the car, when the electric car is plugged into a charging station, the car's battery charges, so the electricity was moving through these components.

b) Controls and display

The driver interacts with the car using controls such as buttons, levers, or a touch screen display, enabling them to control various functions of the car.

c) The rotation mechanism of the wheels

The driver controls the steering wheel, which dynamically influences the steering of the wheels, changing the car's direction.

d) Electric motor

This component transforms the electrical energy into mechanical energy.

e) Transmission system

Transfers power from the engine to the wheels.

2. FORMAL RELATIONSHIPS (STATIC) (=STRUCTURE)

The **static relationships** represent the physical and structural components of the system that remain unchanged during operation.

a) Wires

Electricity flows through the wires to various components like the motor and display. The wires form a static structure, defining the paths for energy transmission.

b) Battery pack

The battery pack stores the energy in order to be used by the engine.

c) Structural entities

These include the chassis and the body of the car. The chassis provides the support framework for the car, while the body gives it shape.

d) Steering wheel

The steering wheel is used by a person to change the direction of the car, but its physical presence remains a static part of the car's structure.

e) Cabin

It is the place where people are accommodated. It remains also fixed in design.

f) Wheels

When the car is stationary, the wheels have a passive structural function, supporting the weight of the vehicle.

Sketch with entities:

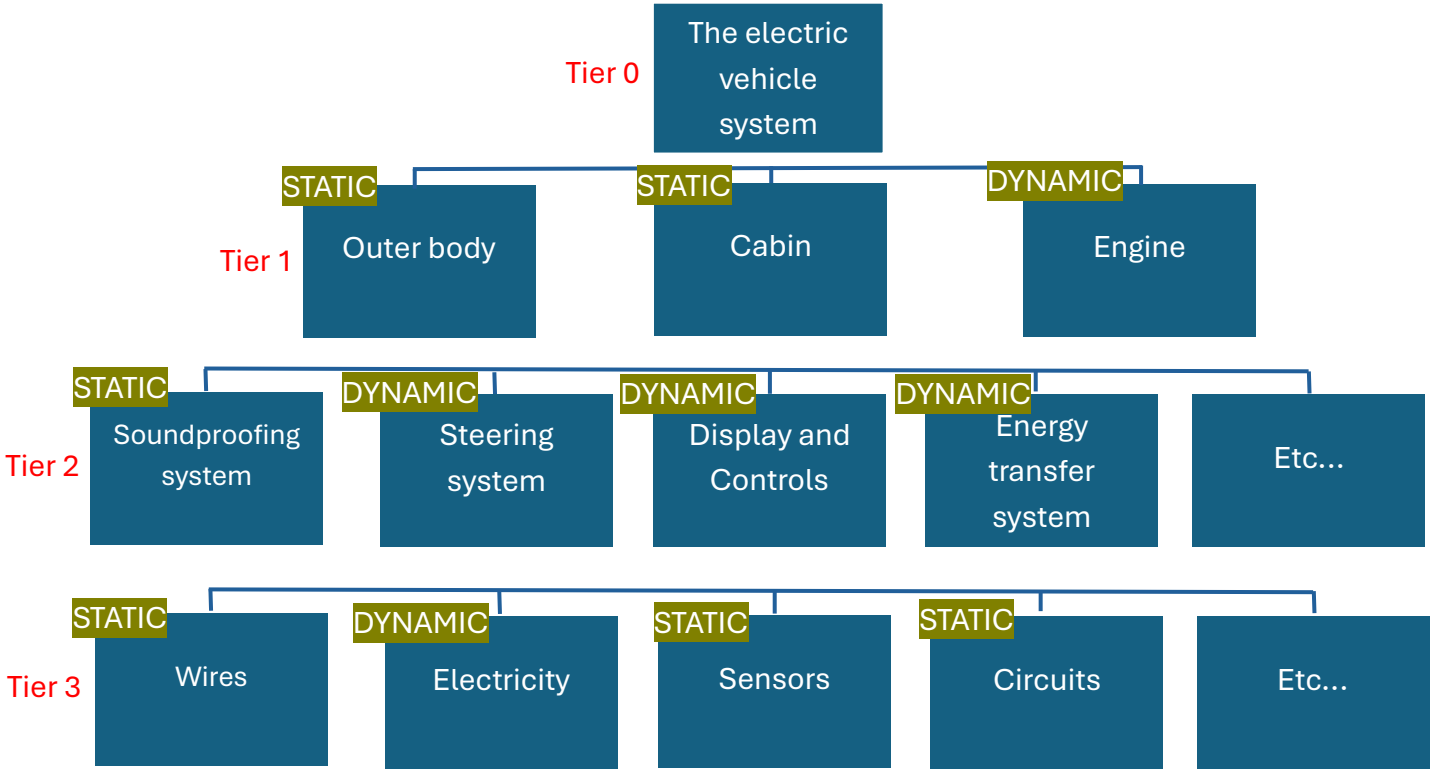

Figure 4 – Relationships among entities

Task 4: Predicting Emergence

Intended Emergence

The intended emergence of an Electric Vehicle is transportation with reduced environmental impact.

Function: Transporting entities in an eco-friendly and efficient way.

Functional Interaction Description: The engine gets electricity from batteries and converts it into mechanical energy, sends it to the transmission which forwards it to the wheels.

Unintended Emergence

An uninteded emergence could be the batteries overheating.

Function: Overheating of battery cells.

Functional Interaction Description: The thermal control system fails to fulfill its job leading to higher than expected battery temperatures.

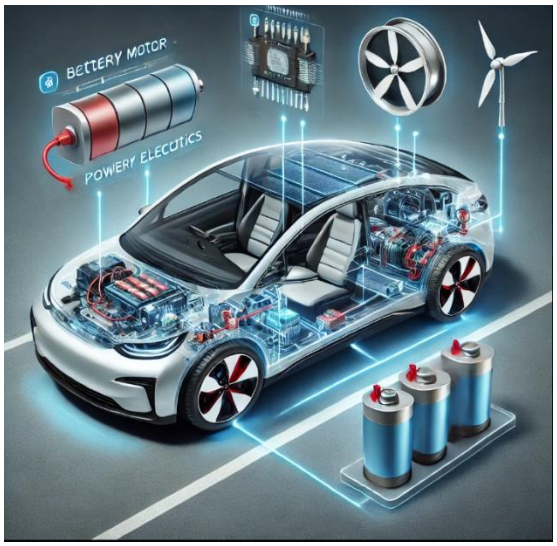

Figure 5 - Intended emergence – AI GENERATED

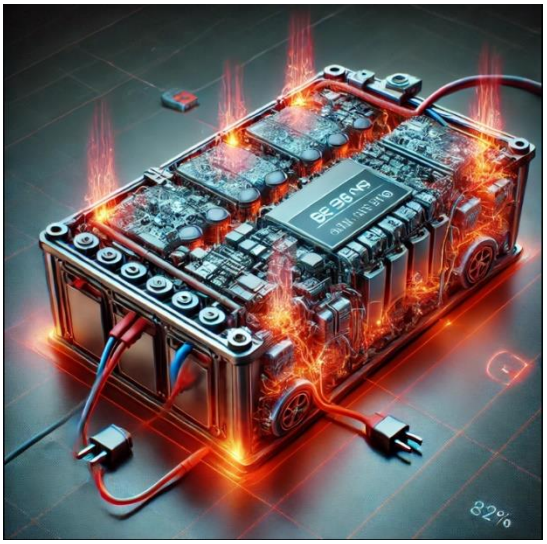

Figure 6 - Unintended emergence – AI GENERATED