AUTO PARKING SYSTEM

INTRODUCTION

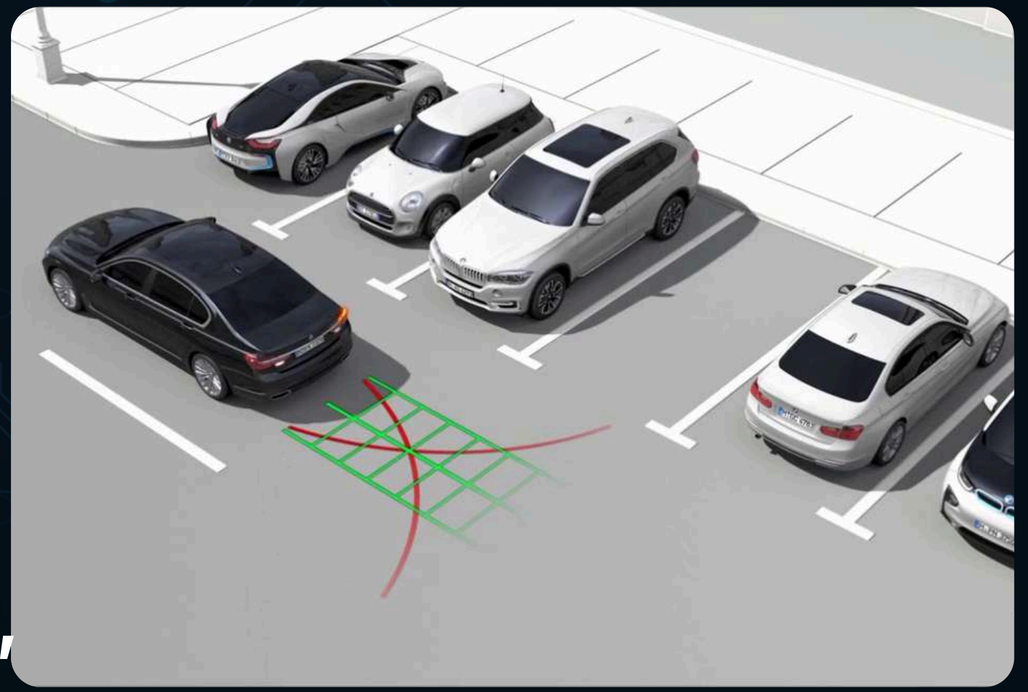
A Smart Auto Parking System (APS) is an advanced automotive feature that allows a vehicle to park itself with no driver input. It uses a combination of sensors, cameras, and control software to detect suitable parking spaces , the system works by continuously sensing the environment around the vehicle and calculating a safe path to move into the parking spot.

CPS Architecture :

Physical Layer
"What moves and senses"

Communication Layer
"How everything talks"

Cyber Layer
"Who makes the decisions"



CPS ARCHITECTURE & LIFECYCLE ANALYSIS

PHYSICAL LAYER :

A) sensors

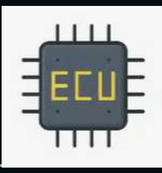
1) *Ultrasonic Sensors*
Measure distance to nearby objects using sound waves. to detect walls or other cars during parking.
2) *Radar Sensors*
Detect moving objects over longer ranges. Useful for identifying vehicles or pedestrians while parking.

C) actuators

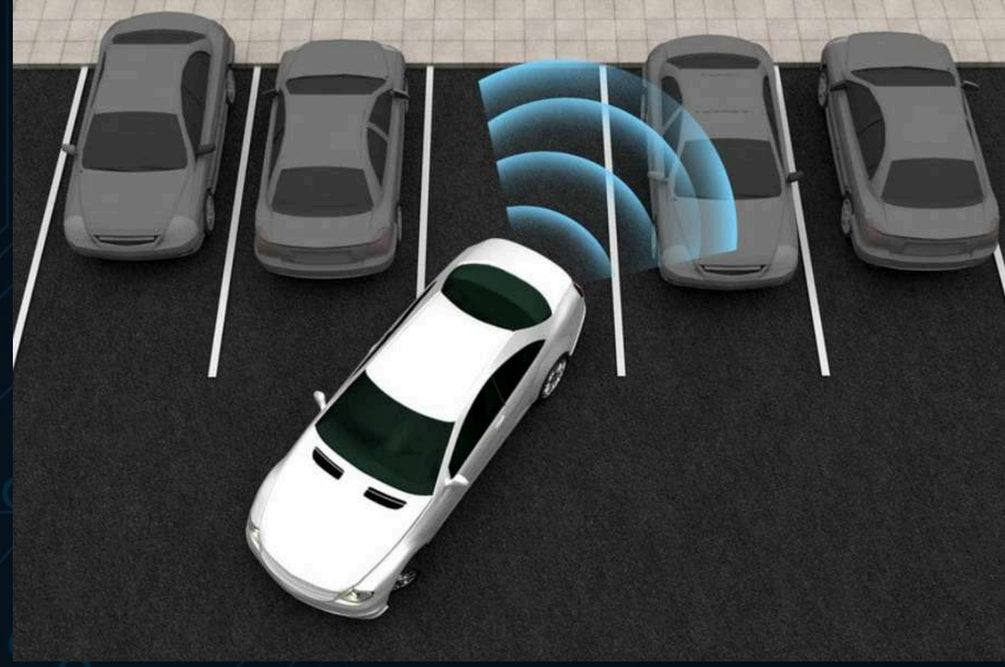
1) Electric Power Steering Motor
Automatically turns the steering wheel during parking maneuvers.
2) Brake Actuators
Apply or release brakes automatically to stop at the right moment.
3) Throttle Control
Controls the car's acceleration slightly to move into the space smoothly.
4) Gear Selector Motor
Shifts between drive, reverse, and park modes under system control.

B) camera
Cameras (Front/Rear/360°) :
Provide visual data for detecting parking lines and obstacles. Used by image-processing software to identify empty spots.

D) ECU (Electronic Control Unit) : Physical hardware microcontroller or embedded computer in the vehicle that executes software
Hosts the Main Control Software, connects to sensors and actuators, communicates via CAN bus



COMMUNICATION LAYER :



A) CAN Bus (Controller Area Network) :

A.1) acts as the **main communication highway** in the car.

A.2) Connects the **sensors** and **actuators**.

A.3) Transfers important messages like:
→ Obstacle detected at front-right!
→ Turn steering 20° to the left.”

B) Gateway ECU (Electronic Control Units)

Ensures messages go to the **right subsystem**.
Also provides **security filtering** → blocks unauthorized **or** wrong data from entering critical networks .

C) Sensor Communication Lines :

- Each sensor (ultrasonic, radar, or camera) sends raw data to the main controller using **wired connections** .
- These links must be **low latency** (fast) and **error-free** because delay can cause wrong parking decisions.

CYBER LAYER:

1 . Main Control Software (Parking Algorithm) working on the ECU

- This is the core software that controls the entire parking process.
- It receives data from sensors, analyzes it, and decides how to move the vehicle.

path planning: Calculates the safest and optimal way into the parking spot.

Motion control: Sends commands to actuators for steering, braking, and throttle .

The algorithm must be real-time, accurate, and safe — small errors can lead to collisions

2.Embedded Operating System (EOS)

- Runs on the car's Electronic Control Units (ECUs).
- RTOS = Real-Time Operating System, which ensures all tasks (like braking or steering) happen at the right time without delay.
- Designed for safety-critical timing and security isolation between processes.

3. Decision Engine

- Combines information from multiple sensors (camera, radar, ultrasonic) into one clear view of the surroundings — this is called sensor fusion.
- Helps reduce noise or false readings.
- The Decision Engine then interprets this data to decide:
- Is this spot large enough?"
- "Should I turn left or right?"
- "Should I stop now?"

4 Data Storage & Logs

- Stores system events, error codes, and driving data .
- Often includes secure storage for logs.
- Needs protection from unauthorized access or tampering

Safety critical elements :

Are the parts whose failure could cause accidents, vehicle damage, or harm to people or damage to environment . These include sensors, actuators, control software, communication networks, and monitoring systems. Identifying these elements is essential to ensure the system operates reliably and safely.

Element	intended Safety Function	Special Measure to Ensure Safety	Impact if it Fails
Brake Actuator	Stops vehicle	Automatic emergency braking override when needed	Crash or failure to stop
Sensors	Detect obstacles	Cross-check sensors to detect errors or blind spots	Misjudges space → collision
Cameras (Front/Rear/360°)	Visual input for path planning	Image-processing validation + redundant cameras to avoid camera failure	Wrong steering/braking decisions
CAN Bus	Transfers messages reliably	Message authentication and error detection; redundant communication path	Delayed/corrupted commands → unsafe commands
Gear Selector	Controls Drive (D) /Reverse (R)	Gear lock prevent accidental gear change	Unexpected change in Gear can lead to crushes.

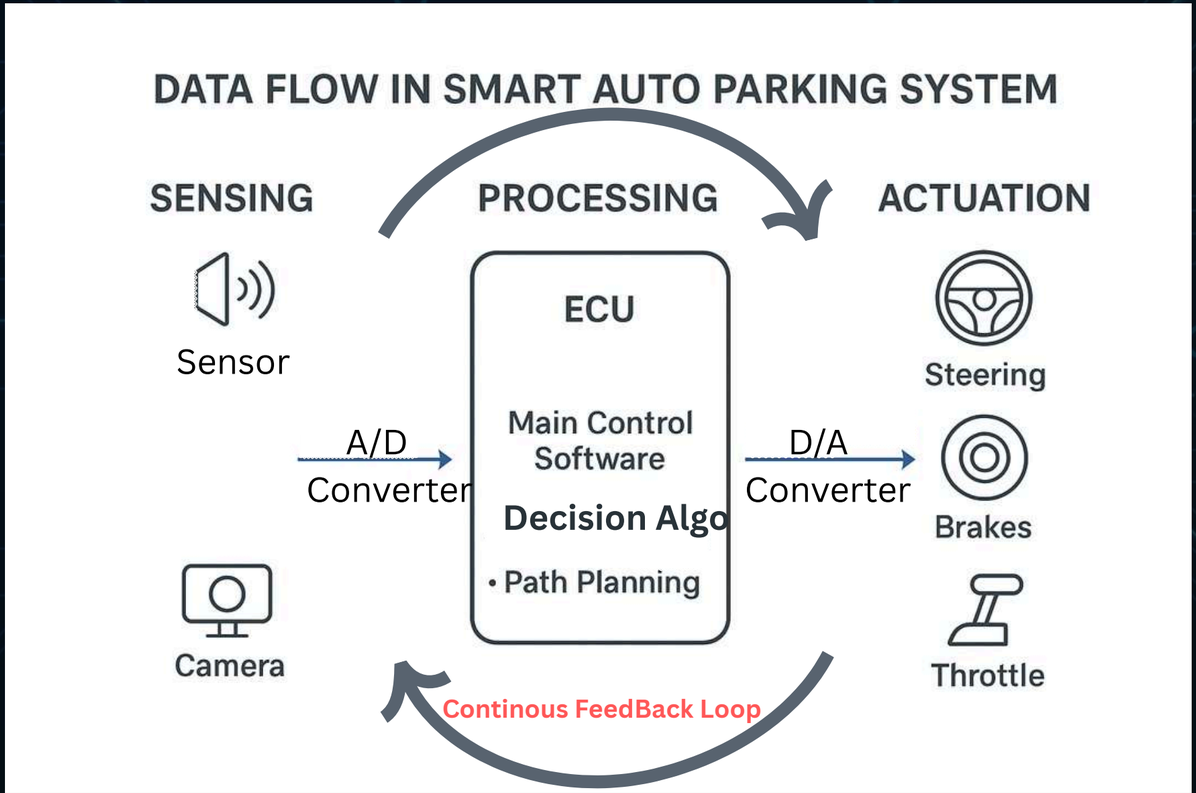
DATA FLOW:

Sensing

- *Sensors and camera : sensing the physical word measurements (spaces , obstacles , humans , available park spots , near car distances , GPS)*
- *Signals: Analog Signals*
- *Function: Sensors detect obstacles, measure distances, identify parking spaces, and monitor vehicle position as an analog signals .*

computation Layer

- *Main Control Software / Parking Algorithm:*
  - *Receives sensor inputs (analog signals are converted to digital format for processing).*
  - *Executes path planning algorithms to calculate optimal decisions.*
  - *Generates control commands for actuators.*
  - *Internally, signals are digital, processed by the ECU software.*
  - *Data will be transmitted over CAN bus networks .*



Actuation Layer (Output / Physical)

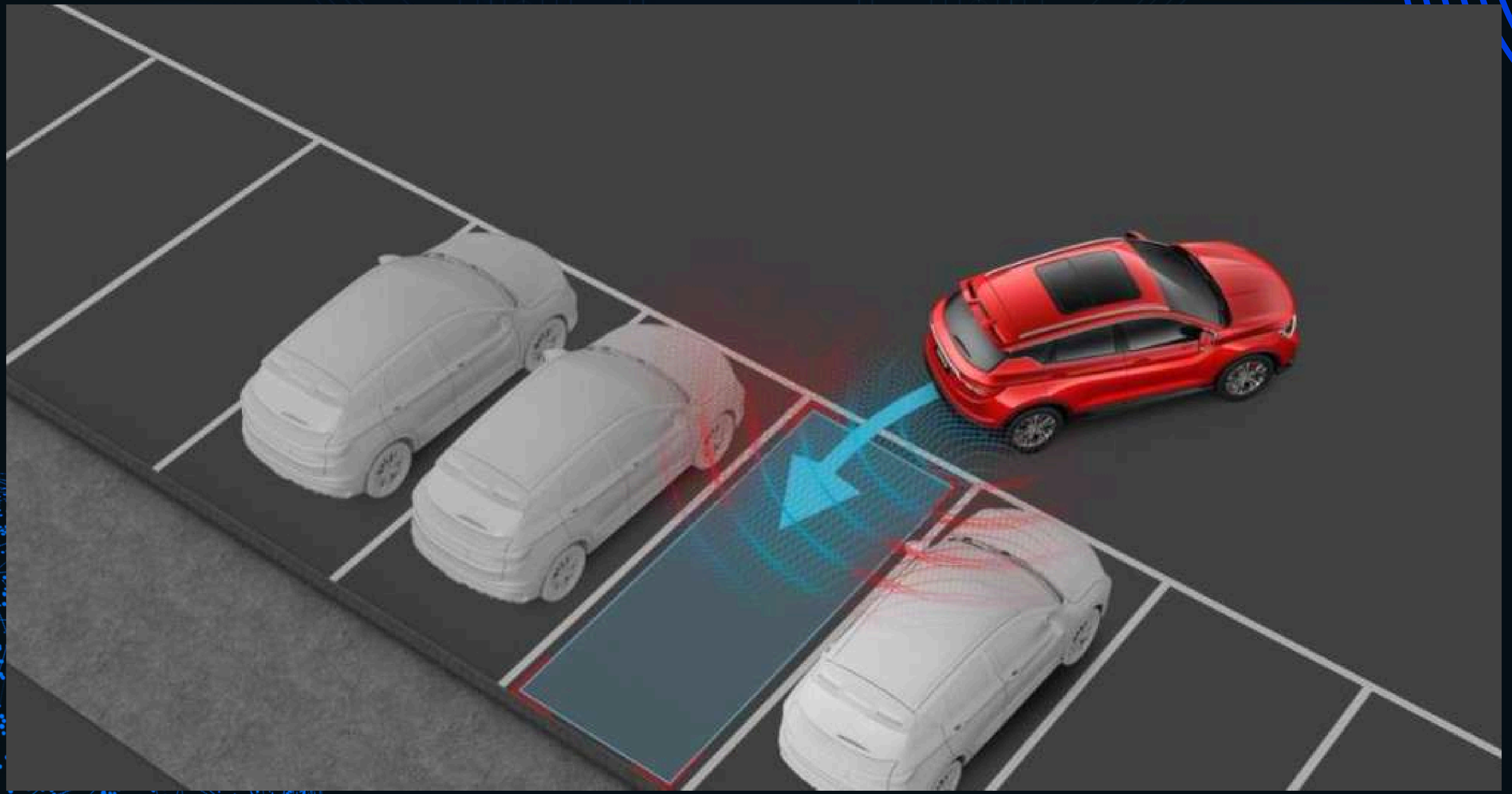
- *Actuators: Steering motor, brake system, throttle control, gear selector.*
- *Signals:*
  - *Digital signals are converted to analog signals to control the actuators .*
- *Function: The vehicle executes the planned decisions: steering, accelerating, braking, or reversing into the parking spot.(interaction with the physical world)*

PHASE 1 :

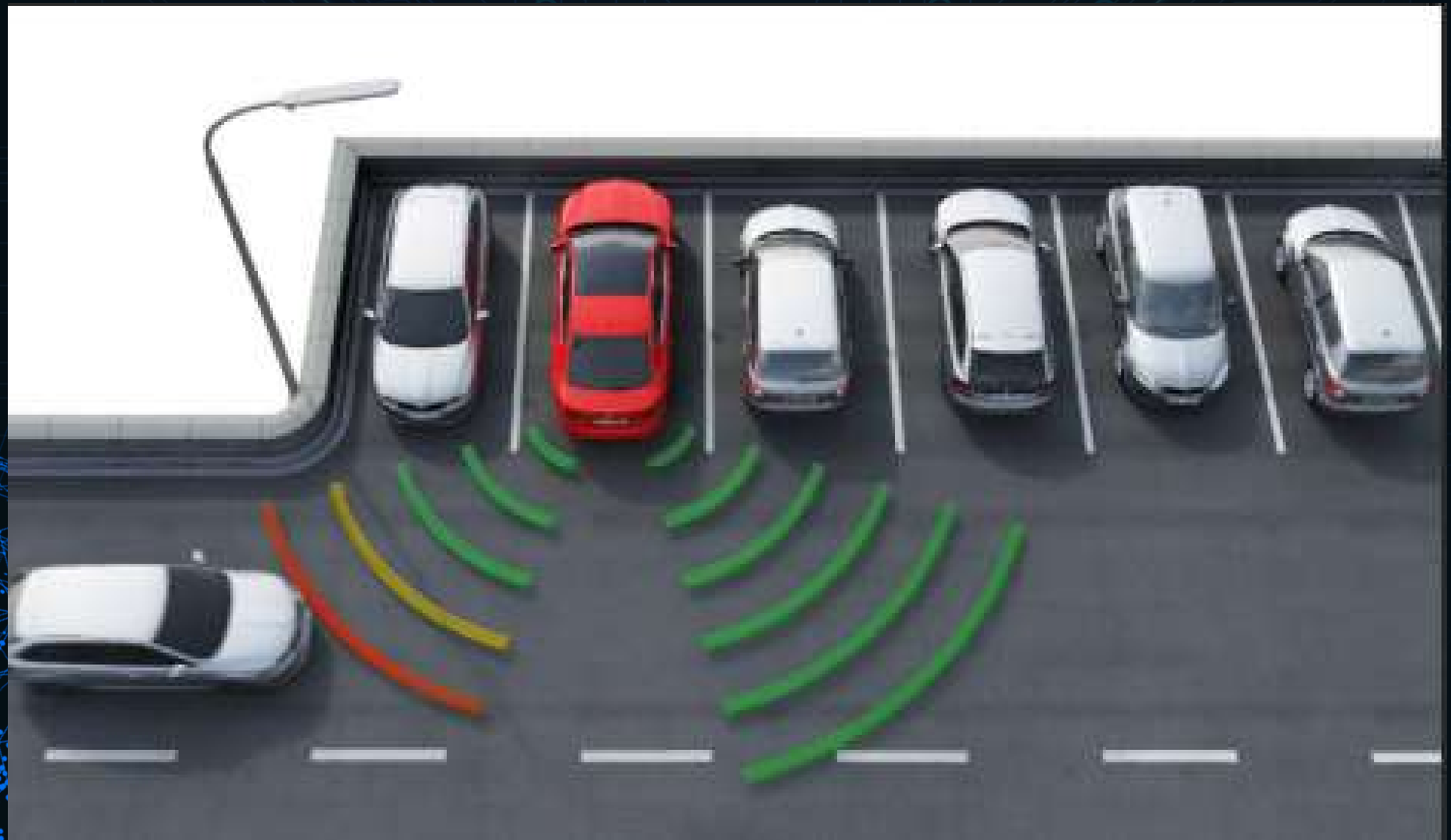
LOOKING FOR AVAILABLE SPACES FOR PARKING.

THEN GOES TO PHASE 2

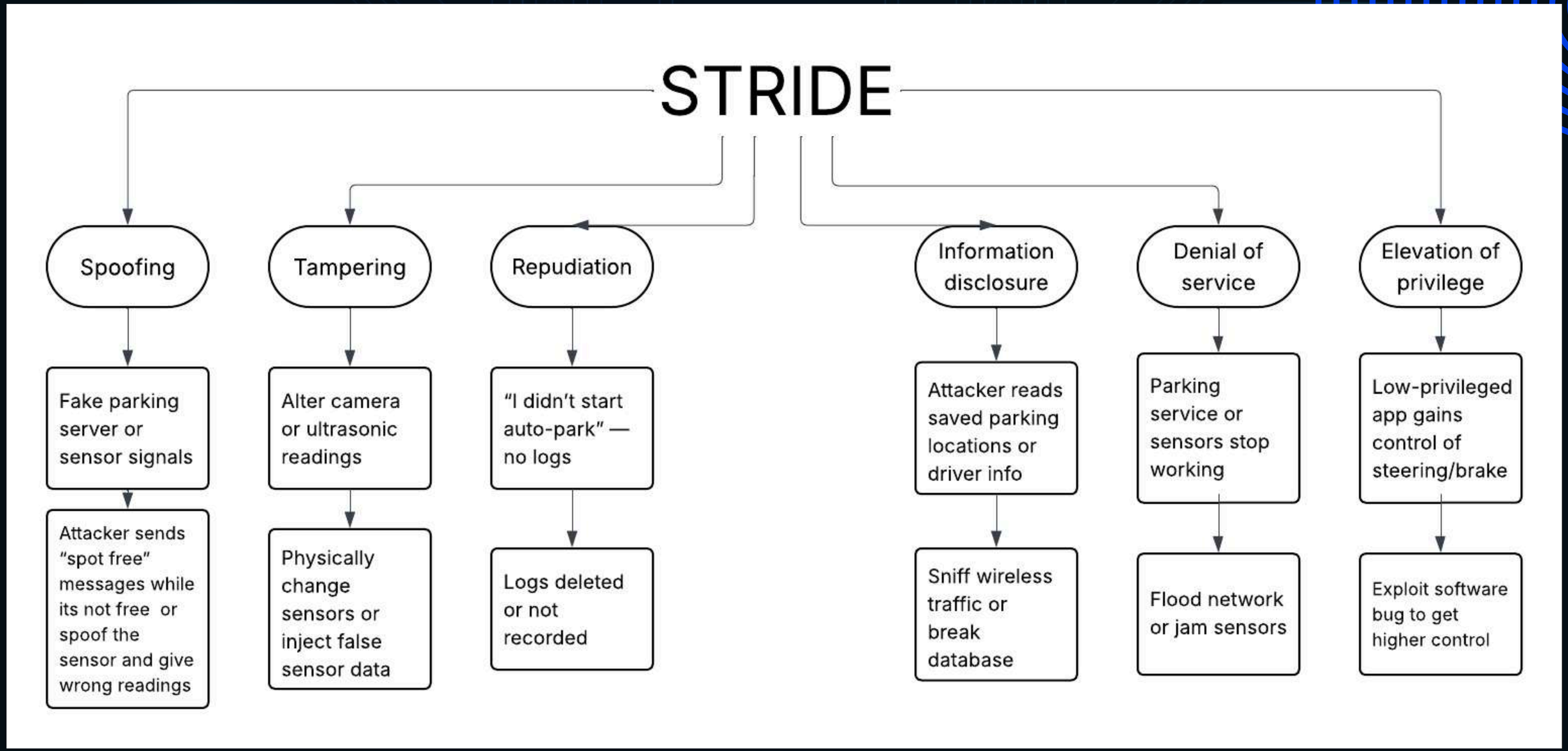
PHASE 2 : START THE AUTO PARKING PROCESS



PHASE 3 :
PARK THE CAR SAFELY AND TURN OFF .



STRIDE MODEL:

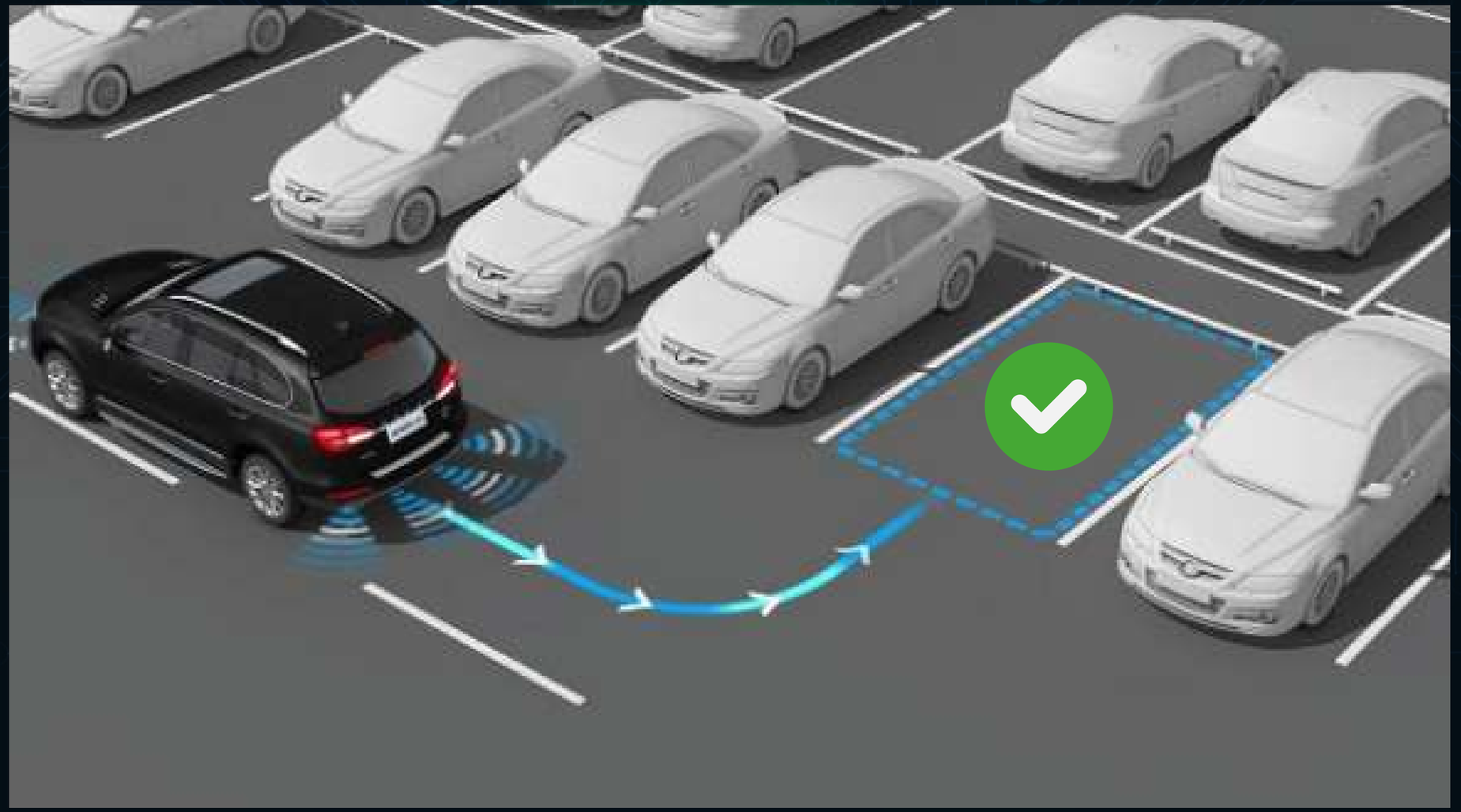


TASK 3 EMERGENCE MATRIX(Q1-Q4) :

QUADRANT	EMERGENT OUTCOME	DESCRIPTION	CPS SECURITY IMPLICATION
Q1 -Expected Positive	safe auto parking	automatically parking the car safely	system achieve its mission safely and effectively
Q2-Expected Negative	known risks and insufficient	something effect the camera or sensor (dirt , fog)	required risk mitigation : redundancy , sensor health checks
Q3-Unexpected Positive	rare beneficial outcome	sunlight and shaded parking area. The parking algorithm unintentionally selects the shaded space	Potential to enhance system resilience by observing, verifying, and adopting measures securely
Q4-Unexpected Negative	malicious attack on the devices	malicious sensor spoofing lead to car crash	require continuous monitoring , threat detection .

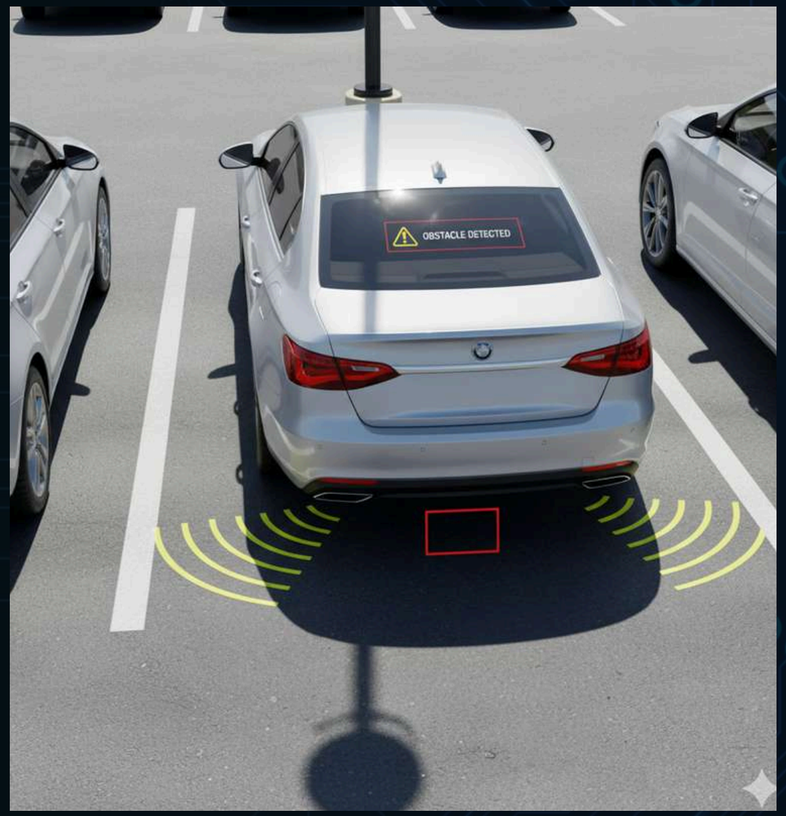
Q1 -EXPECTED POSITIVE

INTENDED RESULTS
SYSTEMS COOPERATE TO DELIVER DESIRED SECURE FUNCTION
(PARKING THE CAR SAFELY)



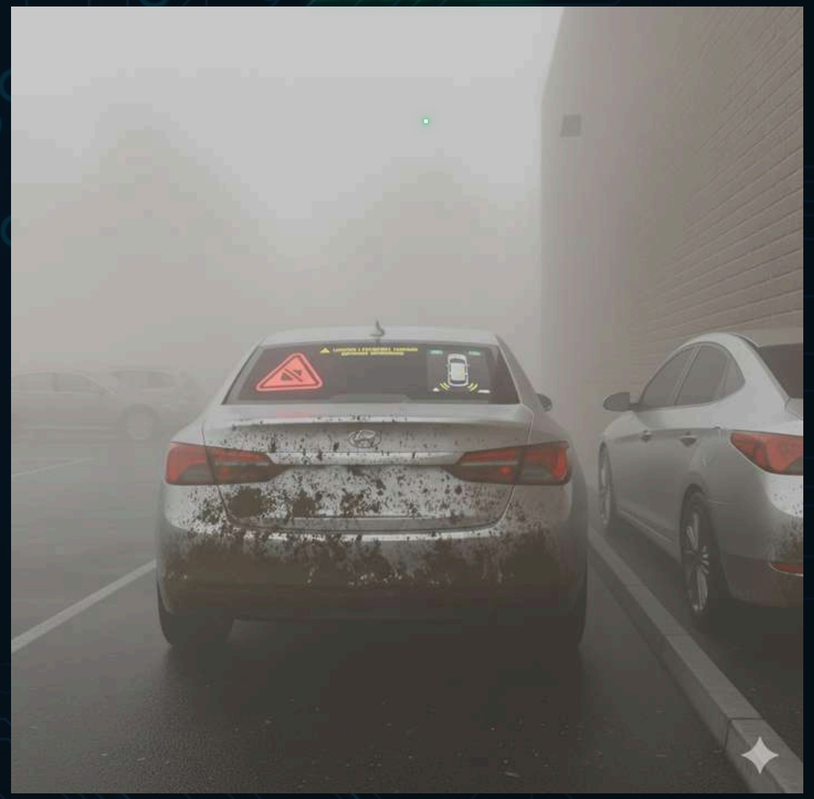
Q2-EXPECTED NEGATIVE KNOWN RISKS AND INSUFFICIENT

FALSE OBSTACLE DETECTION : SENSOR MISREADS REFLECTION (SHADOWS) OR LIGHT AS AN OBSTACLE.



MITIGATION : IMPLEMENT ADVANCED FILTERING AND IMAGE PROCESSING TO DISTINGUISH REAL OBSTACLES FROM SHADOWS.

SENSOR FAILURE IF SOMETHING EFFECT THE CAMERA OR SENSOR (DIRT , FOG) : CAMERA OR SENSOR GETS DIRTY OR BLOCKED.



MITIGATION : INCLUDE SENSOR HEALTH CHECKS TO DETECT OBSTRUCTIONS OR MALFUNCTIONS IN REAL TIME.

Q3-Unexpected Positive

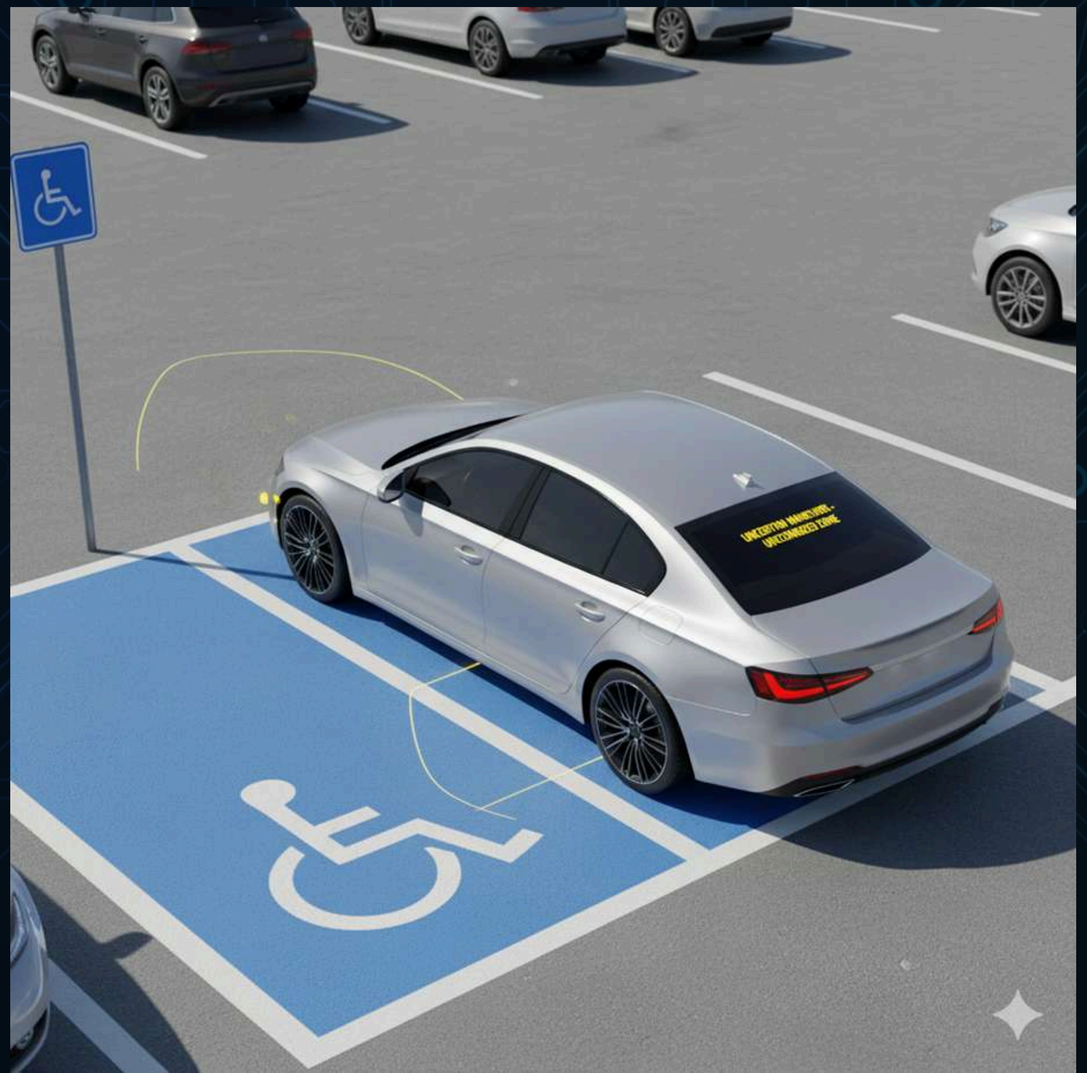
rare beneficial outcomes
(there are 2 option to choose and unintentionally the best option was chosen)
must be studied to avoid risks

EXAMPLE

There are (2) free parking spaces one in the sun the other in shadow the shadow one is chosen)
During autonomous parking, the system is presented with two available spaces of similar size: one located in direct sunlight and the other in the shaded area. The parking algorithm unintentionally selects the shaded space even though it is not designed to choose this .

Q3-Unexpected Positive-
RISK

Risk must be monitored and studied
EXAMPLE :
may be one of the available spaces are
forbidden to park there



Q4-Unexpected Negative

dangerous , unexpected outcomes that can lead to :

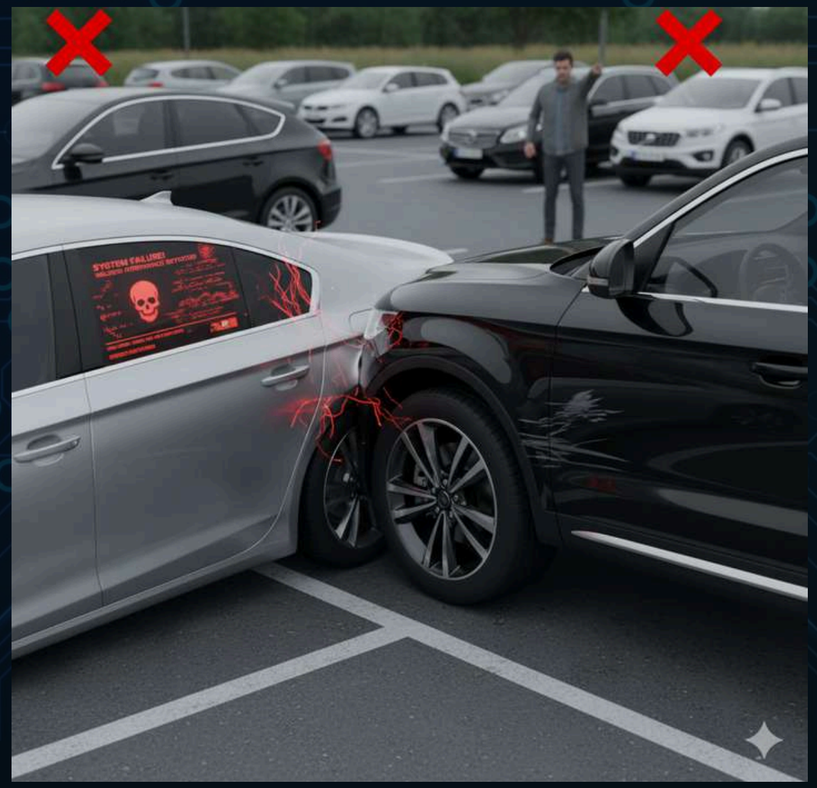
-safety accident

-security incident

malicious sensor spoofing lead to car crash , security incident (attacker spoof the sensor and give false values lead to crash)

this can lead to loss of lifes damage to environment and properities .

security incident----------> saftey accident



SECURITY MITIGATION

Redundant sensors

Prevents false obstacle detection and collisions, ensuring reliable vehicle guidance.

Encrypted communications

Protects data integrity and privacy, preventing unsafe remote commands or interception.

Access control & authentication

Ensures only authorized vehicles or users operate the system, preventing malicious actions.

Fail-safe mechanisms

Stops the vehicle safely when a sensor fails, avoiding accidents.

Regular monitoring & logging

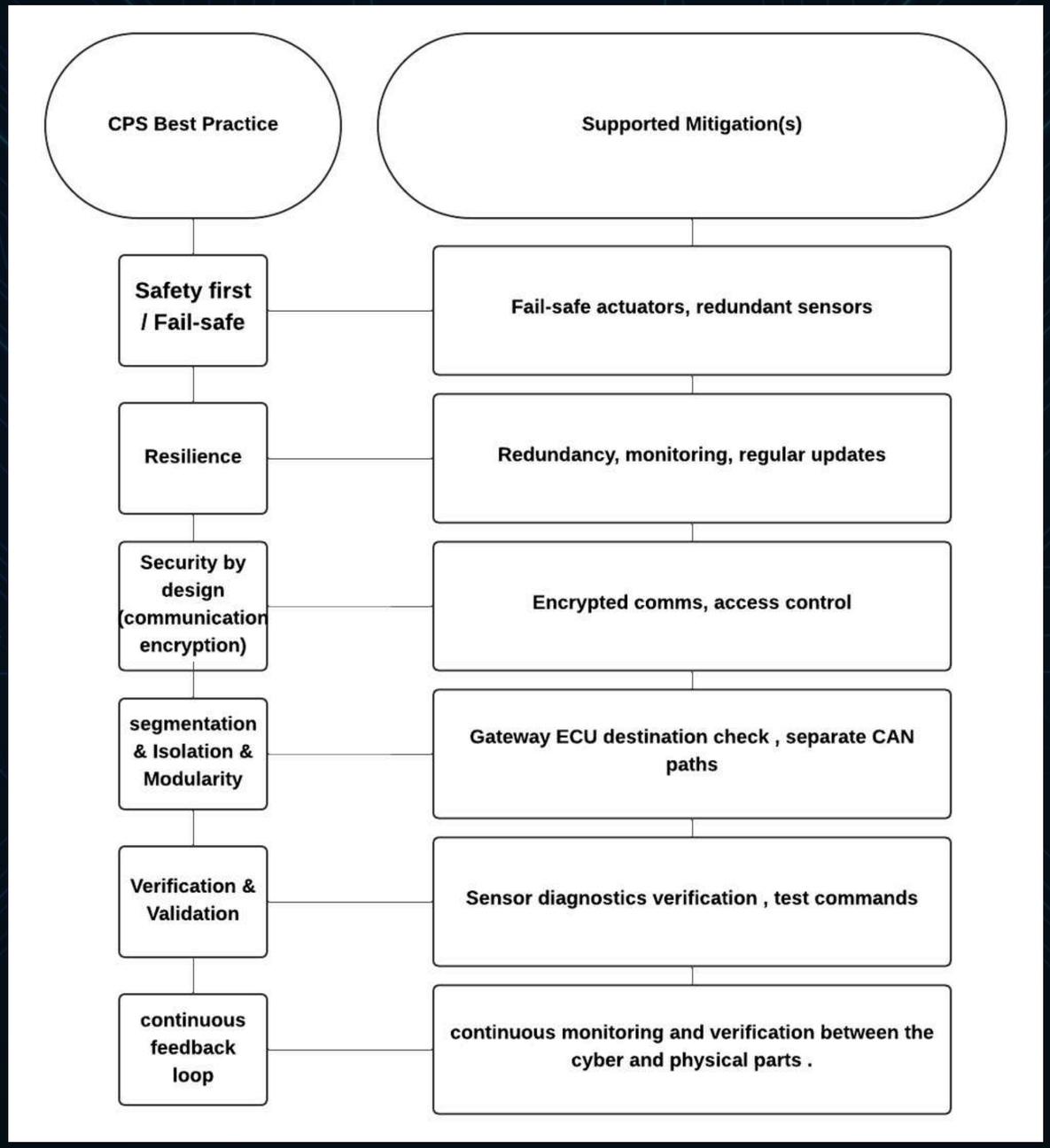
Detects anomalies, sensor faults, or attacks early, reducing risk of unsafe behavior.

COMPONENT SECURITY IMPROVEMENT & SAFETY

Component / Area	Security Improvement	Safety / resilience achieved
Physical: Sensors	Sensor health & integrity checks	Detects blocked/dirty sensors and insure continue working
Physical: Cameras	Anti-tamper / secured image processing	Avoids tampered vision leading to wrong decisions
Actuators (steering, brakes, throttle, gear motors)	Command authentication & fail-safe interlocks	Prevents unauthorized commands via authentication
In-vehicle Communications	Segmentation, message authentication	reduces communication interference impact
Cyber Layer: Main Control Software	Secure design, formal requirements	Prevents logic bugs and unsafe planning

CPS ENGINEERING BEST PRACTICESEST PRACTICE:

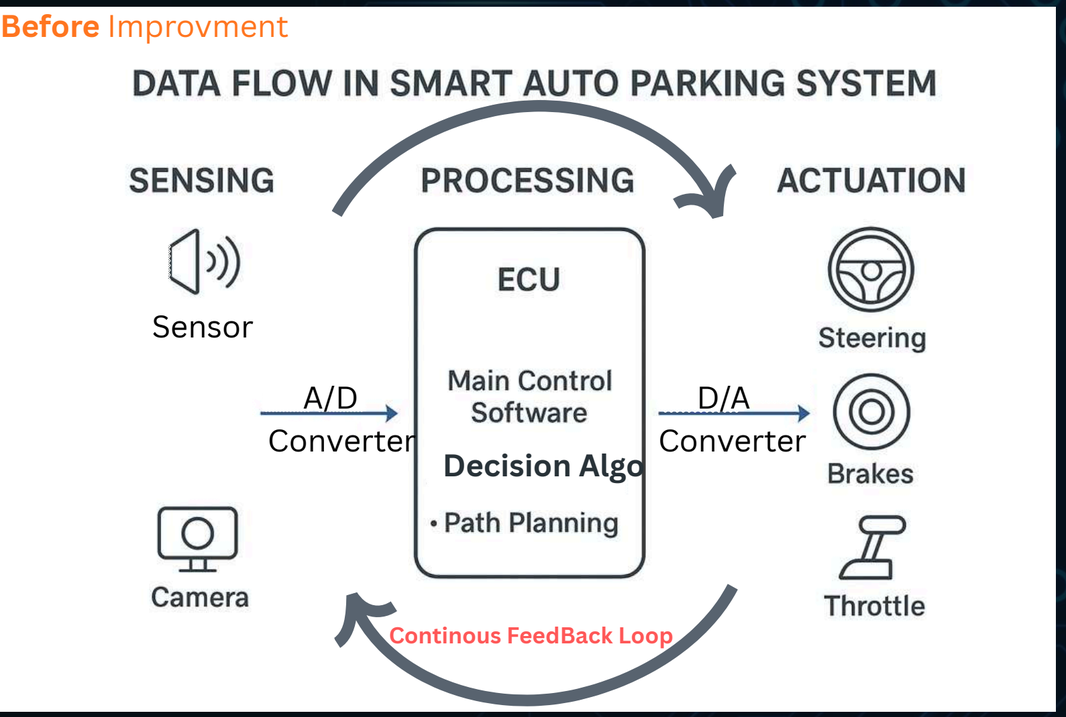
NIST
National Institute of Standards and Technology



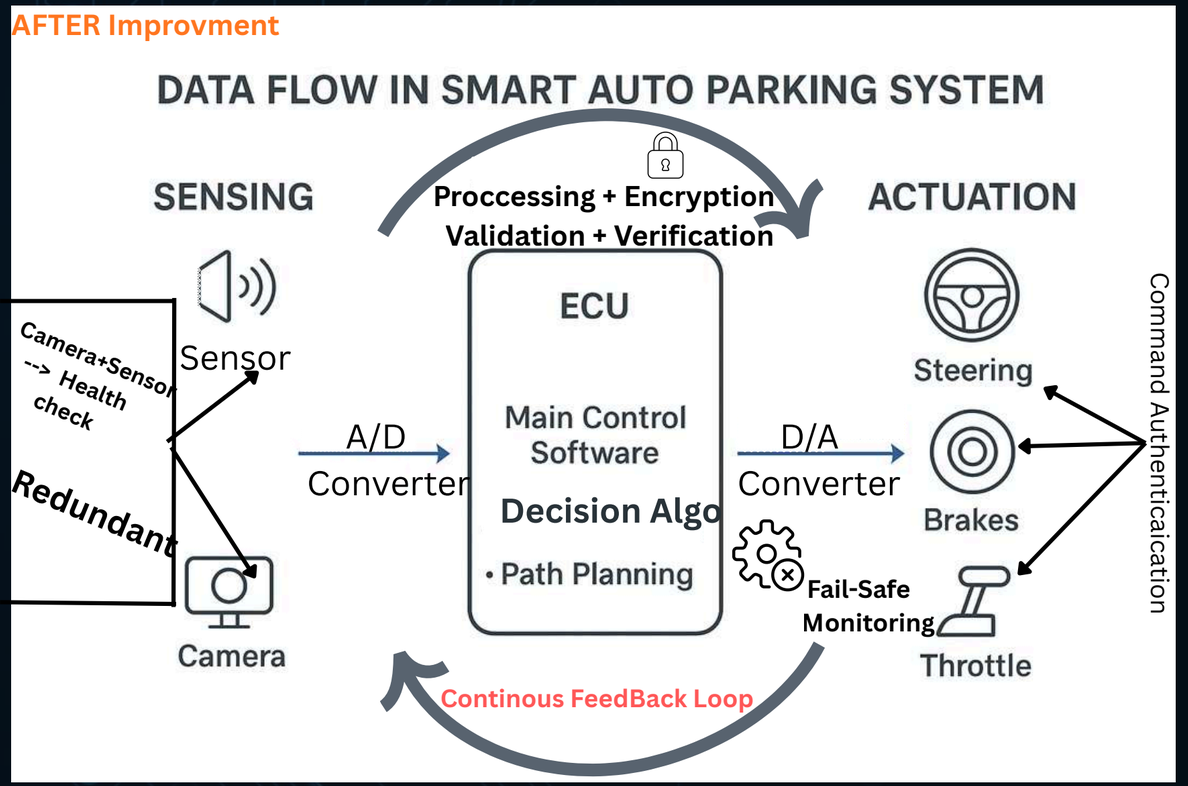
ISO 26262
GUIDE

IMPROVMENT ARCHITICTURE

Before Improvment



AFTER Improvment



References :

IEEE Sensors Journal papers

NIST.SP.1500-201

ISO 26262

NIST SP 800-160

Cps safety and security Book