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TELECOMMUNICATIONS MASTER

Implementation of an automatic parking simulator in Matlab

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1. Theoretical foundation

1.1 Brief history

Industrial automation is an interdisciplinary field between mechanical engineering and electrical engineering, as part of engineering science, which uses methods that lead to the automation of machines and plants for their independent operation, without human participation.

The history of the automated fleet can be traced through the evolution of parking assistance technologies and automated parking systems for vehicles. It can be classified as follows:

- 1920s-1950s: First attempts at parking assistance
  - During this period, the first cars began to have simple parking assistance functions, such as rear-view mirrors and audible signals to guide the driver during parking maneuvers.

- 1960s-1980s: Parking sensors
  - In the 1960s and 1970s, parking sensors were introduced that warned drivers of nearby obstacles. These were used to measure the distance between the vehicle and objects.

- 1990s: Automatic parking assistance
  - Parking assistance technologies have begun to evolve, allowing for a More active steering and acceleration control during parking manoeuvres.

- 2000s: The first automated parking systems
  - In this decade, the first automatic parking systems appeared, initially on luxury vehicles. They could take control of the direction during parallel or perpendicular parking.

- 2010s: Advancing technologies
  - Automated parking systems have become more sophisticated, integrating video cameras, sensors and advanced image processing technologies.
  - Automated parking technologies have also been developed for more complex parking spaces, including in garages.

- Present: Automatic parking under various conditions
  - Automated parking systems have evolved to work in various conditions, such as crowded parking spaces, underground parking lots, and complex obstacle areas.

  - The advancement of autonomous vehicles has led to significant improvements in automated parking capabilities.

1.2 Automatic parking

Automated parking systems are technologies that help drivers park vehicles more efficiently and without the need for direct driver intervention in the parking process. Exists two main types of automated parking systems:The complexity and independence of machines and installations determine their degree of automation.

- **Parking Assistance:** This system uses
  sensors and cameras mounted on the vehicle to detect available parking spaces. The system then provides guidance and instructions to the driver to perform parking maneuvers. However, the driver must maneuver the vehicle, and the system only provides assistance.

- **Automated Parking:** This technology allows the vehicle to perform parking maneuvers without requiring intervention
  Driver. The driver activates the system and the vehicle finds a parking space on its own suitable and perform the necessary maneuvers. This type of system often involves the use of sensors and camera, along with other technologies such as lidar or radar.

This technology uses sensors, radars, and cameras to autonomously take control of specific parking tasks or the entire parking exercise, helping drivers park their vehicle safely without causing damage or damaging nearby vehicles.
The most common automatic parking assistance systems take control of the steering when the driver is parallel parking. Many of these will also turn into a parking space perpendicular to an angle of 90 degrees to the direction in which the vehicle is moving, as can be seen in the following figure:

Figure 1 – Automatic parking with the help of sensors

With this level of parking assist technology, the human job is to use the accelerator and brake pedals to move the car and change gears.
When active, this basic automatic parking assistance technology finds a space of appropriate size for your car. When determining that a parking space
It has an appropriate size, the driver initiates the steering without hands. Then the car will steer into space while you operate the pedals and transmission.

1.3 Sensors

Automated parking systems use a variety of sensors to collect information about the environment and guide the vehicle during parking maneuvers. On-board sensors play a crucial role in this functionality. Such as:

- ✓ **Ultrasonic Sensors (Parking Sensors):** These sensors use ultrasound to detect obstacles around the vehicle. They are generally located in the bumper and on other areas of the vehicle. By measuring the return time of sound waves, ultrasonic sensors can estimate the distance to objects and provide audible or visual warnings during parking maneuvers.

- ✓ **Cameras**: Automated parking systems can include cameras located on various parts of the car. These cameras provide a real-time view of your surroundings and are useful for recognition of objects and markings around the vehicle.

- ✓ **Lidar** sensors: Lidar sensors use lasers to measure distances to objects and create detailed maps of the environment. They are useful for accurately detecting obstacles and providing 3D information about the environment.

- ✓ **Radar Sensors**: Radar sensors use radio waves to detect objects and measure distances. They are effective in low visibility conditions, such as fog or rain.

- ✓ **Infrared (IR) Sensors**: Parking systems may also include infrared sensors to detect heat emitted by surrounding objects. They can be useful in certain lighting conditions and can provide additional information for detecting objects.

- ✓ **GPS sensors:** Parking systems can also use information from GPS sensors to determine the exact position of the vehicle and assist in identifying available parking spaces, etc.

On-board sensors are used to be able to perceive the environment around the vehicle. The perceived environment includes an understanding of road markings to interpret road rules and infer regions that can be driven, obstacle recognition, and detection of available parking spaces.
As the vehicle's sensors perceive this environment, the vehicle must plan a path to a free parking space and perform a sequence of control actions necessary to drive to it. As it does so, it must respond to dynamic changes in the environment, such as pedestrians crossing its path and readjust its

2. Scenario simulation

2.1 Environmental model

The environmental model is a map of the environment. This map includes available and occupied parking spaces, road markings, and obstacles such as pedestrians or other vehicles. Such a map is usually built using Simultaneous Localization and Mapping (SLAM) by integrating observations from lidar sensors and the camera. In this scenario, the map is already provided. The map used is composed of three layers of occupancy grids:

- ❖ Stationary obstacles: This layer contains stationary obstacles such as walls, barriers, and parking limits.
- ❖ Road markings: This layer contains information about road markings, including road markings for parking spaces.
- ❖ Parked cars: This layer contains information about parking spaces that are already occupied.

Each layer contains different types of obstacles that represent different levels of danger to a car navigating here.

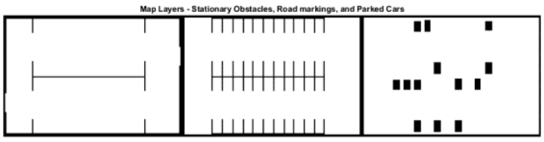

Figure 2 – The 3 plans for the composition of the map

The overall route plan is described as a sequence of lane segments to travel to reach a parking space, using the plans in Figure 2. Before the simulation, the model's PreLoadFcn callback function loads a route plan, which is stored as a table. The table specifies the start and end positions of the segment, as well as the properties of the segment, such as the speed limit, which can be seen in Figure 3.

routePlan =

5×3 table

StartPose			EndPose			Attributes
4	12	0	56	11	0	1×1 struct
56	11	0	70	19	90	1×1 struct
70	19	90	70	32	90	1×1 struct
70	32	90	52	38	180	1×1 struct
53	38	180	36.3	44	90	1×1 struct

Figure 3 – Table for data positioning

2.2 System

Planning is a hierarchical process, each successive layer being responsible for a more precise task. The behavior layer is at the top of this stack. Block Behavior Planner triggers a sequence of navigation tasks based on the global route plan, providing an intermediate objective and configuration for the Motion Planning and Trajectory Generation blocks. Each path segment is navigated using these steps:

- Motion planning: Plan a feasible path through the environment map using the optimal Fast Random Tree Exploration (RRT*) algorithm (pathPlannerRRT).
- Trajectory Generation: Smooth the reference path by matching splines, to it using the Path Smoother Spline block. It then converts the smoothed path to a trajectory by generating a velocity profile using the Velocity Profiler block.
- Vehicle control: HelperPathAnalyzer provides the signal reference for the Vehicle Controller subsystem that controls the direction and speed of the vehicle.
- Goal check: whether the vehicle has reached the final position

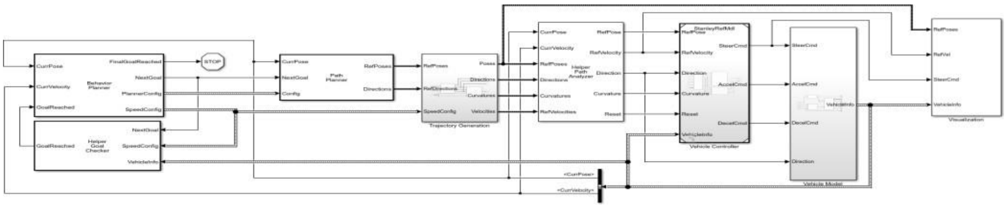

Figure 3 – Diagram of the system used

2.3 Subsystems

The Vehicle Controller subsystem contains a Stanley Lateral Controller block and a Stanley Longitudinal Controller block to adjust the vehicle's position and speed, respectively. To manage realistic vehicle dynamics [3], the vehicle model parameter in the Stanley Side Controller block is set to Dynamic Bicycle Model. With this configuration, additional inputs such as the curvature of the route, the current rate of rotation of the vehicle, and the current steering angle are required to calculate the steering control. The Stanley Longitudinal Control Block uses a proportional-integral switch controller to calculate the throttle and deceleration controls that actuate the brake and throttle in the vehicle.

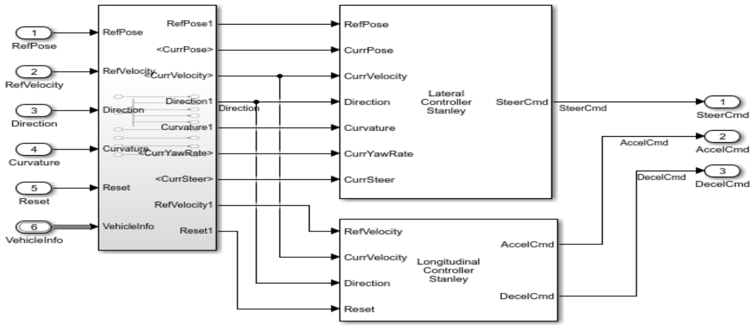

Figure 4 – Vehicle Controller Subsystem

To demonstrate performance, the vehicle controller is applied to the Vehicle Model block, which contains a simplified steering system [3] that is modeled as a first-order system, and a Vehicle Body 3DOF (Vehicle Dynamics Blockset) block shared between the Automated Driving Toolbox and Vehicle Dynamics Blockset. Compared to the kinematic bike model used in the matlab valet automatic parking example, this block vehicle model is more accurate because it takes into account inertial effects such as tire slippage and steering servo drive.

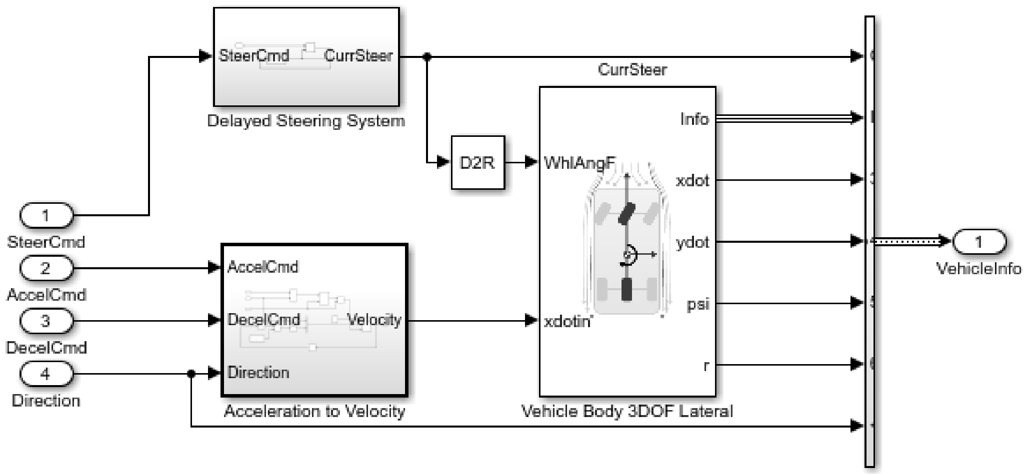

Figure 5 – Model Vehicle Block

3. Simulation results

In Figure 8, one can visualize how the vehicle follows the cue path to a specific empty parking lot in order to be able to perform parking.

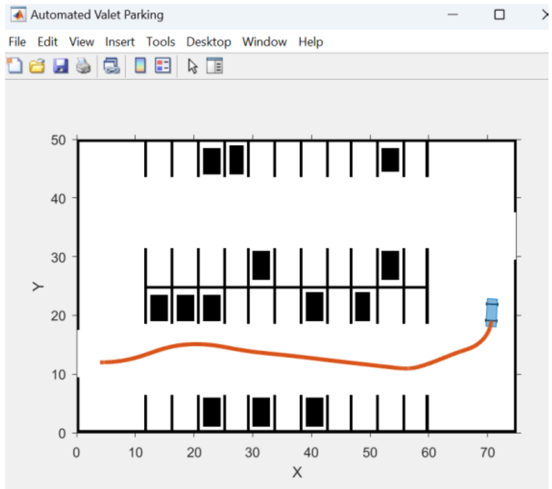

Figure 8 - The route for automatic parking

The estimated time until the vehicle reaches its destination is approximately 40 seconds.

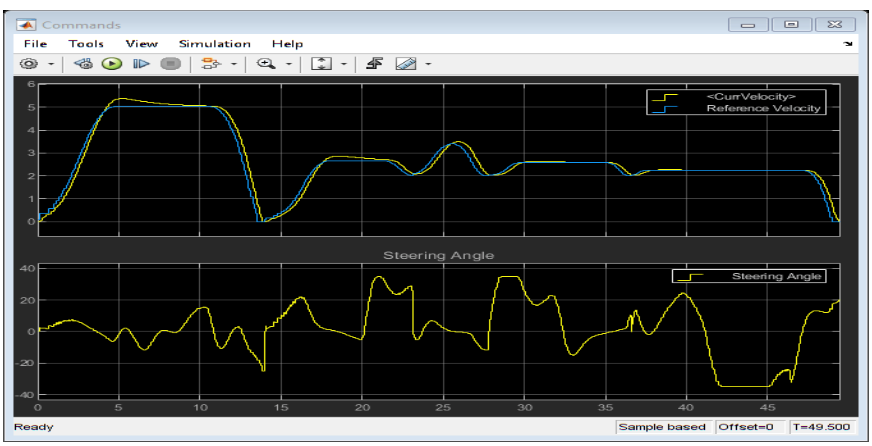

Figure 9 – Visualization of the simulation

In conclusion, automated parking lots bring numerous benefits, including increased efficiency, time and space savings, reduced traffic and emissions, thus facilitating a more sustainable approach to urban mobility. However, their implementation requires adequate infrastructure and significant investments in technology.

4. Bibliography

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