TECHNICAL UNIVERSITY OF CRETE

Autonomous Agents (INF 412)

Compliance with the Road Traffic Code
in an Autonomous Driving Agent

by

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1 Topic of the project

The aim of this project was to enhance an existing autonomous driving agent [1] by ensuring compliance with the road traffic code. The focus was on implementing functionalities for stop sign detection and traffic light recognition, in addition to the already implemented lane keeping and obstacle avoidance capabilities.

1.1 Problem Statement

The existing autonomous driving agent demonstrated proficiency in lane keeping and obstacle avoidance but lacked compliance with essential aspects of the road traffic code. Without the ability to detect stop signs and recognize traffic lights, the system posed safety risks and legal concerns, potentially leading to accidents or violations. Therefore, the project sought to address these shortcomings by integrating stop sign detection and traffic light recognition modules into the driving agent, thereby enhancing its ability to navigate roads safely and legally.

2 Implementation

2.1 Environment selection

For project implementation, we utilized the WeBots R2023b simulator, chosen for its compatibility with the previous project's framework. As the simulation environment the "city.wbt" world was selected for several reasons. Firstly, it offers a compact urban layout, featuring dual-lane roads and essential infrastructural elements such as traffic lights, intersections, and stop signs. To showcase the effectiveness of stop sign recognition, a passing vehicle was introduced as an additional element. The driving agent, represented by a red "BMW X5" car, was equipped with both newly integrated functionalities and existing lane maintenance and obstacle avoidance features. A second "BMW X5" car, colored blue, demonstrated the baseline behavior without the additional functionalities. Sensor equipment, including a front-facing camera for environmental perception and a 2D Laser Scanner (Sick LMS 291) for object detection, enabled both vehicles to autonomously navigate their surroundings.

2.2 Controllers

Four controllers have been developed using the C programming language for this project. The "crossroad_traffic_lights.c" and "crossingObstacle.c" controllers are pre-existing, managing the behavior of traffic lights and obstacle crossings respectively. Another controller, "simple_autonomous_vehicle.c", manages the behavior of the blue vehicle, integrating functionalities from the previous project. Lastly, the focus of this report is on the "autonomous_vehicle.c" controller, which coordinates the actions of the red vehicle.

The controller implementation revolves around two key functions: identifying the stop sign and executing the appropriate response, and detecting the different states of the traffic lights.

2.2.1 Stop Sign Recognition and Response

The implementation of stop sign recognition involves utilizing the camera sensor to detect stop sign objects within the environment. The ”testStpRecognition” function is designed to analyze the camera's recognition data, searching for the specific identifier linked with a stop sign. Once a stop sign is detected, its distance from the vehicle is determined using positional data provided by the recognition system. Based on this information, appropriate responses are executed by the system. To ensure safe behavior, the stopping distance is calculated by summing the reaction distance and the braking distance. This calculation is achieved through the formula: stopping_distance = (current_speed/10)$\hat{2}$ + (current_speed/10)*3. If a stop sign is detected within this calculated stopping distance plus an additional meter, and an obstacle is detected in its path, a full emergency stop is executed by the system to prevent a potential collision. An additional meter is incorporated to ensure the vehicle does not halt directly at the stop sign, allowing for continued detection and response. Conversely, if the stop sign is detected beyond this calculated stopping distance plus the additional 3 meters (allowing for continued detection) and no obstacle is detected, the vehicle is decelerated to a lower speed in anticipation of stopping at the intersection, but it continues with caution without coming to a complete stop.

2.2.2 Traffic Light Recognition and Response

The functionality of the traffic lights within the autonomous driving system is crucial for safe and compliant navigation through intersections. The implementation revolves around a three-step process: traffic light detection ,image processing to determine its state, and executing an appropriate response.

Initially, the ”testTrLightRecognition” function governs the traffic light detection process. It retrieves camera recognition objects and scans for the specific identifier corresponding to the target traffic light. Once identified, it extracts the bounding box information encapsulating the traffic light within the camera image and passes it to the ”detect_traffic_light” function for further processing.

Subsequently, it calls the ”detect_traffic_light” function, that processes the image data, to analyze the color state of the traffic light within an enlarged bounding box, ensuring that it can still see the light clearly even if it's partly hidden. More specifically, it analyzes the camera feed to identify traffic light states by comparing pixel colors within a specified bounding box against predefined color ranges. Based on pixel counts, it classifies the traffic light state as green, orange, red, or undetected. Upon detection, the system executes appropriate responses. For instance, if a green light is detected, the vehicle maintains its speed. Conversely, if an orange or red light is detected within a calculated stopping distance plus a safety margin, the vehicle decelerates gradually or comes to a complete stop, ensuring compliance with traffic regulations and safe navigation through intersections.

3 Difficulties and Results

Encountering challenges during the project was inevitable, especially when transitioning from an earlier version of WeBots to the current one, WeBots R2023b. The differences in functions provided by the updated WeBots libraries posed initial hurdles. However, resolving these issues was relatively straightforward, thanks to the comprehensive and descriptive WeBots reference manual available at `https://cyberbotics.com/doc/reference/index`.

One significant obstacle I faced during implementation, was the detection and recognition of traffic lights. The camera could only recognize Solid nodes with non-empty recognition colors, which posed a problem since the traffic lights were part of a robot consisting of multiple poles with several lights each, making it undetectable. To address this, I converted the robot to a base node, making the specific traffic light I needed identifiable as a solid node by the camera.

Another challenge emerged during image processing, particularly in recognizing the colors of the traffic lights. Initially, the bounding boxes did not contain pixels with the desired colors (red, green, orange). By enlarging the boxes, I managed to detect the colors eventually. Additionally, determining the exact color range was difficult due to lighting effects distorting the colors. To overcome this, I obtained the correct RGB values by printing all the pixels within the box.

Despite these challenges, I am pleased with the overall results of the project. The system's ability to detect and respond to traffic lights effectively demonstrates significant progress and aligns with the project's objectives. Additionally, the stop sign recognition function operates seamlessly, further enhancing the system's compliance with road traffic regulations.

4 Execution of the project

In the WeBots simulation environment, begin by selecting the "city.wbt" world file. Then, access the controllers of all mentioned robots within the simulation, and proceed to build them. Finally, execute the simulation to observe the results.

5 Conclusion

In conclusion, this project highlights the vital role of compliance with traffic regulations in the advancement of autonomous driving technology. By integrating stop sign detection and traffic light recognition functionalities, the system demonstrates significant progress in ensuring safe and legally compliant navigation through urban environments. These advancements underscore the potential of autonomous driving systems to revolutionize transportation by enhancing safety, efficiency, and sustainability. Moving forward, continued research and development in this field will further accelerate the adoption of autonomous vehicles, ushering in a new era of transportation characterized by enhanced safety, reduced congestion, and increased accessibility.

Bibliography

[1] Georgios Protopapadakis. Autonomous Driving Agent. `https://www.intelligence.tuc.gr/~robots/ARCHIVE/2021w/projects/PROTOPAPADAKHS/`, 2021.