Autonomous Navigation of an Autominy based on the "Sliding Window Technique" and 2D detection

Intelligent Systems

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Abstract

The present work describes the development of algorithms for the autonomous navigation of a 1:10 scale Autominy vehicle, with the objective of solving 3 problems: 1) Autonomous navigation without obstacles, 2) The overtaking of a static obstacle and 3) Autonomous parking. The solution is based on reliable artificial vision methods, such as the Sliding Window Technique and the analysis of data coming from a LiDAR sensor; in addition to the control application, ROS and OpenCV.

Each algorithm was tested 50 times in a controlled environment with a minimum light variation, showing a reliability and efficiency percentage of 98% for the first algorithm, 90% for the second one and 95% for the third one.

Introduction

The concept of autonomous vehicles comes from the Futurama exhibit, held at the New York World's Fair in 1939. General Motors created the exhibit to share its vision of the world 20 years from now, and this vision included an automated track system, which guided the cars. Although a world full of robotic cars is not yet a reality, today's vehicles contain features such as assisted parking and braking systems.

Increasing safety, reducing car accidents and improving the driving experience are among the main motivations for equipping cars with advanced automotive assistance systems. Taking this into consideration, ROJAS, Raul. PhD, representative of the "CaroloCup Berlin United Racing" team that has participated in the German competition for scale vehicles "CaroloCup", designed 1:10 scale vehicles (Autominy), which were delivered to several institutions, with the purpose of promoting new technologies for the development of autonomous driving.

According to a report by Stanford Law University, 90% of all accidents worldwide are due in whole or in part to human error. However, there are still impediments to the adoption of intelligent vehicles, such as technological, legislative, ethical and social issues. For this reason, it is desirable to design and implement algorithms to promote awareness of these types of technologies at all grades. Consequently, the "Autominy" scale vehicle is used for the development and implementation of such algorithms.

Materials and methods

The materials needed for this project were a 1:10 scale automobile, a closed track with two lanes and two batteries. As mentioned before, the Sliding Window technique, which locates the local maxima of a processed image to find the beginning of the lines that make up a lane, was used as a basis. Image 1 shows the original image, which is filtered using image processing functions, to obtain a binary image where only the two lines that make up the lane are visible, as shown in Image 2. Subsequently, the pixels are located from bottom to top using windows of a certain height and width, always leaving the window n at the value in x of the average pixel of the previous window. Finally, second degree functions are applied to each line, and from those equations, a recursive algorithm is applied to detect the lane in real time (Figure 3).

Figure 1 Original Image

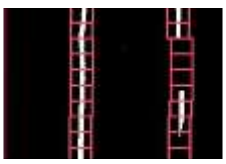

Figure Processed Image

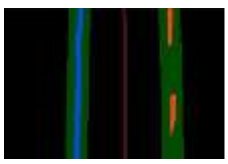

Figure 3 Recursive algorithm

The purpose of the previous method is only the detection of lanes in real scale vehicles; for this implementation a control variable was generated, with which the direction of the vehicle at 1:10 scale could be controlled. This variable was obtained by calculating the average of the lines found, and then generate an angle with respect to the center, to serve as a reference. As shown in Figure 3, the averaged line is located in the middle of the lane, which can be defined as the trajectory to be followed by the Autominy; this is possible thanks to a PD controller, which allows the Autominy to be able to navigate in its own lane without leaving it.

Once the first part was completed, the data collected by the LiDAR was analyzed, from which the graph seen in Image 4 was generated; the data obtained in Image 4 correspond to the degrees and distance generated by the sensor, seen in a real way in Image 5. For static obstacle avoidance, a simple methodology was followed that includes the following steps: a) Detection of the obstacle at a certain distance, b) Knowing the speed in RPM, calculate the time necessary for the Autominy to deviate a certain distance to the other lane, c) Once in the other lane, navigate until no object is detected, and finally b) Return to the original lane using the same logic of the first change.

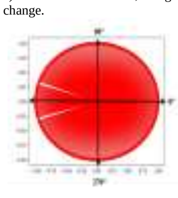

Figure 4 LiDAR information

Figure 5 Representation of data obtained in the real world

Figure 5 Parked Automatic

Finally, an algorithm was developed to allow the Autominy to automatically parallel park. For this task, the logic implemented was the same applied for a full-scale car, which involves moving forward until the rear tires are positioned at the height of the front object; then, using LiDAR ranges, prudent distances were maintained while the vehicle maneuvered forward and backward to park. Basic mathematical formulas such as the Cosine law were used to determine if the distance between the objects was appropriate, as well as a subtraction between the front and rear distances, so that the Autominy was positioned in the middle of the space at the end of the process.

Results

The developed methods were tested in a controlled environment, proving their efficiency by letting the algorithms work in real time and several times. Regarding the first challenge, it was expected that the implemented technique would be able to recognize not only straight lines, but also curved lines, which was successfully achieved by testing the algorithm and achieving an efficiency of 98%, using the proposed control variable, as can be seen in Image 6.

Figure 6 Rail curve

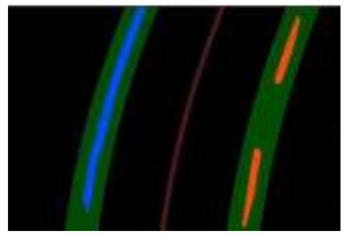

Figure 7 Curve Test

In relation to the second challenge, functional results were obtained, however, some adjustments had to be made to the calculated time in order to compensate for the acceleration and deceleration of the car due to its friction with the floor. Despite the above, satisfactory results were achieved using objects of various sizes as shown in the following images with an efficiency of 90%.

Figure 8 Test with small object

Figure 9 Test with medium object

Figure 10 Test with large object

Finally, multiple tests were performed with different spaces for automatic parallel parking, where the Autominy was able to properly decide whether the space was sufficient or not, and likewise, in 95% of the situations it was able to park itself in the middle.

Conclusions

This work presents a solution to 3 challenges, based on existing techniques and methods. Using the information received by ROS from sensors and actuators, it was possible to merge image processing techniques, such as the filtering of color models like RGB and HLS, and perspective changes using OpenCV; in the same way, the Sliding Window Technique was used, which was only applied to detect lanes in real vehicles, in order to control a vehicle at scale. On the other hand, the other two challenges used simple but effective methodologies to attack the problem, with which they were able to analyze data from the LiDAR, in order to filter and use them.

To obtain more robust results that work in scenarios with unpredictable variables, such as light, it will be necessary to have a camera with a wide perspective and a more complex algorithm that takes into account those variables.

Future of research

This project will serve as a tool for the development of the area of Computational Robotics at the Polytechnic University of Yucatan, acting as a basis for the design and implementation of intelligent systems and algorithms for autonomous vehicle navigation.

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