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*Abstract*—This paper details the composition, testing and implementation of different sensors and microcontrollers to achieve a goal which consist in developing a smart robot car. This car has same special capabilities to operate in an autonomous behavior also fulfilling some criteria. Another fundamental objective that it owns is the ability to function as independent and distributed system. Different sensors like line tracking sensors and ultrasonic sensors can lead the car to different application and contributes also in increasing the overall safety. Another intelligent communication is developed to make the car more reliable and it consist in processing the signals that the car can deliver through certain LEDs. Every hardware component is connected to software by using a model that is generated by UML diagrams. The prototype is able to be adapted for further purposes.

Keywords—Line tracking sensor, ultrasonic sensor, I2C, image processing, communication

# Implementation

## Line tracking sensors

First, The car prototype consist in three main task that the car should full fill in this project .In our prototype an additional feature was decided to be implemented. This feature was associated with providing the car a third autonomous behavior. That was done by using LED and later using image processing to establish a communication between cars .Two tasks consisted in autonomous driving behavior from the car realized by ultrasonic and line tracking sensors .And the Third task was to control this car as a distributed system by using component like raspberry pi and streaming from it . The main task to be involved was line tracking module. The task was to give te car the attributes to follow a black line in an autonomous behavior. To realize this function, was a need to use two line tracking sensors. After some discussion with group members was decided to put the sensor in the middle of the car body .The main reason for this idea consist in the point that the car has enough time to response and follow the line .The implementation of the line tracking consist in some states which were done firstly in a state machine diagram .This Technique helped in building a suitable code .It also helped to come from an abstract idea how the cart should operate in a different states to a concrete level of operating .After a final decision the states machine diagram was implemented in the following way . They were four cases that the car should face. The four cases are implemented in concreate by four different function .Functions are called as they were defined in the state machine diagram .The two sensors were tracking a nonblack area and this was the first case when the car has to move forward with a specific speed that could be set up buy a user .The second behavior of the car was when the car get a signal from the left sensor that now the color has change to black .In this point the left sensor is detecting a black line so the car should turn left .After that the sensors should both recognize white color and car could return to the first stage and move forward .The third case was when the right sensor was detecting a black area .Now the car should turn right and in this point the specific function was called .To give a general view the black line should be in the middle between two sensors and the so car is able to follow it .The last case was when the both sensors detect a black area .In this point the car was programmed to stop .The reason for making this function was done to fulfill one of the tasks of the general project .By implementing this function ,the position of the car was possible to be tracked and relate the sensor date with a real physic position of the vehicle .By adding more of this cases through the black line a remote user that has no visual information regarding to the shape of the black line now is able to create a map and could have precise knowledge where the car is and in which direction it will turn next time .

## Ultrasonic sensors

Another important component that should be added to the car were the ultrasonic sensors. They were three ultrasonic sensors that were combined together to get a better coverage of the area and detecting obstacle in different direction .The position of ultrasonic sensor were in the front of the wooden car prototype and they were shifted nearly with 90 degree to detect obstacles in the front left and right .this was a good idea by the car designer .By inserting the sensors in different position the car was able to work and cooperate with the environment in more efficient way . Before the sensors implementation the information was gathered how they operate .After some discussions with other group members was decided to give the priority the ultrasonic sensors .After this point was a need to change te state machine diagram .After update and addition of these sensors to the state machine diagram ,the implementation in code was done. The main state for sensors was to detect if it was an obstacle in the black line .And if the sensors detect obstacle the car should change the state from running to a full stop despite what values the line tracking were generating .If we would like to see it in a hierarchical form the ultrasonic sensors are in the top and after them are the line tracking sensors. The ultrasonic sensors were able to detect the distance from different physical object without defining the nature of the object or obstacles. The Distance value from the object is stored and this value will help to switch from the different states .In this point the car has two state running and making a full stop or decrease the speed of the motors .If the sensors were detecting an obstacle in front of the car the car. The car should stop even the line tracing sensors are generating right values. Because the ultrasonic sensor has a higher priority .The second case was occur when there are no obstacle and the car was safe to continue forward in the black line .In other words if there were not objects in the predicted range so the three sensors were not getting obstacles .In the second case the car control is taken by the line tracking sensors as it was defined and design in state machine diagram . The ultrasonic sensors were implemented and programed to check for obstacle every time without any interruption on time .The car will be able to stop immediately if something fall in black line accidentally and prevent car from crashing .By implementing in this way the general safety of the car is increased .Due to further integration the ultrasonic sensors were added another functionally . By combining together three ultrasonic sensors the car was able to find a free path .In different condition for example a maze the car was able to find a free and right path ,This function provides the car with a powerful ability to operate in a better autonomous behavior and without any surveillance. Even the car has that capability it was not necessary to be implemented in overall project .This was a demonstration that the ultrasonic sensors combined together could be more beneficial than just a single one .The scope of implementation is wide and can be composed with different varieties .

## I2C comunication

The third feature that this car should have, consist in implementing different microcontrollers to control the car. This should be done by using different communication interfaces that the microcontrollers offer. The connection should be done between raspberry pi and Arduino. The type of communication that was chosen was i2c .The raspberry pi was the master and the Arduino was te slave .This type of communication was selected because it is a powerful connection that allow one or may masters connected to one or many slaves .The connection was done by using pins and wires .The connection was fast and reliable .A specific command was sent to test the communication .One LED was connected with Arduino and from raspberry pi were send commands to turn the LED on and off. The connection was fast and the devices were able to communicate .There was a good example to demonstrate that each device was able to send and receive information .In the Arduino was obvious that the light turn off and on but also in raspberry pi were send text that indicate the light state .This was the communication that was done between components in the car .

## Some Common Mistakes

Another communication that was developed by us that added some new features to the car, were LED signal .This communication was done in a simple way by using different LED with different colors .The LED were connected with ultrasonic sensors .In the case of an object or obstacle in front of the car ,the car will stop and red LED will turn on .This will indicate there is an obstacle and other cars that are behind can process this image by using the camera that they had previously installed .This would make the car to stop and wait for another signal .This was an innovative way of communication that was developed .There are no other resources used only the existing parts .By implementing this solution the car now has three main components for operating in an autonomous way. The other situation was occurred when the car was moving forward and there were no obstacle and the LED in this case was green. This mean that the path was clear and other cars behind can process this information and continue their operational state. If something will happened and for a reason or another the cars that were behind our car would have a failure in the ultrasonic sensors they still will be able to get signal from our prototype and will continue to operate in optimal conditions .In This case the LED signals would work as a sensor for the other cars .The image processing was not fully implemented because was out of the project scope but it might be implemented in a later point.

# Evaluation

## First inspection

During the code evaluation some problems that were produce by line tracking sensors should be managed .This difficulties consist in physical constraint. Two most significant were the thickness of the black line and the light .The thickness of the line should fit between two line tracking or the line tracking sensors should open more wide to fit the state machine functions .The other problem was light, due to different light changing conditions and reflection to the black line .The sensors were generating wrong values and as a consequence the car was taking wrong decision and did not behave in an appropriate way as it was defined .This two problems were solved in a manual way .For the case of the thickness was solved by increasing or decreasing the space between sensors in a way to fit the line .Also the light reflection was optimized by increasing or decreasing the sensitivity of the sensor .These adjustments were done manually .To realize and discover what was the best case and values some different test with different values were needed firstly to be done . in conclusion which values were the best were chosen and after this point the implementation took part. Also the changes were done in the software part not only in hardware. After some different version the most efficient one was selected. Despite this fact both hardware and software need to be optimized for better usage in future .In this point this feature was implemented in a successful way and the car was able to operate independently .

## Second inspection

During the implementation, tow problematic situation should be handled in which the ultrasonic sensors might give wrong results. The first concern was the frequency in which ultrasonic sensors operate. A theoretical example is when the car is operating in the same environment with different ultrasonic waves and this can interfere with other frequencies and distortion might occur .The second theorical problem scenario might be the temperature of the environment when ultrasonic sensors are operating this also might lead to incorrect values and have a huge impact in overall process and functionalities .Despite of this concerns during the testes this problems were not met because the environment was optimal and suitable .Never the less If something will occur a prevention was implemented by combining together sensors and getting a better result in the end .Another possibility was buy making necessary changes in the code and implemented it in this new circumstances. Also, the ultrasonic sensors would make possible to add a significant feature to the car. In case of obstacle a light will be changed from green to red this will held to establish a communication between cars. Further explanations have been mentioned below. As a result was able to put together two components and now the car has more possibilities and has gone in a higher level towards the autonomous scale .Also sensors are collaborating together but ultrasonic sensors were in a higher priority in certain condition .The tests proved that the functionality of the components was at satisfactory level .

# Acknowledge

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