PERFORMANCE EVALUATION AND ANALYSIS OF A VISION-BASED MOBILE ROBOT WITH SENSOR FUSION CAPABILITIES

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ABSTRACT. The study focuses on the performance evaluation and analysis of a vision-based mobile robot equipped with sensor fusion capabilities for line following tasks. The combination of camera and IR sensor array were aimed to enhance the robot's line following capabilities by combining data received by the sensors. The first step is developing a base model of 4-wheel mobile robot with esp32 as the main controller. Sensor fusion techniques including data fusion and feature-level fusion are employed to combine visual data from the Pixy2 camera and positioning data from the IR sensor array. This fusion process results in a comprehensive representation of the line's position and orientation thus enabling precise and accurate line tracking. The performance evaluation focuses on assessing line tracking accuracy, stability and responsiveness of the vision-based mobile robot with sensor fusion capabilities. Experimental results demonstrate the effectiveness of the fusion approach in improving line following compared to using individual sensors. The system exhibits robustness and adaptability in varying environmental conditions and noise interference. Overall, this study has been able to generate another option of vision-based mobile robots with sensor fusion capabilities providing valuable insights into the combination of visual and positioning sensing for precise line following. The evaluated system serves as a foundation for further fun experiments in the field of mobile robotics enabling autonomous robots to navigate accurately.

KEYWORDS: autonomous mobile robot; sensor fusion; vision based mobile robot

1 INTRODUCTION

Navigation as of Line following is a fundamental problem in mobile robotics (Alatise, M., & Hancke, G., 2017), enabling autonomous robots to navigate along predefined paths. The accurate and reliable tracking of lines poses challenges due to sensor limitations and noise from the surrounding environment. To address these challenges, this study focuses on the performance evaluation and analysis of a vision-based mobile robot equipped with sensor fusion capabilities for line following tasks.

The integration of a Pixy2 camera and an IR sensor array aims to enhance the robot's line following capabilities by combining data received from these sensors. The Pixy2 camera provides visual data enabling the detection of the line's position and orientation while the IR sensor array offers positioning data allowing the robot to measure its distance from the line.

To achieve a comprehensive representation of the line and improve line tracking accuracy the study employs sensor fusion techniques such as data fusion and feature-level fusion. These techniques combine the input from the sensor to enable precise and accurate line following.

2 THE MOBILE ROBOT PLATFORM DESIGN

This section will explain the mechanical and electronic design of this study.

2.1 The Hardware Setup

This mobile robot uses the DFRobot Baron 4WD as the chassis. This platform is made from aluminium and has a four-wheel drive. The platform is driven by a geared DC motor which has 0.07Nm torque and paired with a rubber wheel. The platform also has more than enough space to place all the electronic components, camera and sensors. With a max load of 800g this chassis is more than suitable for this study.

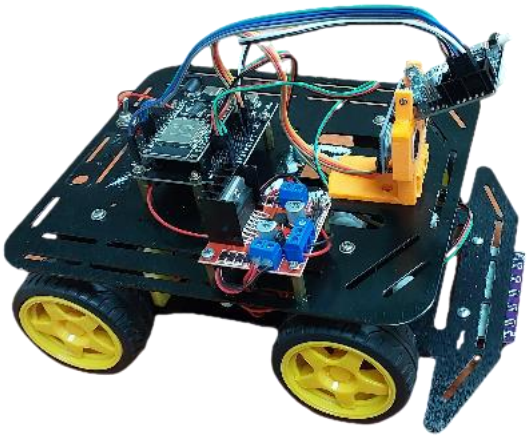

Figure 1: Figure shows a complete built of the mobile robot used in this paper.

2.2 The Electronics Component and Setup

The electronic components play the crucial part in this study and the main factor of the parts selection is based on cost, availability and resource of references to support the design and algorithm. ESP32 has been chosen as the main controller because of its versatility. Arduino is the main environment of this study and to integrate all the electronic components. The Pixy2 camera is used to provide the input to the ESP32 from the line reading. This camera has on board processing and a predefined program to read the line and provide multiple output to the microcontroller. This is very convenient and the ESP32 can focus more on other tasks like controlling the motor driver. This idea also has been mentioned by Abdulazeez, A. M., & Faizi, F. S. (2021). IR sensor array was installed at the bottom of the robot platform and provided an analog signal to the microcontroller. Single L298N is being used to control 4 dc motor. Each output port of the motor driver is connected to 2 dc motor each.

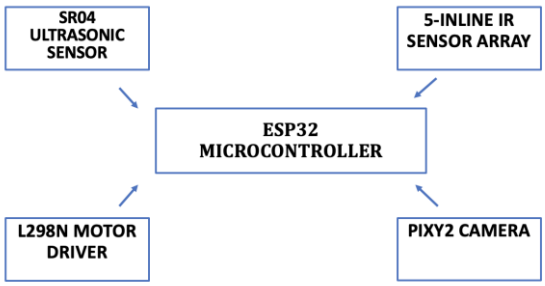

Figure 2: The figure above shows the block diagram of connection between ESP32 microcontroller and all other component.

2.3 Sensor Data Fusion

In this study, a fusion technique is utilized to combine the data from the Pixy2 camera and the IR sensor array for the purposed of improving line following mobile robot performance. Agarwal et. all,. (2019) also propose the same method to define better localization. The data fusion process involves integrating the data obtained from both sensors to obtain a comprehensive representation of the line's position and make more accurate control decisions.

By combining the data from the camera and the IR sensor array the robot benefits from the data of both sensors. The camera provides visual data and the IR sensor array give a proximity information that can be helpful in scenarios where the line is on the blind spot area, in this study it was at the area in range of 30cm in front of the mobile robot platform. The fusion of these two sets of information results in a more robust and reliable line-following system. Barreto-Cubero et. all,. (2021) are using an advanced approach with neural network design.

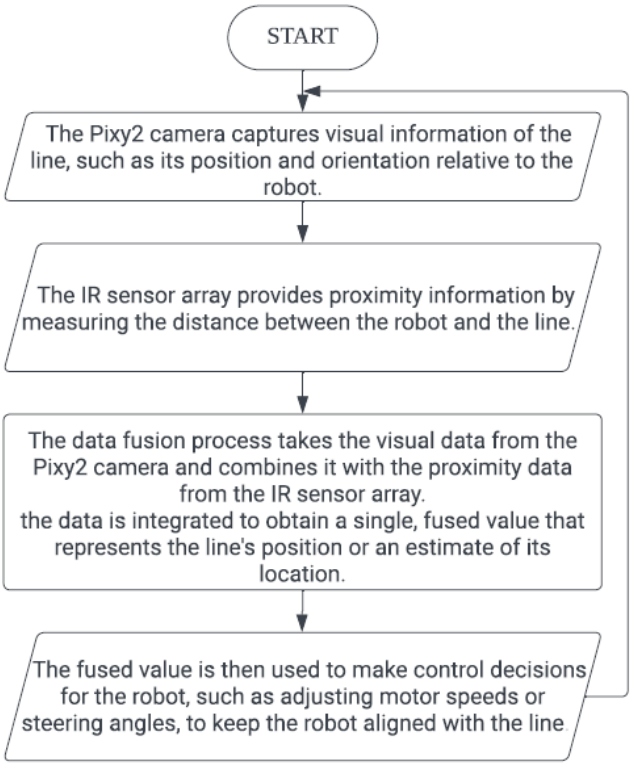

Figure 3: Flow chart of the sensor fusion process and executions.

3 PERFORMANCE AND ANALYSIS

To get the performance of this study, the mobile robot with fusion-sensor technique is being compared with mobile robots that use only camera and IR sensor array. The performance is assessed based on the ability of the mobile robot to follow the black line circuit of 2 meter in length. The time to complete the circuit is being recorded. There are 3 method of configuration and algorithm that being assessed in this study, which is mobile robot using IR sensor only, mobile robot with Pixy2 camera only and mobile robot with the sensor fusion of Pixy2 camera with iIR sensor. The faster it takes to complete 1 round of the circuit is being considered to be more highly efficient than the other algorithm.

For the camera only method, the firmware used is the default program provided by the manufacturer to follow the line and added with configuration of the dc motor only. For the method of using only IR sensor array is placed perpendicular with the black line at the front of the mobile robot platform. The results of evaluation are shown in Table 1.

Table 1: The results of performance evaluation for each method for mobile robot.

Method/algorithm	Lap 1	Lap 2	Average time
Method 1(IR sensor)	35s	34s	34.5s
Method 2(Pixy2 camera)	37s	35s	36s
Method 3(Pixy2 + IR sensor)	32s	34s	33s

During observation, all methods are able to complete the black line circuit in a controlled environment, with no excessive light from outdoor. The testing location is being held in the laboratory with all lights ON. It might be a little noise in the form of IR light from the windows but it has been ignored.

All methods are able to move without missing a turns or out of line boundary except for method 2. It might be because of the noise from the environment. Method 2 just missed 1 turn during the testing period. Besides that, everything are works as programmed.

Method 1 is a bit slower than method 3 because method 1 move is not as smooth as method 3. There is a time where method 1 has a bit of over-turn during cornering but it manages to back on track. Method 3 also manages to maneuver with no over-turn.

4 CONCLUSIONS

The testing results show the fusion sensor method is the best in terms of time taken to complete the circuit. This method also has the best movement out of 3 methods. The main factor for these results is the algorithm used in method 3. The pixy2 camera gives output that is used as the main direction for the mobile robot and the IR sensor array will help to determine and smoothly maneuver the mobile robot with better positioning.

However, the study shows that IR light radiation is still a concern when using a camera as it can highly impact the data recorded. Full direct contact of light into the camera lens will result in total blindness and mobile robots will behave irregularly. Future work will include image filtering to get better visual data and less noise.

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