DEVELOPMENT OF AN EMERGENCY BRAKING SYSTEM FOR AUTONOMOUS AGRICULTURAL VEHICLES

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ABSTRACT

An emergency braking system (EBS) in autonomous vehicle is crucial to ensure safety when it is running. This feature has been missing in some of the autonomous vehicles used for agricultural use in Malaysia. Therefore, the objective of this study is to propose an autonomous emergency braking (AEB) system using Light Detection and Ranging (LiDAR)-based system to detect obstacles and stop the vehicle before it reaches the object. A TIM781 SICK LiDAR sensor has been used alongside a linear actuator to implement the system. The result shows that the system is able to detect an obstacle and trigger a warning light siren before it reaches the object. The evidence from this study suggests that an AEB system implementing LiDAR for autonomous agricultural vehicle is feasible.

Keywords: Emergency Braking System, Light Detection and Ranging, autonomous, agriculture

INTRODUCTION

This paper delves into the comprehensive research and development of an Emergency Braking System (EBS) specifically tailored for an autonomous agricultural vehicle. With the aim of augmenting the safety measures already in place, this system is designed to provide a swift and reliable response in unforeseen situations, thereby reducing the risk of accidents and safeguarding both the autonomous vehicle and its surroundings.

The complexity of agricultural environments, characterized by varying terrains, unpredictable weather conditions, and the presence of diverse obstacles, poses unique challenges to the implementation of effective emergency braking systems. This research endeavors to overcome these challenges through a multi-faceted approach, combining a LiDAR sensor, a linear actuator, an alarm system and real-time data processing to enable rapid and accurate decision-making by the autonomous vehicle's control system.

According to Lee, Kim, Kim, and Huh (2014), actuator speed is a critical aspect in the development of an autonomous braking system because it affects the braking performance and stopping distance. However, the type of vehicle used in the authors' work is a car which generally has a much higher moving speed than an agricultural tractor. Bae, Lee, and Kang (2020) designed a variable braking algorithm based the time-to-collision. However, their work is on a simulation and not yet proven on a real application.

This study incorporates a TIM781 SICK LiDAR sensor in conjunction with a linear actuator to establish the operational framework of the system. It is expected that the system will be able to detect an obstacle and give an alarm trigger according to the obstacle's distance.

MATERIALS AND METHODS

Design specifications

The AEB is to be used in an autonomous agricultural tractor. Therefore, the tractor's attributes such as weight and average operating speed have to be taken into consideration when designing the AEB. Based on a typical light tractor's attributes of 2 Mg weight (Bakken et al., 2009) and 11 kmh^{-1} operating speed, the design specifications of the prototype are shown in Table 1.

Table 1. Design specifications of the AEB prototype

No	Subject	Details
1	Obstacle detection range	At least 18 m
2	Deceleration value	Between 2.15 and 5.51 ms^{-2}
3	Additional feature	Alarm trigger

LiDAR sensor

The SICK TIM781 LiDAR sensor used in this research and its general specifications are shown in Figure 1 and Table 2.

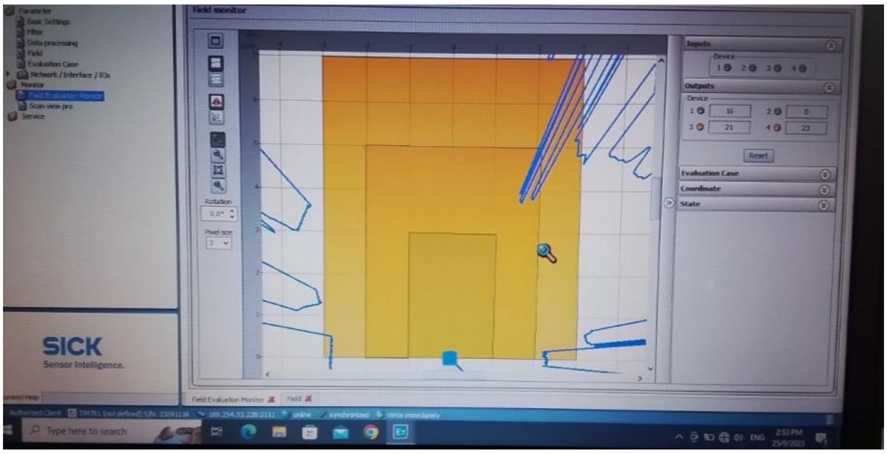
Figure 1. SICK LiDAR sensor used in this research

Table 2. Specifications of TIM781 SICK LiDAR

No	Subject	Details
1	Measurement principle	High Definition Distance Measurement Plus (HDDM+)
2	Application	Outdoor
3	Light source	Infrared (850 nm)
4	Laser class	1 (IEC 60825-1:2014, EN 60825-1:2014)
5	Scanning frequency	15 Hz
6	Working range	0.05 m to 25 m
7	Scanning range	Min. 8 m
8	Enclosure rating	IP67

It has three active low outputs corresponding to three distance profiles. The three profiles have been programmed into the sensor using a SICK proprietary software, SOPAS Enginering Tool (ET). An example of the distance profiles is shown in Figure 2.

Figure 2. An example of distance profile setting using SOPAS



Arduino controller
For the output of the LiDAR sensor to be useful, a controller is needed to utilize the LiDAR signals and control the braking system. Arduino Mega 2560 controller has been chosen based on its market availability and wide community support. However, since the controller's operating voltage is 5V whereas the LiDAR's output is 12V, a voltage divider circuit has been used to step down the LiDAR's signal.

Linear actuator
To simulate brake pedal pressure by a driver, a linear actuator has been used. The actuator movement speed is based on the distance to the obstacle. To vary the speed, a pulse width modulation signal output from Arduino is used. The speed is based on the distance of the obstacle from the vehicle.

Motor driver
Since Arduino can only give a maximum of 5V output, whereas the linear actuator's input is 12V, a L298N motor driver has been used to convert the Arduino output to a signal usable to the actuator.

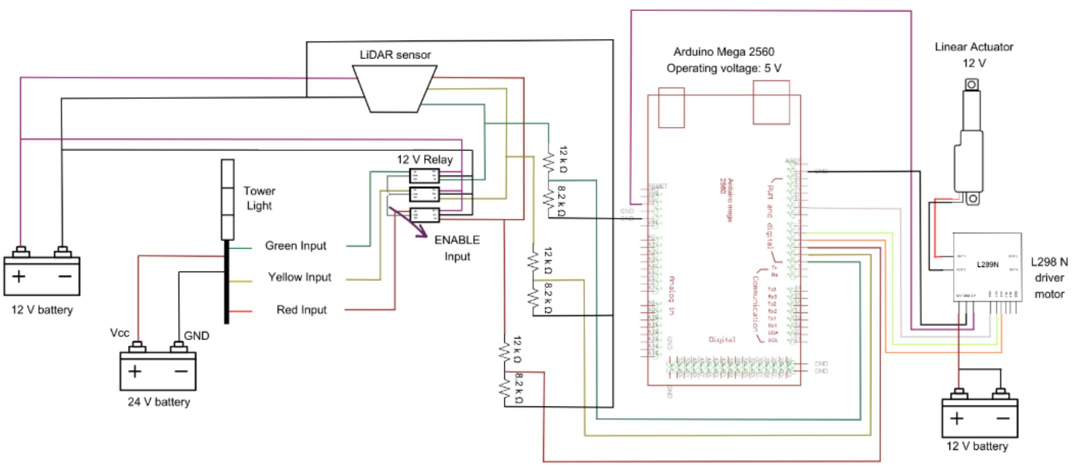
Alarm trigger
To give a warning when an upcoming obstacle is detected, a tower light with relay circuit has been used. The tower light has 4 inputs; green light, yellow light, red light and alarm. The relay will turn on the lights and alarm according to the conditions in Table 3.

Table 3. Conditions set for alarm trigger

Condition	Obstacle distance (m)	Relay signal
1	20	Green light
2	18	Yellow light
3	15	Red light and alarm

Overall system
Figure 3 shows the overall circuit diagram of the AEB prototype. It has been mounted on an autonomous ground vehicle prototype to test and verify its performance.

Figure 3. Overall circuit diagram



RESULTS AND DISCUSSION

Verification of obstacle detection
To verify the system's performance, several conditions have been tested as in Table 4. The tests have been first performed indoor before being repeated outdoor. Each test has also been repeated five times. The results are shown in Table 5.

Table 4. Conditions used to verify system's performance

Condition	Distance between obstacle and vehicle (m)	Obstacle/ vehicle movement
1	20	Vehicle moved
2	18	Vehicle moved
3	15	Vehicle moved
4	20	Obstacle moved
5	18	Obstacle moved
6	15	Obstacle moved

Table 5. Results of verification experiments

Condition	Tower light response
1	Green light
2	Yellow light
3	Red light and alarm
4	Green light
5	Yellow light
6	Red light and alarm

As can be seen in Figure 2, three rectangular-shaped obstacle detection boundaries have been programmed. The rectangular shape has been chosen to prevent false detection due to the experimental setup arrangement. In real applications, a half circle shape should be used to get a more accurate obstacle detection range around the vehicle.

CONCLUSION

The objective of this paper is to verify the performance of the AEB on a prototype vehicle. It was found that the system was able to detect an obstacle and give an alarm trigger according to the obstacle's distance. The outcomes of this research not only contribute to the advancement of autonomous agricultural technology but also serve as a benchmark for safety standards within the broader domain of autonomous systems.

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