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ARTICLE

Engineering

How Are Manual Braking Systems and Automatic Braking Systems Affected by Speed?

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Every year, over 1.3 million people die from road accidents, making it the leading cause of death for people between the ages of 5 and 29 (World Health Organization, 2022). Higher speeds often result in more severe accidents (The Government of Canada, 2022). Autonomous technologies such as the braking capabilities in Teslas have been developed to reduce road collisions. These technologies use sensors and computer systems to gather information about the vehicle's surroundings and prompt drivers to take the necessary safety measures. As such, the switch from manual to autonomous vehicles can potentially increase driving safety and reduce accidents.

INTRODUCTION

In this project, the concept of autonomous technologies was adopted. This concept used an Arduino microcontroller (Arduino, Turin IT) and Arduino IDE software to build and program a model vehicle, Tassi Dynamics, equipped with sensors, motors and other electronic parts. The project compared the braking distance of this modeled autonomous vehicle to a manually controlled one. The effect of speed on the braking distance was also investigated.

This project helped develop essential knowledge and skills related to robotics and automated systems, specifically during the system's assembly, programming, and testing. The research and experiments enhanced my understanding of Arduino hardware and software systems and how autonomous vehicles can revolutionize safe transportation.

MATERIALS AND METHODS

To answer the research question "How are manual braking systems and automatic braking systems affected by speed?", an internet search was conducted for a suitable system to construct the model vehicle for experimentation. After evaluating several options, Arduino hardware and software components were selected and used to design and build a small autonomous vehicle capable of detecting and avoiding obstacles while following a line tracker. The materials used for the construction of both autonomous and manual models included an ultrasonic sensor, an L298N motor driver board, four DC motors, a servo motor, an Arduino Uno R3, a V5.0 Expander, two batteries, a plywood base, connection cables, four wheels, and a pushbutton. The Arduino IDE software was used to program the vehicle's operations. The complete assembly, materials and schematic view of the vehicle has been displayed in Figures 1, 2, and 3, respectively.

Once the vehicle was operational, an experiment

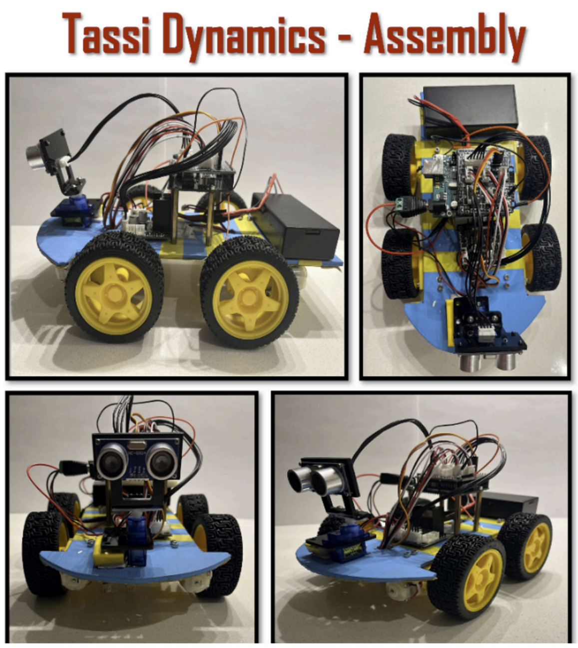


Figure 1: Photograph of the tested robotic vehicle from different angles

Figure 2: Diagram of materials used to construct the robotic vehicle

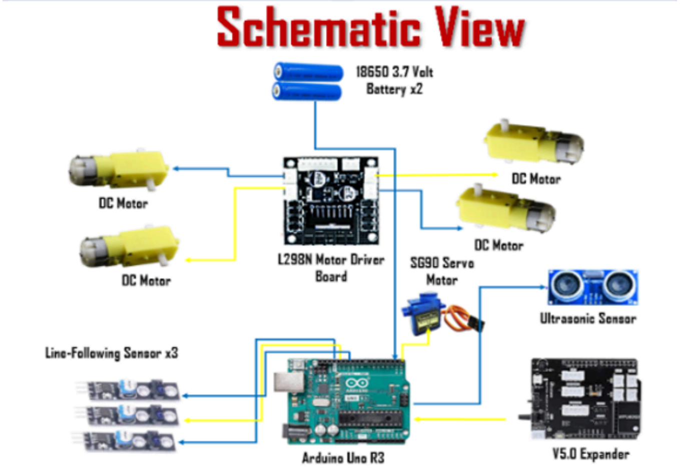


Figure 3: Schematic view of electrical components in the robotic vehicle

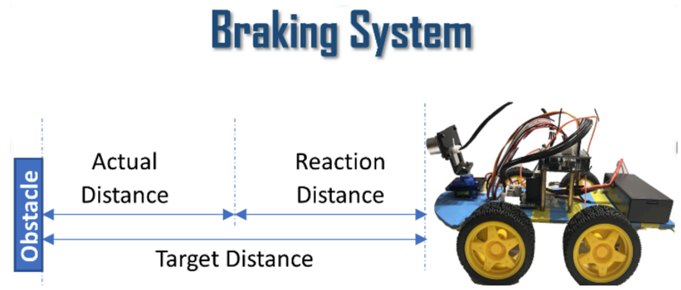
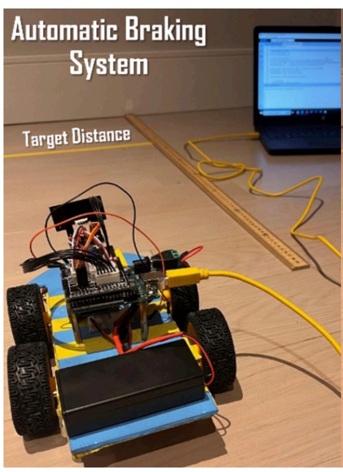


Figure 6: The measurement of the braking system

was designed to evaluate the effect of speed on the reaction distance for both the manual and automatic braking systems (setup displayed in Figures 4 and 5). The Arduino software was coded to set speeds of 17, 33, 50, 67 and 83 cm/s. The reaction distance for each speed in both manual and automatic braking modes was calculated by subtracting the actual distance (when the vehicle stopped) from the target distance specified in the program, as shown in Figure 6.

During the experiment, the vehicle accelerated from a distance of 300 cm away from the stationary obstacle. The vehicle was programmed to stop for the autonomous braking test when it detected an obstacle 30 cm away (target distance). For the manual braking tests, a marker was placed on the track to mark the 30cm target distance, and the user-controlled the braking with a "push-button" connected to a breadboard powered by the Arduino Uno. The actual distance (in centimetres) from the obstacle when the vehicle stopped was recorded using the serial monitor within the Arduino program. The results were recorded, graphed, and statistically compared.



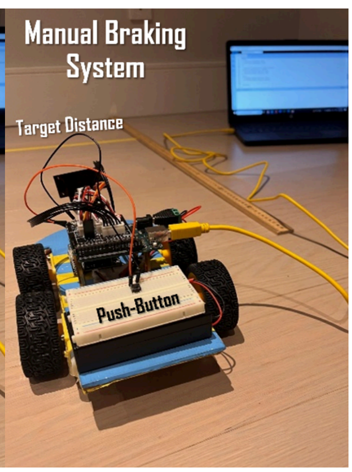


Figure 4: Setup of the Automatic Braking System

Figure 5: Setup of the Manual Braking System

RESULTS

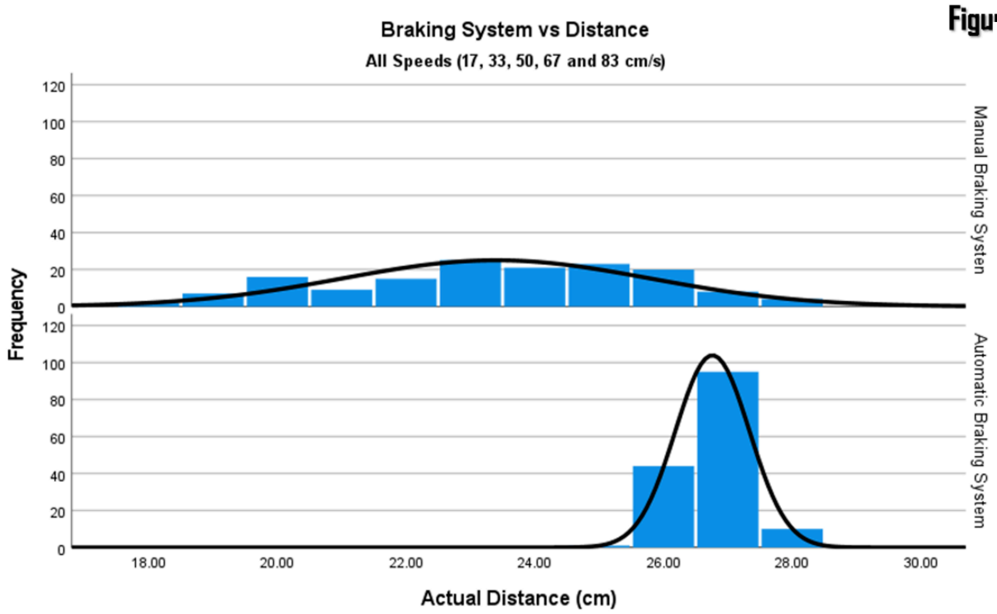
As observed from Figure 7, the results of this study indicate that the automatic braking system consistently had a lower reaction distance than the manual braking system at most speeds except for the lowest speed of 17 cm/s. At 17 cm/s, the automatic and manual braking systems had a similar average reaction distance of 3.4 cm and 3.6 cm, respectively. As the speed increased, for the automatic braking system, the model vehicle stopped closer to the pre-set target distance and further away from the obstacle compared with the manual braking system. The difference was greatest at the highest speed of 83 cm/s, where the reaction distance was 3.0 cm for the automatic braking system compared to 9.6 cm for the manual braking system.

Furthermore, variability in reaction distance was observed between the different braking systems at different speeds. At a speed of 17 cm/s, the manual braking system had a standard deviation of .89 cm compared to .63 cm in the automatic braking system. At the high speed of 83 cm/s, the standard deviation for the manual and automatic braking systems was 1.19 cm and 0.59 cm, respectively. The manual system showed more variability in reaction distance, increasing as the speed increased. The automatic braking system showed less variability in the reaction distance; thus, it was more dependable and consistent than the manual braking system (see Figures 7-9).

It was also noted that the average reaction distance of the automatic braking system was consistent at 2.9 - 3.5 cm , in all tested speeds. This meant that the autonomous vehicle consistently came to a stop at the same distance from the target distance, regardless of speed. On the other hand, the manual braking system showed more variability in average reaction distance at 3.6 - 9.6 cm, with these average distances increasing as the speed increased.

The experimental findings suggest that autonomous vehicles have a more consistent reaction distance than manual vehicles, especially at higher speeds. This suggests that autonomous cars could potentially reduce the risk of accidents, as the vehicle consistently stops at a safe distance from the obstacle. However, it is important to note that other factors, such as driving conditions and weather, could affect the reaction distance of both braking systems. Further research is needed to fully understand the differences between autonomous and manual vehicles in terms of reaction distance and safety.

Figure 1



Group Statistics

BRAKESYS		N	Mean	Std. Deviation	Std. Error Mean
DISTANCE	Manual	150	23.4000	2.39406	0.19547
	Auto	150	26.7600	0.57557	0.04699

Figure 7: Statistics of the manual and automatic braking systems

Table 1: Automatic Braking System Data

Trial #	50 RPM	100 RPM	150 RPM	200 RPM	250 RPM
1	27	27	27	27	26
2	27	27	27	27	27
3	27	27	27	28	28
4	27	26	26	28	28
5	26	26	27	27	28
6	26	27	27	27	27
7	27	27	27	27	27
8	27	27	27	28	26
9	27	26	27	27	27
10	26	26	26	27	26
11	27	27	27	27	27
12	26	26	27	27	28
13	27	27	27	27	27
14	27	27	26	27	27
15	27	27	27	27	26
16	26	26	27	27	27
17	26	26	26	27	27
18	27	27	26	27	27
19	26	26	26	27	27
20	26	27	26	27	27
21	27	26	27	27	27
22	28	26	27	27	27
23	26	26	27	27	28
24	25	26	27	27	27
25	27	27	26	27	27
26	27	26	27	28	26
27	26	26	26	27	27
28	26	27	26	27	27
29	26	26	26	27	27
30	27	27	26	27	27
Mean	26.6	26.5	26.6	27.1	27.0
Median	27.0	26.5	27.0	27.0	27.0
Mode	27.0	27.0	27.0	27.0	27.0

Table 2: Automatic Braking System

Trial #	50 RPM	100 RPM	150 RPM	200 RPM	250 RPM
1	27	25	25	23	20
2	26	25	24	22	21
3	28	24	24	19	20
4	28	26	24	23	22
5	27	25	25	20	19
6	26	24	23	23	18
7	26	26	22	22	21
8	25	25	24	23	20
9	27	24	25	23	20
10	28	25	23	24	19
11	28	25	23	24	21
12	26	26	23	24	20
13	27	24	23	23	22
14	25	26	23	23	23
15	26	24	24	22	19
16	26	25	23	22	21
17	26	25	24	23	20
18	27	25	23	22	20
19	27	25	23	19	23
20	25	25	24	19	20
21	26	24	23	20	20
22	27	26	24	23	21
23	25	24	24	22	20
24	26	25	24	22	21
25	26	25	23	20	20
26	27	25	22	19	20
27	26	25	23	22	18
28	26	26	22	22	21
29	26	24	23	20	21
30	26	25	23	22	21
Mean	26.4	24.9	23.4	21.9	20.4
Median	26	25	23	22	20
Mode	26	25	23	23	20

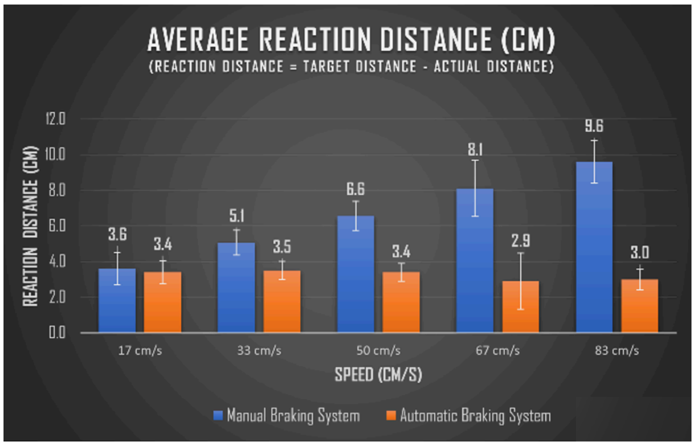


Figure 8: Bar graph displaying data of average data sets and standard deviation of the average actual distance

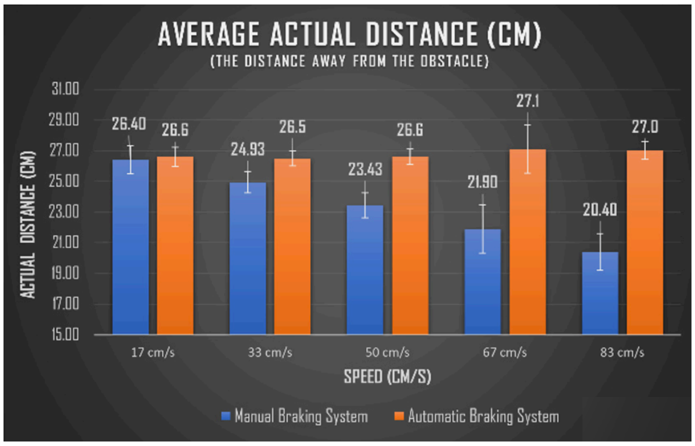


Figure 9: Bar graph displaying data of average data sets and standard deviation of the reaction distance

DISCUSSION

The study showed that the automatic braking system had consistent reaction distance across all tested speeds. In contrast, the manual braking system's reaction distance varied with speed and the driver's reaction time, as shown in Figures 9 and 10, and Tables 1 and 2. When comparing the two braking systems, the autonomous vehicle had a more reliable and consistent Reaction Distance, especially at higher speeds, assuming all other conditions remained unchanged.

Future Improvements: Use a speedometer to ensure the vehicle accelerates to the required speed. The speedometer could eliminate any variability that may have occurred due to inconsistent speed.

Further Research: Use different operators to determine whether there are any changes in manual braking reaction distances due to differences in human reaction time.

Experiments could be conducted using different Target Distances (30, 20, 10, or 5 cm) at which the vehicle must stop, to determine the effect on the Reaction Distance. These findings could provide insight into the safety and reliability of braking systems.

CONCLUSION

Using sensors in automatic braking systems allows for faster detection and response to challenges than a distracted human driver, potentially reducing the number of collisions. However, it is also important to note that reaction distance is only one aspect of overall safety. Autonomous vehicles can still encounter unique obstacles such as software faults or hardware malfunctions. Continued testing and upgrading of autonomous technology is essential to ensuring road safety. Autonomous vehicles have the potential to improve transportation by eliminating the need for a driver, thereby allowing passengers to relax or work during the ride. This also reduces issues associated with human-operated vehicles, such as fatigue and human error. However, the current cost of autonomous technology is high due to its advanced capabilities. The cost is expected to decrease as the technology is improved and widely used (Sypnosis, n.d.). Overall, autonomous vehicles have the potential to revolutionize transportation by improving safety, convenience, and efficiency. However, there are challenges that still need to be addressed before a complete switch to autonomous driving. These challenges can include evaluating cost-to-build, safely building microcontrollers, and developing very advanced systems that mimic humans.

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Abrahim Tassi, a 12-year-old from London, Ontario, is proud of his scholarly achievements and leadership roles. He has won competitions in science, mathematics, and spelling, and earned platinum medals in Kumon, completing the entire English program in grade 4. He has represented his school at provincial spelling bees, as well as city-wide and Canada-Wide Science Fairs, and was honored to serve as his school president in grade 7. Beyond academics, Abrahim enjoys basketball, playing piano, reading, and socializing with friends. He is committed to improving himself and his community and hopes to one day impact the world in a positive way.