Automatic Head-on Anti-Collision System for Vehicles using Wireless Communication

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***Abstract*— A model of an anti-collision system for vehicles was designed, in a way that to avoid head-on collisions only. Two small motorized cars were built. Each car consist of Arduino microcontroller, ultrasonic sensor module, RF module and two DC geared motors. Each car is driven by a couple of DC motors from the rear end while the front is only a castor. As a form of differentiation each car was given the name of its Arduino controller which are Mega car, and Leonardo car. The controller of each car measures the distance ahead continuously using the ultrasonic module and checks the measured distance against the respective car's ahead distance through the wireless module. If the received distance found to be less than 40cm for the Leonardo car and less than 50cm for the Mega car then the two cars will stop their movement completely as if there is an impending collision in reality. The Arduino microcontroller is programmed using the Arduino programming language and C language to implement all the desired objectives which are related to each car's actions.**

Keywords—Safety; Communication; Vehicles; Arduino

I *INTRODUCTION*

Taking safety precautions while driving a vehicle are the most instinctual behaviour of humans at hazardous circumstances. Due to global urbanization vehicles are increasing in a rapid rate, for example in Malaysia, automobile manufacturing companies had increased their production from 80000 units since 1985 to 240000 units a year which is considered three times of its starting production rate in 1985. Meanwhile, accidents are also increasing but in a feasible rate, for example between the years 2005 and 2009 according to the department of statistics in Malaysia accidents had increased by 21% [1].

So far, several intelligent systems are beginning to be included in commercial vehicles, such as Antilock Braking Systems (ABS), Collision Warning, Lane Keeping, four Wheel Active Steering (4WAS), and Active Suspension systems. With respect to longitudinal dynamics, Adaptive Cruise Control (ACC), mainly used on highways, is capable of detecting the speed and distance of the vehicle ahead and modifying the speed accordingly [2].

Aside from developing a safety system that steeply reduces the very high rate of accidents each year, the anti-collision system would definitely pay off in saving individual lives and also their budget in order to fix their damage parts resulted from accident

II *LITERATURE REVIEW*

The ability to quickly reduce speed in a stable manner is one of the vital functions of a vehicle. However anti-collision systems going to make a dramatic alleviation on the severity of road accidents and consequently on our lives and mortality.

Fuzzy aid rear-end collision warning/avoidance system

It's a system incorporates the two anti-collision manoeuvres CWS and CAS. Using the Local Control Station (LCS) (see Figure 1), each vehicle get to know the respective vehicle's current speed and location plus the environmental situations wirelessly so as to take all safety precautions. In case if the decision was to steer the fuzzy control smoothens the steering wheel changes so as to allow car's occupant maximum comfort. Additionally fuzzy logic control can incorporate human procedural knowledge into control algorithms [3].

Figure 1 shows the final output of the system which is to steer according to many variables which are beyond the scope of this study, but the variable SLd is actually the variable of the main concern which represents the minimum acceptable distance between the leading and the trailing vehicle when D = 0 in meters [3].

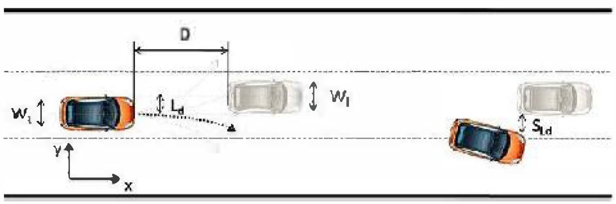

Figure 1: The fuzzy anti-collision scenario [3].

Vision-based anti-collision system

Range-based sensors such as laser and radar provide an accurate and precise measurements but they are too expensive solutions for automotive industry compared with digital cameras. The human visual perception system is perhaps the best example of what performance might be possible with such sensors, if the appropriate algorithm were used.

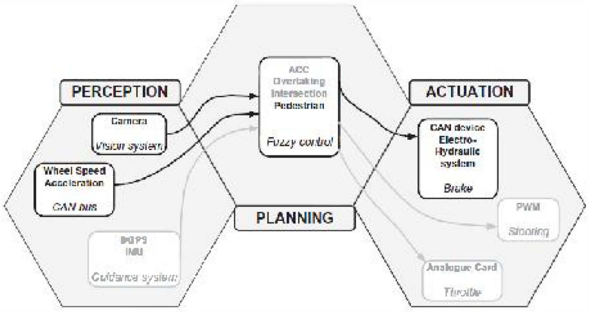

Figure 2: Prototype Vehicle Control Architecture.

Three hexagons attached to each other are shown in Figure 2 above, the first one which is perception is where all the sensorial inputs coming from the environment are acquired. The vehicle is equipped with differential global positioning system (DGPS) and inertial measurement unit (IMU) that are used for the vehicle guidance. The last one is actuation which is to execute the commands received from planning and generates voltage levels that can be sent to the actuators [4].

III *METHODOLOGY*

The research involved 3 aspects of design which were, the mechanical design, the electronic design and the software design.

The Mechanical Design

The design was carried out using CATIA software. Only one design was made since the design will be duplicated to accommodate each vehicle's prototype. Figure 3, shows the basic isometric view of each car's structure.

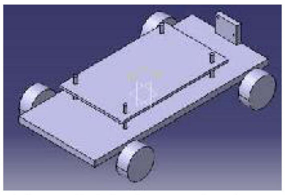

Figure 3: The Isometric view.

The Electronic Design

Figure 4 shows the system's major components which are the LCD, LEDs, wireless module, ultrasonic sensor, DC motor and finally the microcontroller.

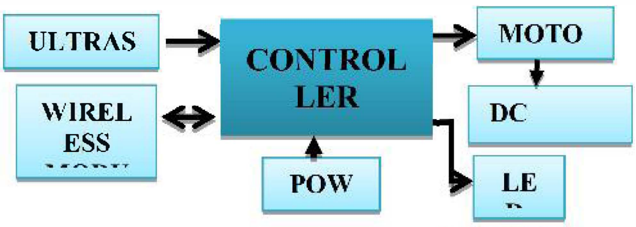

Figure 4: The electronic block diagram of the vehicle.

The circuit diagram has been constructed using FRITZING software (Figure 5), which is a new circuit designing software made for beginners and hobbyists. What made it so easy to use is that the circuit design starts from the virtual breadboard circuit.

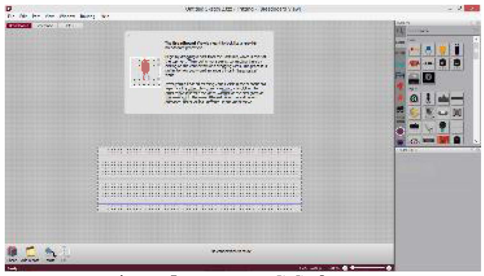

Figure 5: FRITZING Software.

Arduino Microcontrollers

In this paper two types of Arduino controllers were used, which are the ARDUINO LEONARDO and the ARDUINO MEGA2560.

Sensors

Figure 6 shows the ultrasonic sensor which was used to determine the distance ahead of each car. However, two brands have been used which were HC-SR04 for the Mega car and DYP-ME007 for the Leonardo car.

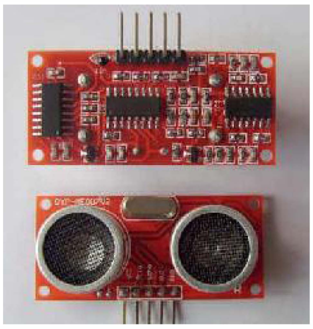

Figure 6: The Ultrasonic Module (DYP-ME007).

Actuators

DC motors were the selected type of actuators, gear ratios 12.7:1, 38:1, 115:1, and 344:1, which are all depend on the target design.

RF Modules

Both RF modules (Figure 8 & 9) work with frequency of 433 MHZ. It also provides some very useful functions to send and receive data, however the conversion of data at the end was done using the C code instead.

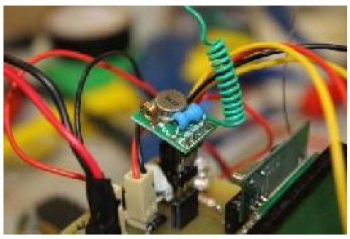

Figure 8: The transmitter module.

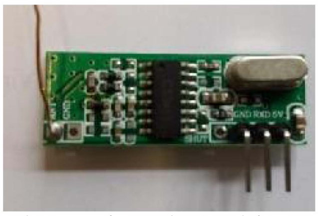

Figure 9: The receiver module.

Schematic Diagram View of Leonardo and Mega circuits

Figure 10 & 11 show the schematic diagram for the Leonardo shield and Mega shield respectively. The schematic was actually auto-routed by FRITZING.

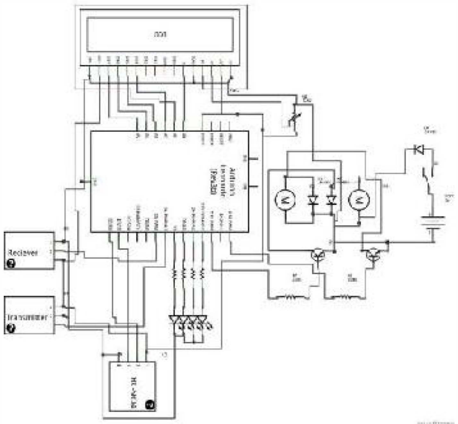

Figure 10: Schematic diagram for Leonardo circuit.

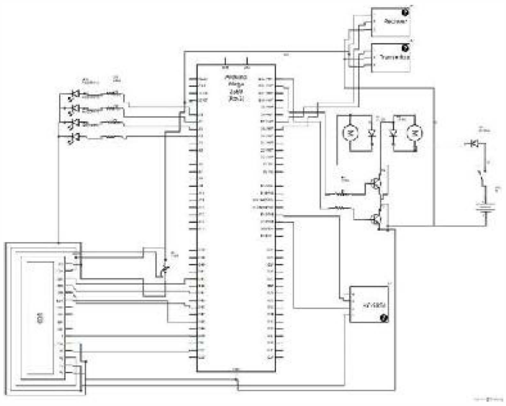

Figure 11: Schematic diagram for Mega circuit.

Software Design

The IDE (Integrated Development Environment) is a special program running on the computer (see Figure 12)

Figure 12: Arduino IDE.

IV RESULTS & DISCUSSION

The control target is to limit the distance ahead of the car by decelerating the car and then completely stop it. Only one car was able to decelerate which is the Leonardo car while the other one was only able to either run into its highest speed or stop completely. Right after assembling each car, they were programmed using the Arduino IDE. Figure 13 shows the complete assembly of each car.

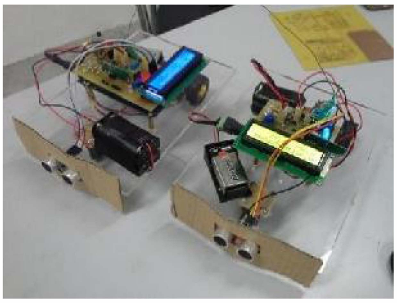

Figure 13: Complete Assemble of both cars.

Distance Measurement and Accuracy

Each reading was recorded for the actual and the reading distances by the ultrasonic sensor. Then the differences between both readings were calculated using the following formula:

Difference = |Actual distance – Reading distance| (1)

Right after that, the error was also obtained for each test using the following formula:

Percentage Error (%) = ———— (2)

Where,

The true value = Actual distance (cm)

The overall error was obtained using the formula:

Overall error = ———— (3)

The resulted data were then tabulated in Table 1 which shows actual and reading values and the differences. It also shows that the highest error occurred at the first test (40%) while the lowest error occurred at the 7th test (23%). Figure 14 and 15 interprets the readings as well as error percentages respectively in terms of bar graph.

Table 1: Comparison between the sensor readings (HC-SR04) and the actual readings as well as the error percentages.

Tests	Actual distance (cm)	Reading distance (cm)	Difference	Error (%)
1	5	3	2	40
2	10	7	3	30
3	15	10	5	33.3
4	20	14	6	30
5	25	18	7	28
6	30	22	8	26.6
7	35	27	8	22.8
8	40	30	10	25
9	45	33	12	26.6
10	50	37	13	26
Overall error	26.83%			

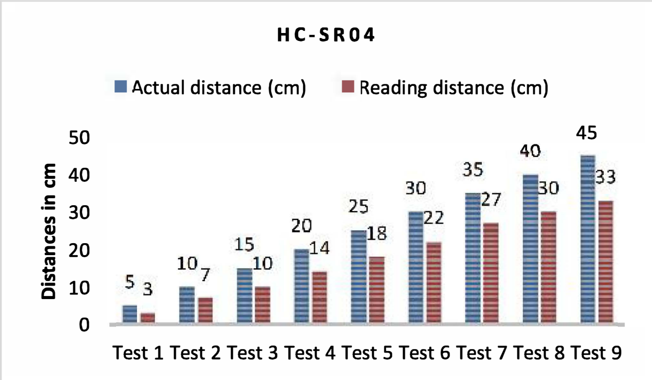

Figure 14: Reading comparisons for the HC-SR04 sensor.

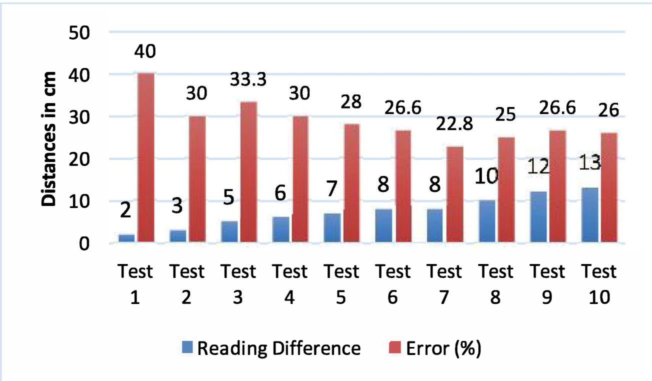

Figure 15: Percentage of error representation compared to the reading difference of the HC-SR04.

The same tests analysis was applied for the DYP-ME007V2 ultrasonic sensor, and all resulted data was recorded and tabulated in Table 2. Moreover Graphical representations as made for reading differences as well as error percentages which are shown in Figure 16 and 17 respectively. Results showed that the highest error occurred at the first test (40%) while the lowest error occurred at the 7th test (14.2%).

Table 2: Comparison between the sensor readings (DYP-ME007V2) and the actual readings as well as the error percentages.

Tests	Actual distance (cm)	Reading distance (cm)	Reading Difference	Error (%)
1	5	3	2	40
2	10	7	3	30
3	15	11	4	26.6
4	20	15	5	25
5	25	19	6	24
6	30	24	6	20
7	35	30	5	14.2
8	40	33	7	17.5
9	45	35	10	22.2
10	50	39	11	22
Overall error	24.15%			

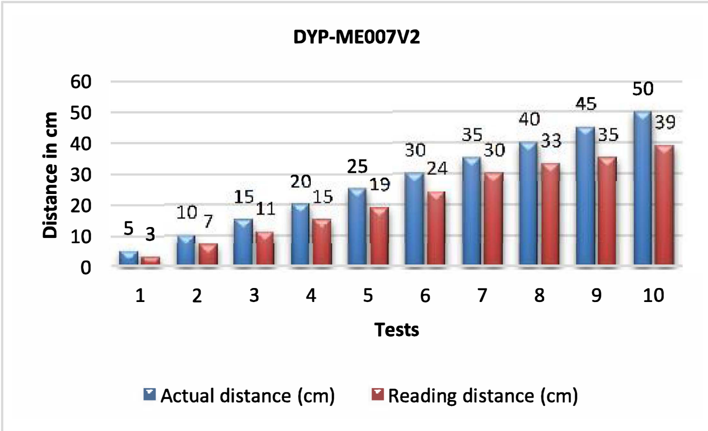

Figure 16: Reading comparisons for the DYP-ME007V2 sensor.

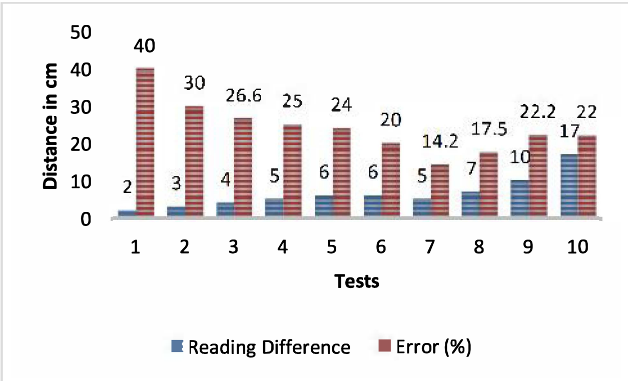

Figure 17: Percentage of error representation compared to the reading difference of the DYP-ME007V2.

The accuracy readings of the ultrasonic sensor mainly depends upon the obstacle position no matter how its outer surface looks like. Figure 18 shows from the centre of the ultrasonic receiver until 20° approximately to the left and to the toward both sides is the best performance in terms of distance detection.

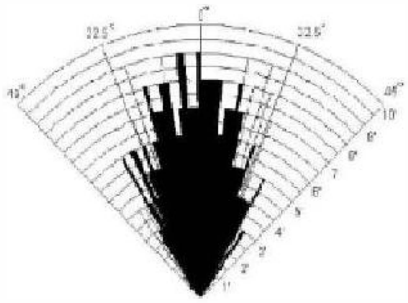

Figure 18: Ultrasonic sensor's test performance [5].

Anti-Collision Performance

Table 5 shows when Leonardo stops only if Mega's ahead distance is less than 20cm, and Mega stops only if Leonardo's ahead distance is less than 20cm. When both cars tested at distance between 30cm to 60cm the anti-collision performed improperly with accuracy of (50%). Accuracy as well as overall accuracy were calculated using the following formulas:

$$\text{Accuracy (\%)} = \frac{\qquad}{\qquad} \text{X } 100 \quad (4)$$

$$\text{Overall accuracy (\%)} = \frac{\qquad}{\qquad} \quad (5)$$

Table 3: Anti-performance accuracy when both cars stop at less than 20cm.

Tests	(0 – 10)cm	(10-30)cm	(30 – 60)cm
1	1	1	1
2	1	0	1
3	1	1	0
4	1	0	0
5	1	1	0
6	1	0	1
7	1	0	1
8	1	0	0
9	1	0	0
10	1	0	1
Accuracy	100%	30%	50%
Overall Accuracy	60%		

The second time both cars were programmed to stop if the distance received from the respective car is less than 40cm. Observations were recorded as shown in Table 6. It has been observed from the past two experiments that the error reduces whenever the distance to stop increases. As a result another type of experiment has been conducted to see which car is having slow in response, and results have been tabulated in Table 7 and 8 for each car.

Table 4: Anti-performance accuracy when both cars stop at less than 40cm.

Tests	(0 – 10)cm	(10-30)cm	(30 – 60)cm
1	1	1	0
2	1	1	1
3	1	1	1
4	1	1	1
5	1	1	0
6	1	0	0
7	1	1	1
8	1	1	1
9	1	1	1
10	1	1	0
Accuracy	100%	90%	60%
Overall Accuracy	83.3 %		

Results in Table 7 when Leonardo been forced to stop or its motors are switched off while Mega is running, it showed an overall accuracy of 86.6% while in Table 8 when the same tests been conducted but in the opposite way in terms f cars stopping distance, it showed an overall accuracy of 96.6%.

Table 5: Anti-collision performance when Leonardo forced to stop (Only motors are disabled) while Mega moves and only stop at received distance of less than 40cm.

Tests	(0 – 10)cm	(10-30)cm	(30 – 60)cm
1	1	1	0
2	1	1	1
3	1	1	0
4	1	1	0
5	1	1	0
6	1	1	1
7	1	1	1
8	1	1	1
9	1	1	1
10	1	1	1
Accuracy	100%	100%	60%
Overall Accuracy	86.6%		

Table 6: Anti-collision performance when Mega forced to stop (Only motors are disabled) while Leonardo moves and only stop at received distance of less than 40cm.

Tests	(0 – 10)cm	(10-30)cm	(30 – 60)cm
1	1	1	1
2	1	1	1
3	1	1	1
4	1	1	1
5	1	1	1
6	1	1	1
7	1	1	1
8	1	1	0
9	1	1	1
10	1	1	1
Accuracy	100%	100%	90%
Overall Accuracy	96.6%		

As a result, the distance of which both cars should stop has been increased as to increase the accuracy. For Leonardo it has been kept the same but for Mega the distance have been modified to 60cm. and results have been tabulated in Table 9, which shows a great improvement in the system's performance.

Table 7: Anti-Collision performance accuracy when Leonardo stops at received at received distance<40cm and Mega stops at received distance<60cm.

Tests	(0 – 10)cm	(10-30)cm	(30 – 60)cm
1	1	1	1
2	1	1	1
3	1	1	1
4	1	1	1
5	1	1	1
6	1	1	0
7	1	1	1
8	1	1	1
9	1	1	1
10	1	1	1
Accuracy	0%	0%	90%
Overall Accuracy		96.6 %	

Letting Leonardo stops if the received distance is less than 40cm and Mega stops if the received distance is less than 60cm was found to be the best design, as the accuracy improved by 36.67% from the first case and it becomes 96.67% as shown in Table 9. The overall accuracy was calculated using the following formula 5.

Figure 10 shows the accuracy for each range in terms of graphical representation.

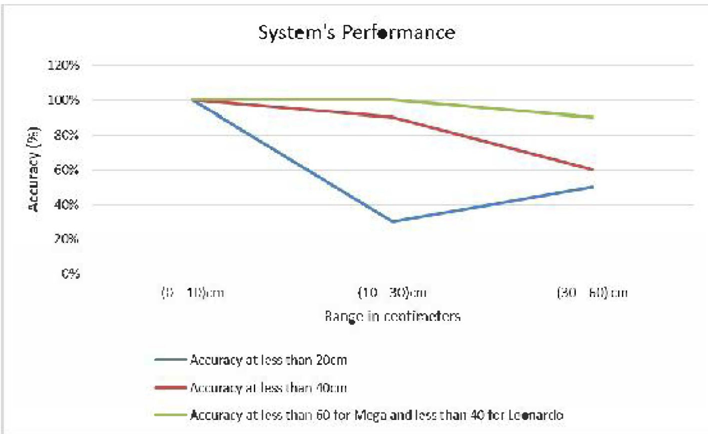

Figure 10: System's performance results at various ranges.

V *CONCLUSION*

The designed anti-collision system only works if the two cars are facing each other while accelerating. Analysis showed that it takes time for each car until it receives the respective car's distance, and performs the required comparison operations. Thus it took dozens of iterations to optimize the system performance and choose the best distance to stop with. Observations have been recorded when the system programmed to stop movement if the received distance through the RF module is less than 20cm and it showed an overall accuracy of 63%, but when the same system programmed to stop at less than 40cm the overall accuracy increased to 96%. The given reading distance of each ultrasonic sensor used in the system has been compared to the true physical distance and analysis showed that both ultrasonic sensors used in the system gave an overall error of 25% roughly. The error can be diminished by calibrating the sensors through the Arduino code but analysis showed that the difference between the reading distances by the ultrasonic sensor and the true distances are absolutely nonlinear.

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