Abstract

Distracted drivers cause nearly 4.5 million car crashes between 2010-2014 [1]. Our proposed idea is to introduce gesture recognition to control the auxiliary systems in cars. This is done using a 1D Light Detection and Ranging (LiDAR) sensor, that will detect gestures posted by the driver while driving. The response is simulated in an app interface. Its accuracy, efficiency and robustness under different situations is measured. Our prototype is able to accurately detect six static gestures, without being affected by the surrounding, such as lighting conditions and noises. Several future improvements for it to sustain in the market are also suggested in this report.

Introduction

Distractions are classified as three types: visual, manual, and cognitive [2]. This project attempts to eliminate interfaces that require visual and manual attention to control the auxiliary systems, and instead, replace it with a gesture control system, thus reducing the chances of an accident. The gesture control system will utilize a maximum of 6 fingers to form gestures corresponding to auxiliary systems controls (see Table 1). Response of the auxiliary system is simulated using an app interface, where the status of subsystems are shown using red and green LEDs. (see Figure 1)

Sensors background

A few sensors are available to choose from: an RGB camera, a stereo depth sensor, or a LiDAR sensor. They are all capable of detecting hand gestures, hence to determine which sensor was best suited for the project, the methods, advantages and disadvantages were considered .

A RBG camera works the best for image recognition in optimal lighting conditions, but would be rendered ineffective due to loss of shadows and details in bright sunlight. It requires some advanced image recognition algorithms as the program has to be able to parse out the fingers and determine the position of each of them [3].

A depth sensor gives depth data by measuring the time of flight of emitted laser beams. This allows more complex hand gestures. Unfortunately, the data degrades in bright sunlight [4].

A LiDAR sensor captures the distance via measuring the time of flight of emitted laser beams [5]. For the model RPLiDAR A1M8, it can spin 360 degrees continuously and produce a distance map. Even better, it is not susceptible to the effects of sunlight [6]. Thus, it was chosen, as it can work under a wide range of brightness of the surrounding, thus ensuring reliability and consistency of the sensor data.

Methods

Following the aim, the system needs to be designed to not require diverting eyes from the road, or removing hands from the steering wheel. Hence, the final design is as follows:

1. Steering wheel is 3D printed with slight alteration to accommodate space for the sensor as well as to ensure the fingers are in the optimal scanning range of the sensor. (See Figure 2)
2. The sensor is placed right underneath the steering wheel, as shown in Figure 2 so that the sensor is able to detect fingers easily when the driver performs a gesture while driving.
3. The sensor will map out the distance data and computes the number of fingers:
   - 3.1. The sensor will send the distance data to MATLAB via arduino continuously.
   - 3.2. Data is filtered to contain only those within the range of interest, i.e. around the circumference of the steering wheel. This could help to filter out noise.
   - 3.3. Distance data will be grouped depending on the angle of separation.

3.4. The width is computed to determine whether it's a human finger. The range of the finger width is referenced from international ring size statistics [7]
3.5. The gesture is then determined by counting the number of fingers detected. Then, the corresponding dashboard function is activated, shown in a simulation interface (figure 5)

Results and discussion

Table 2 and Table 3 shows the results of the project. Overall, the prototype is able to detect all six static gestures with an average accuracy of above 90%. However, the response time is long, i.e. average of approximately 4 seconds and a maximum of 6.5 seconds. This is due to the need of having an Arduino to be the middle person between the sensor and Matlab, This issue can be solved by having a direct communication between the sensor and the controller.

The effect of lighting of the prototype is tested by placing it in different lighting (see Figure 3) As shown in Table 2, the accuracy and response time is not affected by the lighting condition. This is because the LiDAR sensor uses a laser, which is of a different frequency than visible light and hence is not affected by lighting conditions.

The effect of noise on the prototype is also tested. Noise is simulated using everyday objects that might exist in a car, shown in figure 4. It is deduced that the prototype is not affected by noise as long as it is out of the range of the finger width, i.e. between 9.91 to 24.47 mm. The robustness towards noise can be further improved by narrowing down this range, such as registering the finger width of the driver’s fingers when initialising the system.

To be able to determine the worth of a new idea, it must be compared with existing mechanisms. For instance, BMW's existing mechanism is able to recognise gestures, but it isn’t able to avoid visual and manual distraction. This is because their mechanism involves having the user’s hand to leave the steering wheel [8]. Another example would be the steering wheel control, which is of similar functionality with our solution. Although it is able to avoid manual distraction, i.e. keeping the driver’s hand on the steering wheel when performing control, it still requires some amount of visual attention, as the driver will need to find the position of that particular button, which eventually results in visual distraction while driving. Steering wheel control is also less flexible as the button are pressed at the fixed position on the steering wheel, whereas our system allows gestures to be posted at any position at the circumference of the steering wheel,

To achieve the aim, the gestures must be able to be produced while holding the steering wheel, limiting the number of gestures that can be posted. This limitation is troublesome, as the car’s infotainment system provides a multitude of functions [9], and the number of gestures may not be enough to encompass all the functions. To resolve this, the actions are mapped to simpler functions in the infotainment system, such as volume control, song selection, or call answering as those are the main systems that the user would logically interact with while driving, as the complicated functions such as the GPS would be logically set before starting the trip, and thus mapping hand gestures to them would be difficult and complicated. This implementation can also be seen in BMW’s limited gesture library, as they only retained the most important functions [10].

This limitation can be further overcome by incorporating dynamic gesture, i.e. scrolling tapping using finger(s). In order to implement this, the system needs to be able to track the position and movement of each finger, and deduce the corresponding gesture. Due to the time constraint of this competition, we only included static gestures to keep the system easy and straightforward.

Although this is one area that may be improved on, the current hardware used does not have the capability of detecting dynamic gestures. An alternative way is to detect whether the fingers are clustered together, and of which hand do they originate from though distance grouping. This would allow more hand gestures, and thus more actions that can be included.

Furthermore, this solution comes with another difficulty, as the lidar module has to be situated right in the middle of the steering column. This is so that the lidar is able to look at the plane that is parallel to the steering wheel's plane to be able to intercept the fingers. This poses a great issue as the steering column is a complicated and critical mechanism [11], and it might not be possible to place a lidar there without modifications to the column mechanisms. Solutions could be to use a lidar that does not intercept the plane of the column, or a re-designed steering column.

Conclusion

In conclusion, we chose a lidar sensor as our sensor of choice, and built the gesture recognition system. To recognise gestures, we counted the number of fingers, detected as gestures, to control the infotainment system. The algorithm we implemented for the finger detection will automatically filter out non-finger items/objects from the detection, and its performance is independent of lighting conditions. Overall, it achieves the aim of the project and is a success.

Acknowledgement

Many thanks to Monash University Malaysia for sponsoring the equipment required to build this device, IMDC Mathworks and the Continental group for aiding us in solving problems, and not forgetting our advisor Dr. Alpha for guiding us throughout this competition.

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Appendix

Table 1: Gestures and corresponding controls in the infotainment system in cars

Gesture (number of fingers detected)	Action / corresponding control	Simulated response in app
One	Accept incoming calls	Green LED for answering calls light up
Two	Decline incoming calls	Red LED for declining calls light up and dims again
Three	Turn on radio	LED for radio status turns green / lights up
Four	Turn off radio	LED for radio status turns black / dims
Five	Turn on GPS	LED for GPS status turns green / lights up
Six	Turn off GPS	LED for GPS status turns black / dims

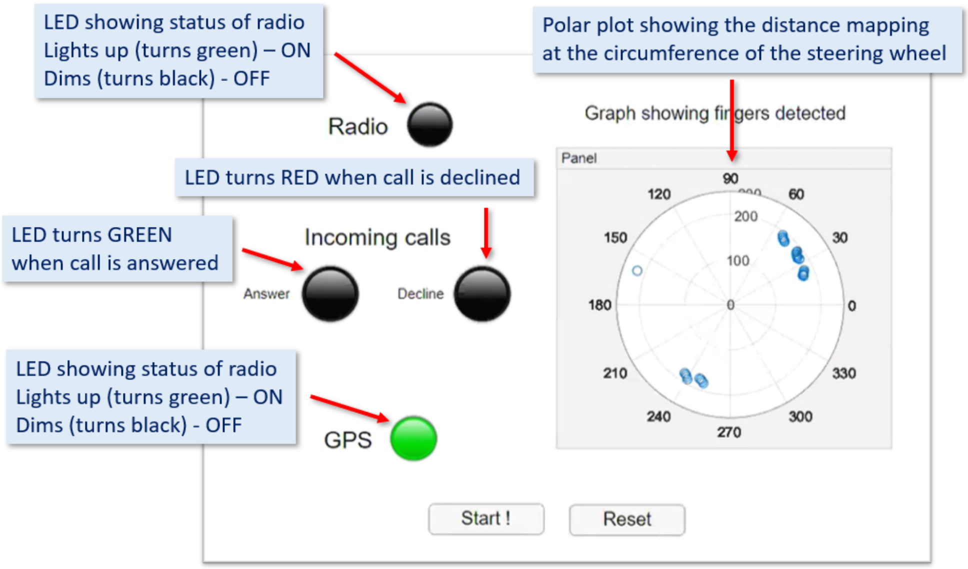


Figure 1: App interface simulating the response of the infotainment system

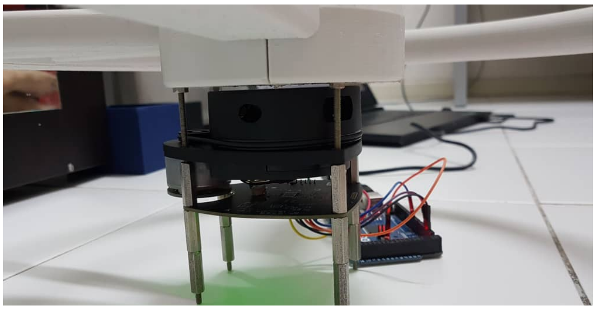


Figure 2 : Position of RP Lidar in the steering wheel.

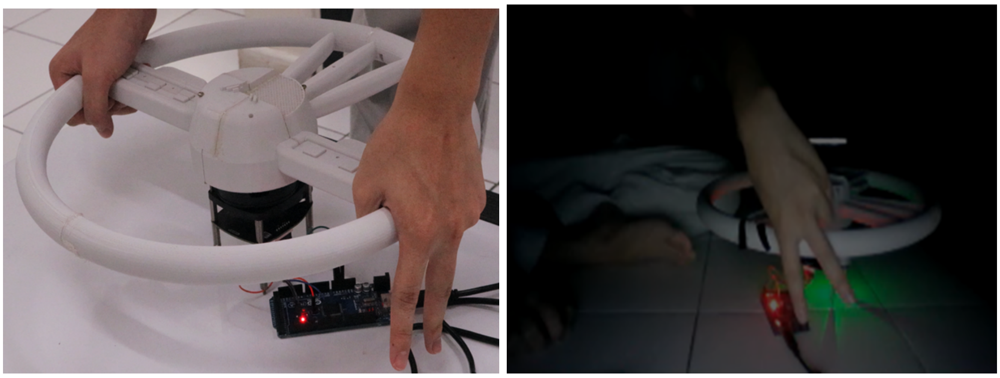


Figure 3: Testing prototype under normal lighting conditions (left) and in the dark (right)

Table 2: Accuracy and response time of system under different lighting conditions

Scenario / Gesture		No gesture posted	Gesture “One”	Gesture “Two”	Gesture “Three”	Gesture “Four”	Gesture “Five”	Gesture “Six”	Average accuracy & time
Lighting condition	Normal lighting	100% (N/A)*	100% (6.5s)	100% (3s)	100% (4s)	70% (2.5s)	100% (3s)	100% (3.5s)	95.71% (3.75s)
	In the dark	100% (N/A)*	70% (6.3s)	80% (6s)	100% (3s)	100% (3s)	100% (3s)	100% (3s)	92.86% (4.05)

*Note: response time when no gesture posted couldn’t be measured since it gives no response

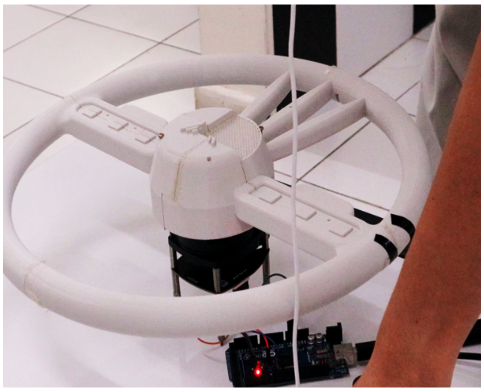
(a)  (b) 

Figure 3: Testing prototype using simulated noises:

(a) Items of width smaller than finger width range - Phone charging wire

(b) Items of width larger than finger width range - Human wrist

Table 3: System response to noise (showing the robustness towards noise)

Senario		System response	Explanation
Introducing noise	Changing wire	No response	Wire is of smaller width than human fingers, hence it is not recognised as a ‘finger’, no gesture is detected.
	Human wrist	No response	Wrist is of larger width than human fingers, hence it is not recognised as a ‘finger’, no gesture is detected.