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Automated Driving Test Implementation Based on LabVIEW

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ABSTRACT

This study presents the implementation of a fully automated driving test procedure for selected parking tests using the integration of LabVIEW (graphical programming environment) with the selected microcontroller. The system is designed to replace the existing conventional system which is based on human observation, and decision and requires a lot of manpower. In Malaysia, there are several driving test tracks such as reverse parking tracks (L-shaped), side (parallel) parking tracks, slope (incline) parking tracks, S-shaped parking tracks, and Z-shaped parking tracks. This study focuses on the possibility of implementing a fully automated driving test on the reverse parking track or parallel track. Here, the vehicle movement in the L-shaped parking track will be detected by the motion sensors around the track, and the movement sensors will communicate with LabVIEW Graphical User Interface (GUI) through wireless communication protocol and microcontroller to determine the test status; fail or pass. The results of the study show that the proposed system is capable of determining the status of driving tests accurately. The proposed system is capable of showing the duration taken to complete the test for beginner drivers and intermediate drivers.

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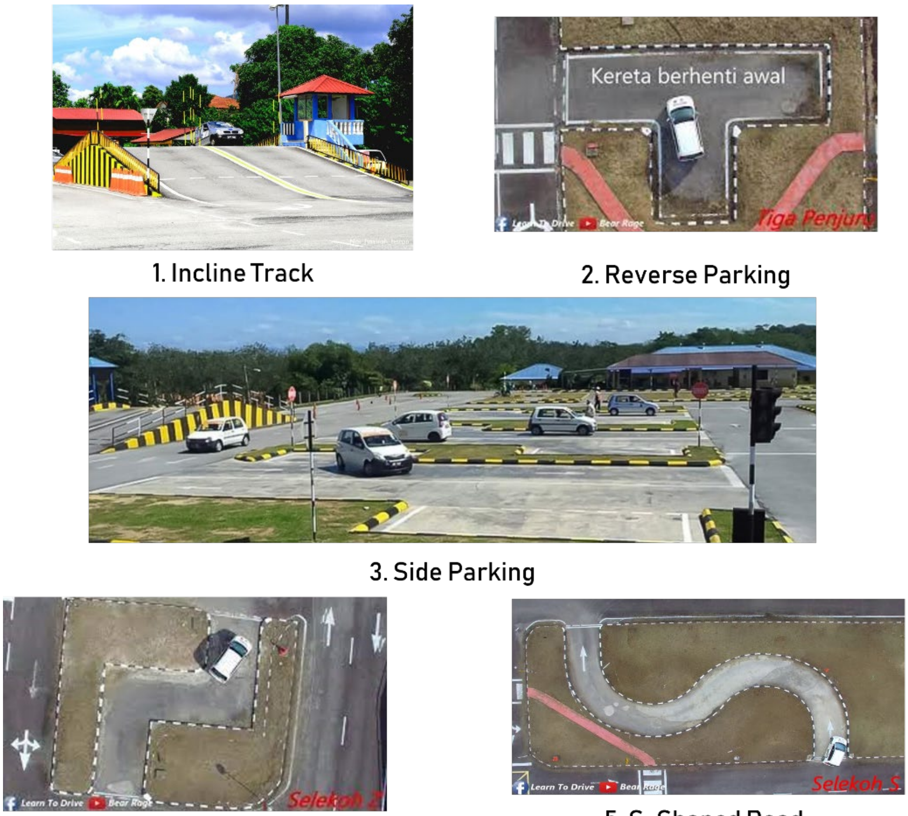
1. INTRODUCTION

Nowadays, the driving license test procedure in Malaysia still undergoes a manual evaluation system. In brief, the driving school company will register the total number of people who apply for the driving license examination (*Driving License - JPJ Portal - Jabatan Pengangkutan Jalan*). The Malaysian authorities (JPJ) in charge of managing the booking slot will then manage the date and list of availability to the driving school. During the driving test for vehicle parking, it will require about 2 to 3 JPJ authorities to be at each control post checkpoint throughout the driving license assessment [1]. There are five different tracks as shown in Figure 1 that must be completed to obtain a driving license certificate in Malaysia, which are the incline track (slope), reverse parking track, side parking track (L-shaped), S-shaped road, and Z-shaped road. As illustrated by Figure 1, the existing driving test system requires human interventions and is prone to human errors. This will greatly influence the accuracy and integrity during driving tests [2]-[3]. Moreover, the issue of the infrequent availability of driving tests or exam slots that applicants can apply for each year is another demanding task because more JPJ manpower is required [4]. Among the criteria for a driving test are speed monitoring of the vehicle, lane discipline, braking analysis, and parking assistance.



1. Incline Track

2. Reverse Parking

3. Side Parking

4. Z-Shaped Road

5. S-Shaped Road

Figure 1. 5 types of parking track for driving test in Malaysia [1]

There are various automation methods in driving tests that have been implemented by researchers a couple of decades before. The existing studies have demonstrated the implementation of the automated driving test on the H-shaped, S-shaped, and 8-shaped as shown in Figure 2 where the driving skills and capabilities of the drivers are evaluated based on the on-road and off-road tests (parking tests). Here, the tracks can be chosen, with the H-shaped track being popular. The system architecture consists of a microcontroller, movement sensors, crash sensors, a GSM module for tracking vehicles, and RFID sensors for storing the data information of the candidates [5]-[7]. Another approach is the implementation of the Internet of Things (IoT) and cloud-based automated driving tests to produce well-trained drivers to obtain driving licenses where the layout of the driving test is elucidated in Figure 3 [7]-[8]. Furthermore, the researchers have implemented the perpendicular parking assist system using ultrasonic sensors and a microcontroller for the automated driving test system. This system is a semi-automated system of guiding the driver to park the car perpendicularly. The measurement parameters are parking accuracy, safety distance, parking steps, and vehicle speed [9]. However, the implementation of automated driving tests on the L-shaped has not yet been tested. The challenge in the development of the automated driving test is the wireless communication protocol for the sensors to communicate with the microcontroller.

Figure 2. Types of driving tracks in India [5]-[7]

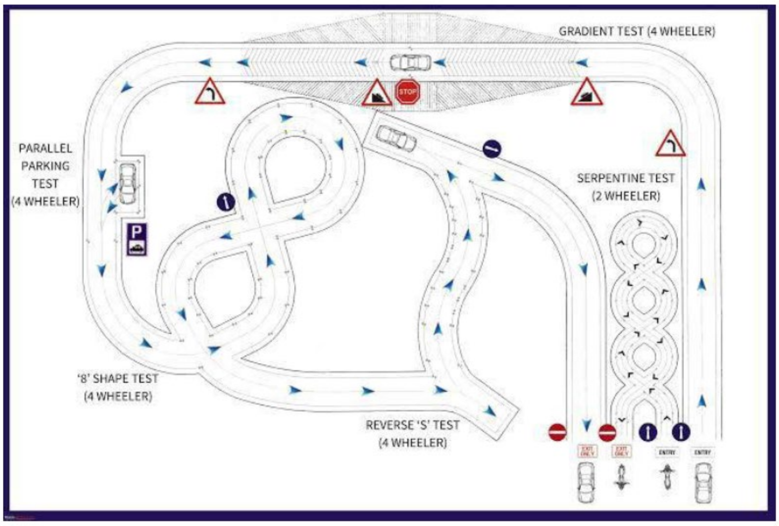


Figure 3. Different layout of the driving test tracks [7]

For the communication protocols, researchers implemented various methods such as Zigbee, ESP8266, Serial Communication, Transmission Control Protocol/Internet Protocol (TCP/IP), Client-Server Protocol, and Test protocol. Among the vital communication parameters are the bidirectional wireless serial communication, communication protocol between microcontrollers, and software and hardware interaction. The selection of communication protocols is crucial since the selected communication should be able to interact with LabVIEW correctly. The MQTT (Message Queuing Telemetry Transport) protocol is the most effective protocol for interacting with LabVIEW. LabVIEW clients can enter the necessary credentials for establishing the connection using the public (CloudMQTT) server, which has been tested to enable evaluation under varied network circumstances and to provide sufficient connection data [10]-[18]. The selected existing research on the automated driving test is listed in Table 1.

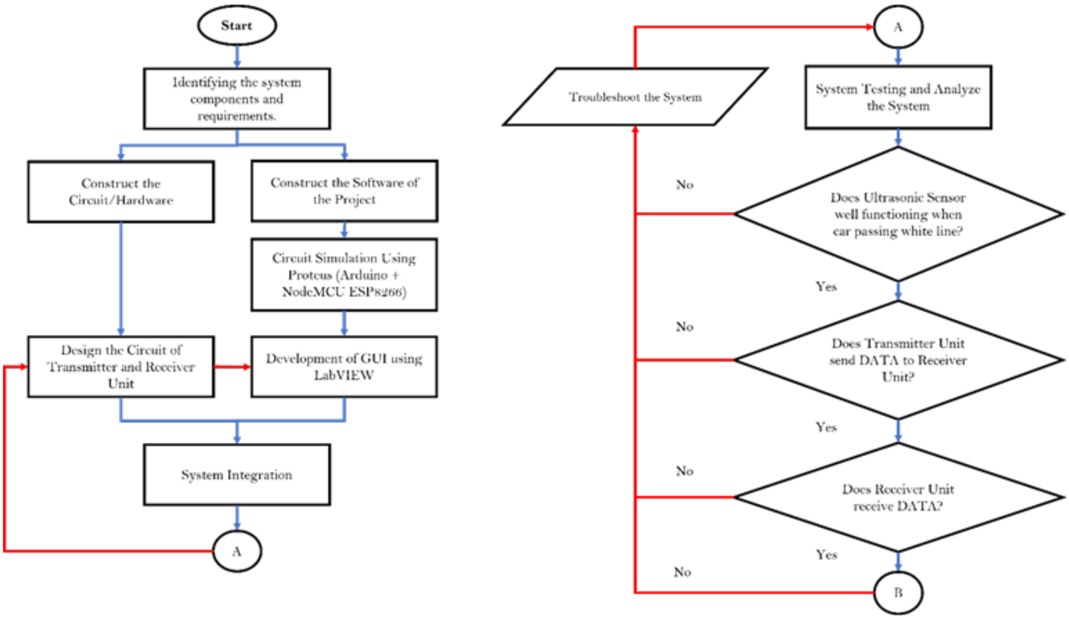
Table 1. The existing studies on automated driving test

Author	Methods	Results
[11] (John & Joseph, 2013)	Automated issuance of a driver's license with remote-end monitoring using ZigBee and LABVIEW.	The vehicles tested on the H pattern-track are merely monitored by NI USB 6009 DAQ Card and photo sensors.
[12] (Zinkevich, 2021)	The study case on the UDP (User Datagram protocol) in the Wi-Fi network and Espressif ESP-NOW protocol.	The performance of both UDP and ESP-NOW is not good and has limitations
[13](Štor & Tonković, 2018)	MQTT protocol is implemented on cloud-base database and wireless connection	Good performance protocol for its brevity, minimal weight, and interoperability with devices with little resources

[3] (Aparow et al., 2021)	The implementation of an autonomous vehicle simulation on various types of traffic situations in Malaysia.	The system performance is based on deep learning dynamic object detection, YOLOv3 and detection rate.
[10] (Lee & Chang, 2014)	A perpendicular parking semi automatically is designed by using ultrasonic sensors and electrical power steering.	The standard specification and test parameters passed as demonstrated.
[14] (Jayalakshmi et al., 2018)	Proposing a driving evaluation system.	Driving evaluation system by using the motion of a light detector pair.

2. METHODS

In this study, LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is selected to assess a driving test performance due to its graphical programming approach, real-time data acquisition, and compatibility with various hardware components. The overall process flowchart of the proposed system is illustrated in Figure 4. LabVIEW Graphical User Interface (GUI) can display the real-time sensor data, show the test progress, and pass and fail status.



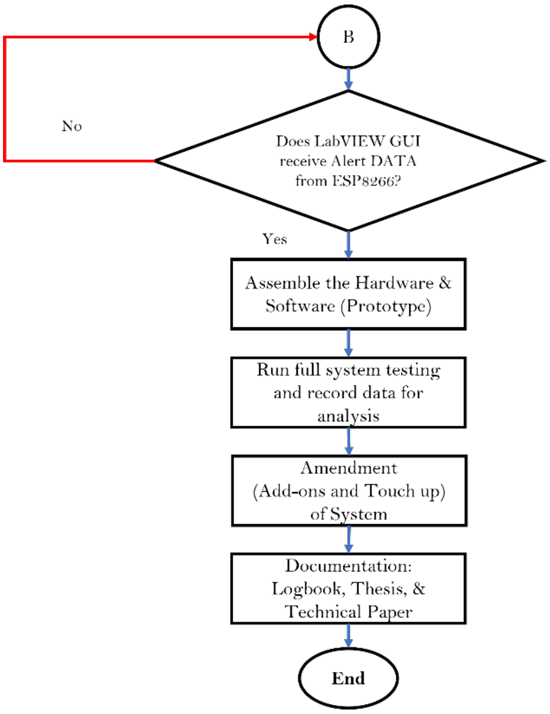


Figure 4. Overall process flowchart of the study

The study has employed LabVIEW (Laboratory Virtual Instrument Engineering Workbench) to assess a driver's performance by implementing an Automated Driving Test System using LabVIEW due to its graphical programming approach, real-time data acquisition, and compatibility with various hardware components [19]-[20]. The study started with the determination and selection of the system requirements and components including the design of the electrical circuits and construction of the LabVIEW coding (block diagram). Next, the system integration is constructed by testing the communication protocol between the hardware (sensors and microcontroller) and LabVIEW.

3.1. Communication Protocol

The study has investigated and implemented various communication protocols to provide good communication between the sensors, microcontrollers, and LabVIEW. This study involved the usage of the following communication protocol to provide good integration between the microcontroller, sensors, and LabVIEW.

3.1.1 Serial Communication

In this study, serial communication is employed to send signals among the microcontroller where Arduino Mega will send signals from the ultrasonic sensor to another microcontroller, NodeMCU ESP-8266 for the continuation of the system operating process. As stated in the Introduction section, this method is preferable to avoid data loss by using the strings as data [6]-[10].

3.1.2 ESP-Now Protocol

This protocol is employed to act as a mediator for two main circuits (transmitter circuit unit and receiver circuit unit) to interact with one another NodeMCU ESP-8266. Thus, the chosen protocol is the ESP-NOW protocol that was created by *Espressif* since the protocol can be used for two-way communications or a full duplex. Even though, there is some restriction since only 250 bytes of transmission data can be transmitted or operated, it should be more than enough for the sensors to send data to data [11]-15].

3.1.2 TCP/IP Communication Protocol

In this study, a TCP/IP connection is set up and implemented. Here, the NodeMCU ESP-8266 module needs to be set up to connect to a Wi-Fi network to create a TCP/IP connection with LabVIEW. NodeMCU ESP8266 will be contacted by LabVIEW through TCP/IP after they are linked. Using the networking features included in LabVIEW, a TCP/IP communication interface can be built. Depending on the arrangement, the NodeMCU ESP-8266 module can act either as a TCP/IP server or a client [16]-[21]. The ESP8266 module's

IP address and port number are entered into LabVIEW to establish the connection [22]-[25]. Once connected, LabVIEW can use TCP/IP communication methods to deliver and receive data from the microcontroller.

3.2. System Operation

There are 3 checkpoints for the parking test labeled as checkpoints 1(A), 2(B), and 3(C). In order to pass the 3 checkpoints, the driver needs to drive at the allocated L-Track equipped with movement sensors as shown in Figure 5 and Figure 6 respectively. The candidate needs to control the car to not touch the white lines. Here, if the vehicle crosses a white line or skips the checkpoint, the driving test will be considered a failure. Otherwise, the driving test will be considered successful. The receiver unit in the system will obtain and process the data from the transmitter unit and communicate with LabVIEW GUI to indicate the pass and fail status. Here, the blue LED will turn on if the candidate passes the driving test. Meanwhile, the red LED will turn on if the candidate fails the test. Checkpoint 1 indicates that the candidate enters the L-Track which is at the starting point of the evaluation. At checkpoint 2, it means that the candidate is currently undergoing the side parking step procedure. Lastly, at checkpoint 3, the applicant will be seen leaving the parking space and making it to the end session of the L-Track assessment.

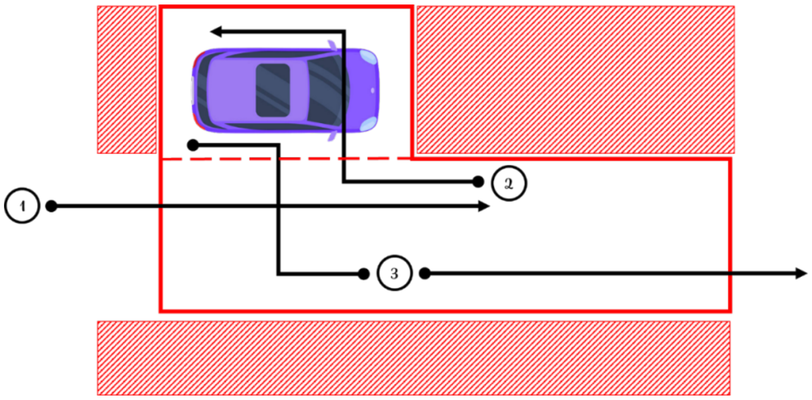


Figure 5. Checkpoint for L-shaped parking test

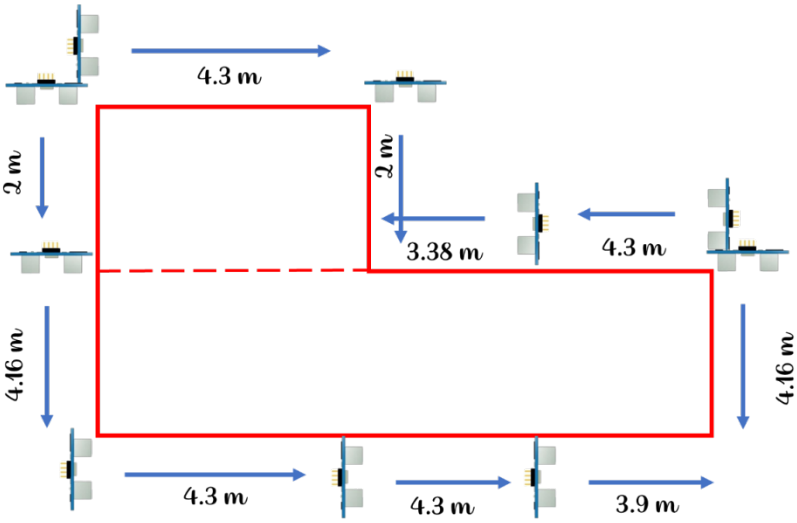


Figure 6. Sensor location for L-shaped parking test

Figure 7 describes the full operation of the proposed system. The system started up after turning on the hardware for the On-Vehicle Control Unit (acting as a transmitter part of the system) and Central Control Unit (acting as receiver part of receiver part of the system), with LabVIEW GUI in the standby mode. If the system is in ready mode, the LCD will show "Driving Test Start".

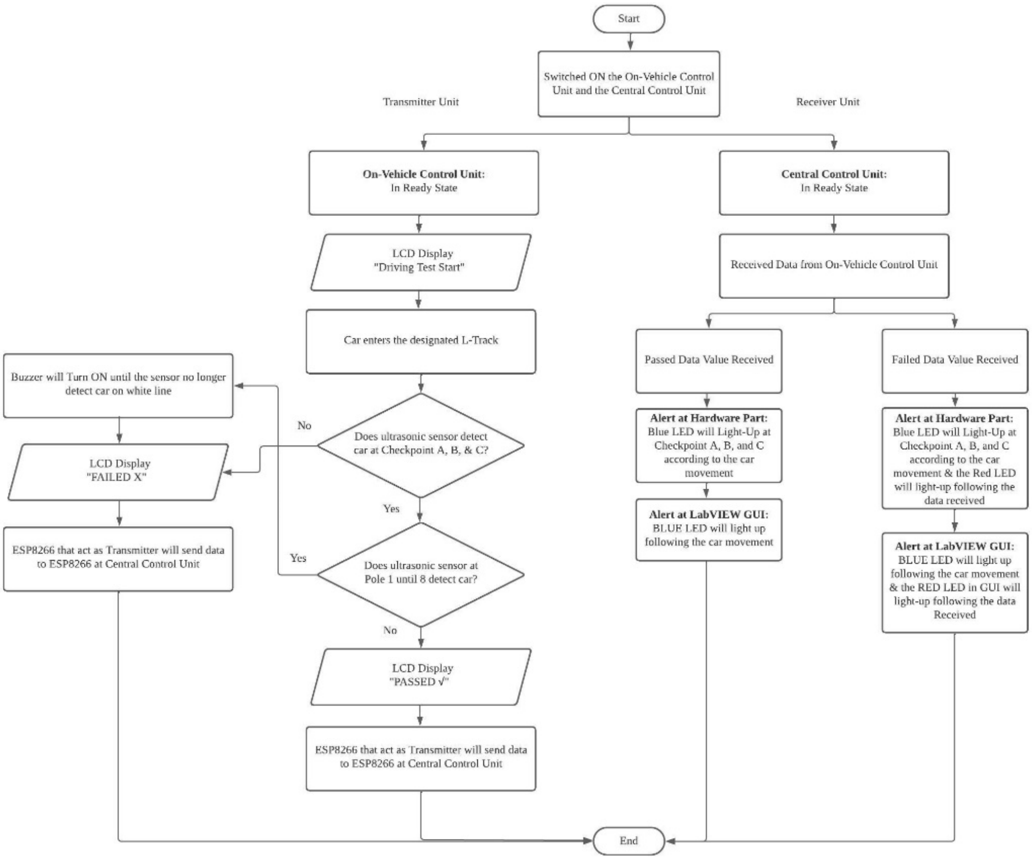


Figure 7. Operation of the proposed system

The transmitter unit, or on-vehicle control unit, and the receiving unit, or central control unit, are shown in the block diagram for the smart driving test system as shown in Figure 8. The central control unit will be communicating with the on-Vehicle Control Unit and vice-versa. Here, the vehicle movement within the L-Track parking is detected and tracked by the transmitter circuit unit. The ultrasonic sensors interact with the Arduino microcontroller when the car crosses the white lines, and the Arduino microcontroller subsequently sends messages to the reception circuit unit through the NodeMCU ESP-8266 microcontroller. The LabVIEW GUI, LCD, and LED are three alternative ways that the receiver circuit unit presents the information it decodes from these signals. The blue LED will turn on, along with a corresponding LabVIEW GUI indicator, if the candidate passes the driving test. Conversely, if the candidate fails, the red LED and corresponding LabVIEW GUI indicator will light up.

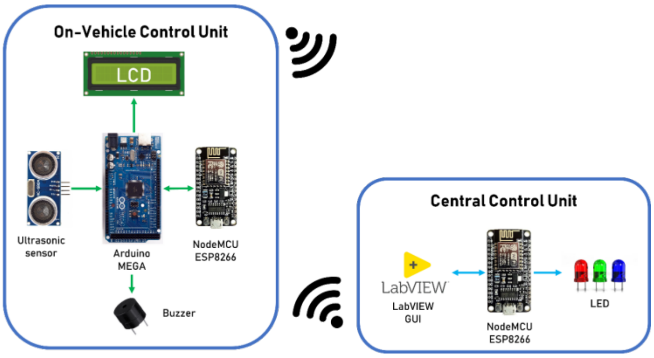


Figure 8. Communication between on-Vehicle control unit and Central control unit

3.3 Simulation of the system electrical circuit

The simulation of the system's electrical circuit is conducted to test the functionality of the transmitter and receiver unit. The simulation is done using Proteus software as depicted in Figure 9 and Figure 10 respectively. The simulation results show that the transmitter unit, receiver unit, LCD, ultrasonic sensors, and Arduino microcontroller function well and can communicate with each other.

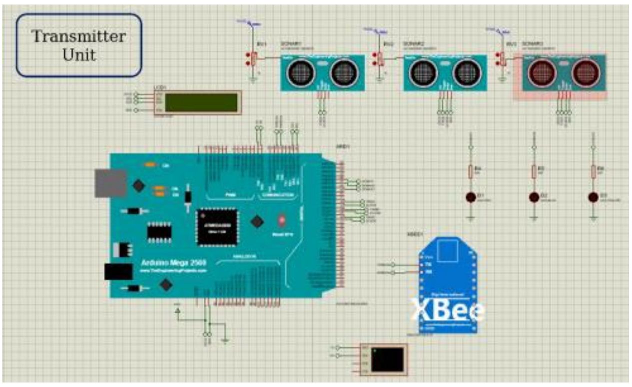


Figure 9. Simulation of the Transmitter unit using XBee and Arduino microcontroller

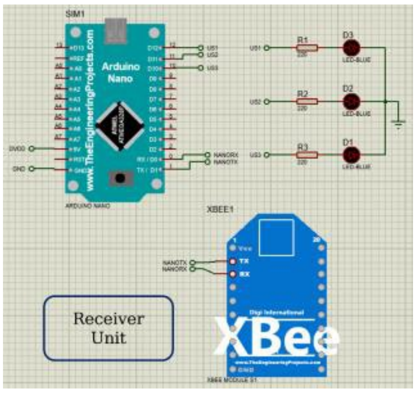


Figure 10. Simulation of Receiver unit using XBEE and Arduino microcontroller

3. RESULTS AND DISCUSSION

There are two categories of subjects chosen for this study in terms of driving experience in order to make the automated driving test system more robust. This study involves the implementation of the system of L-shaped parking (reverse parking) where the candidate needs to drive the car to enter the L-zone parking and then drive the car out of the L-zone parking. The required time to pass the L-shaped parking is below 3 minutes. There are 3 beginner levels and 5 intermediate levels are involved in this study. The beginner level has about 1 year of driving experience on the road including the training on driving. Meanwhile, the intermediate level has about more than 3 years of driving experience. Figure 11 depicts the duration to make a complete L-shaped parking and pass the driving test where the average time taken by beginner participants is 270 seconds (more than 4 minutes). Meanwhile, for intermediate-level participants, the average duration to complete perfect L-shaped parking is merely 156 seconds (less than 3 minutes) whereas the faster time to complete the test is only 60 seconds (1 minute). Obviously, there will be no problem for intermediate-level participants to pass the L-shaped parking. Figure 12 on the other hand, indicates the duration taken by the beginners level that fail the L-shaped parking test where the average duration of the parking is 435 seconds (more than 7 minutes). The number of trials and duration for the beginner-level participants to pass the L-shaped parking test are illustrated in Figure 13 where participant number 3 (subject C) needs to undergo 6 trials to pass the L-shaped parking.

Figure 11. Duration taken by subjects to pass the driving test on L-shaped parking

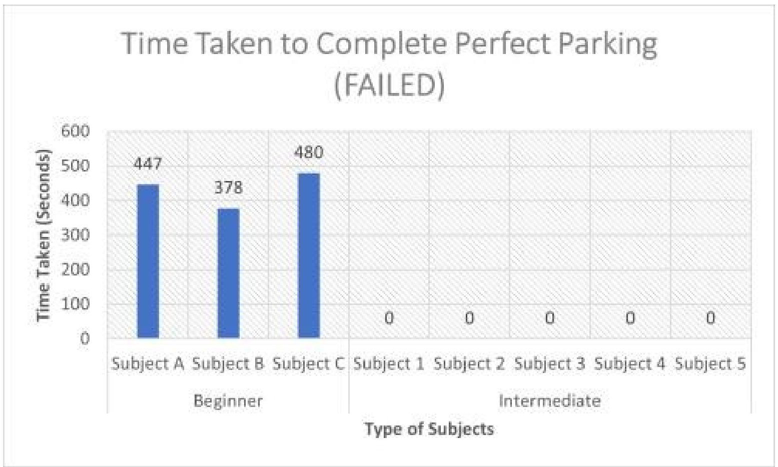


Figure 12. Duration taken by subject to fail the driving test on L-shaped parking

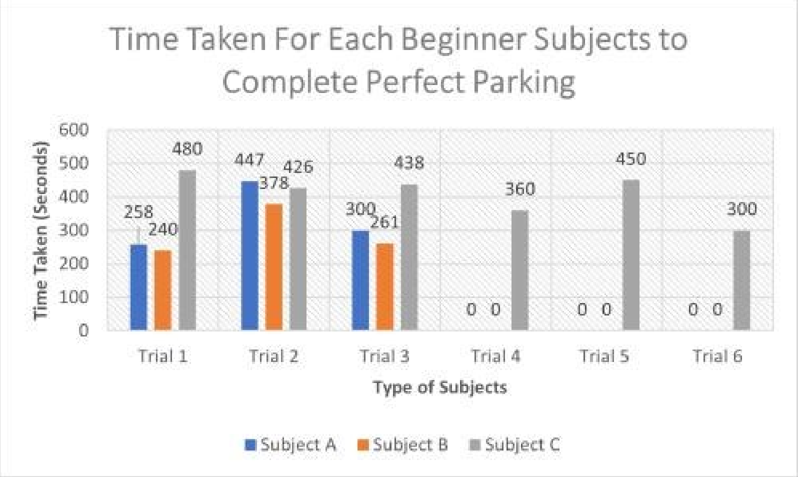


Figure 13. The number of trials and duration taken by beginner level participants

As described in the Methods section, LabVIEW software is employed to process the communication data that are received from the movement sensors that are installed at the parking zone. The LabVIEW block diagram is shown in Figure 14. The TCP-IP communication protocol is employed in LabVIEW for the communication between LabVIEW and NodeMCU ESP8266 microcontroller. The usage of the TCP-IP communication protocol is indicated by the LabVIEW toolbox inside the red square box.

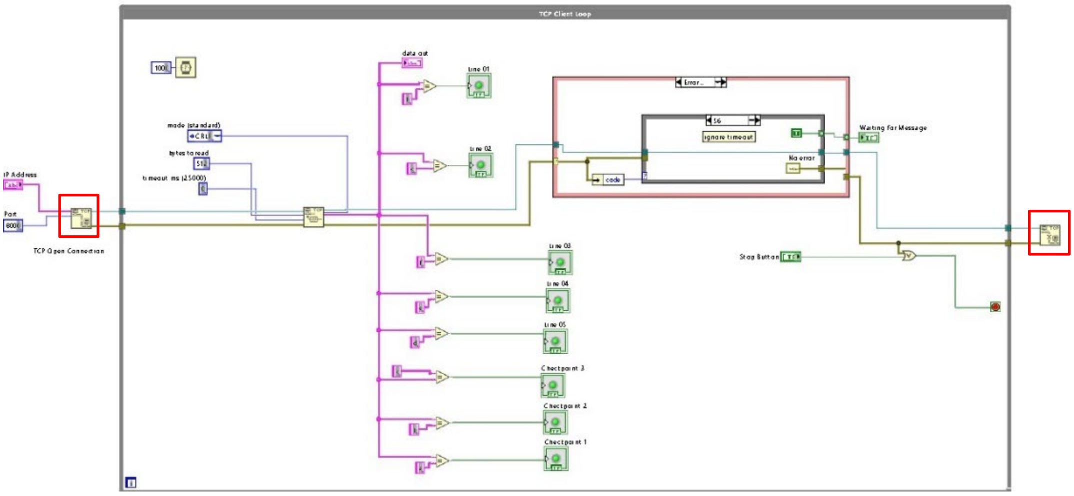
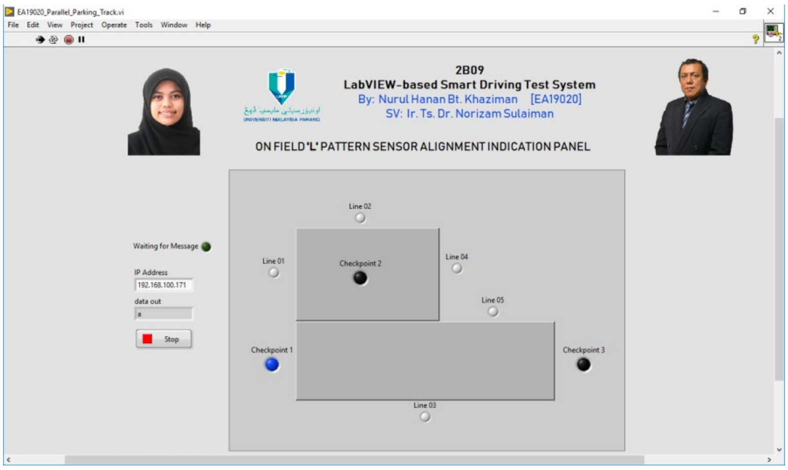


Figure 14. LabVIEW block diagram to implement the system

The testing on the system is implemented by driving the car in the L-shaped parking zone as shown in Figure 15. Once the car enters the L-shape parking zone, checkpoint 1 will be triggered and the movement sensor at the on-vehicle control unit will send a data packet to the central control unit through ESP-NOW. The receiver unit then will turn on the blue LED to indicate that the car is currently entering the L-shaped parking zone and the blue indicator in LabVIEW will turn on simultaneously as shown in Figure 16.

Figure 15. Car entering L-shaped parking at checkpoint 1



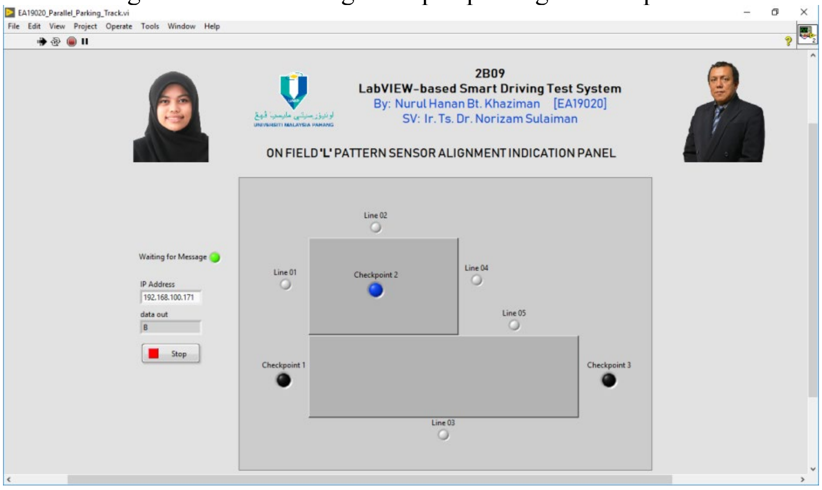
IP Address 192.168.100.171

data out a

Figure 16. LabVIEW GUI for the L-shaped parking test at checkpoint 1

At checkpoint 2, the participant will maneuver the car to enter the L-shaped parking by reversing the car to enter the parking slot. Once the participant can park the car correctly at checkpoint 2, the blue LED light at the central control unit and LabVIEW GUI will be turned on simultaneously as illustrated by Figure 17 and Figure 18 respectively. If the car does not cross the white line at the L-shaped parking zone, the LCD at the on-vehicle control unit will display 'PASSED' status. Meanwhile, Figure 19 and Figure 20 illustrate the participant maneuvered the car to leave the L-shaped parking zone where the blue LED light at the central unit and LabVIEW GUI will turn on simultaneously.

Figure 17. Car entering L-shaped parking at checkpoint 2

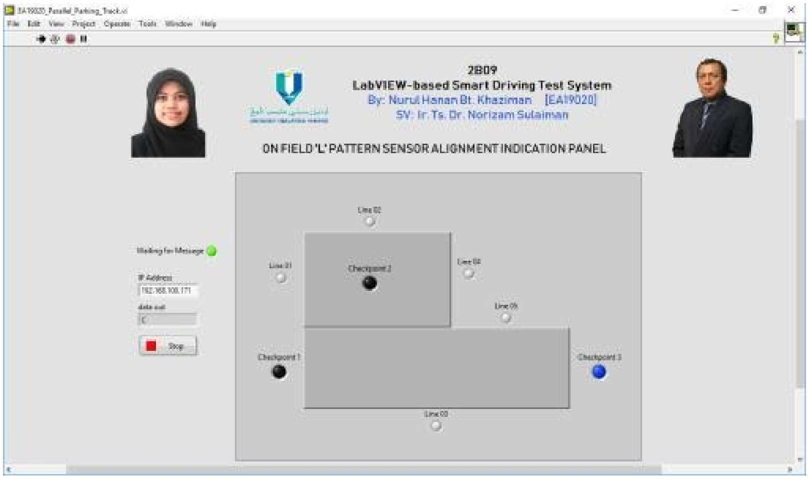


IP Address 192.168.100.171

data out B

Figure 18. LabVIEW GUI for the L-shaped driving test at checkpoint 2

Figure 19. Car leaving L-shaped parking at checkpoint 3



IP Address: 192.168.100.171

data out: C

Figure 20. LabVIEW GUI for the L-shaped parking test at checkpoint 3

During the L-shaped parking testing, the driving test will be considered if the car crosses the white line at the L-shaped parking zone. Once the car crosses the white line as shown in Figure 21, it will trigger the buzzer at the on-vehicle control unit. Next, the on-vehicle control unit will send a data packet to the central control unit. Then, LabVIEW will turn on the red LED light and indicate the area where the car crosses the white line as illustrated in Figure 22. The LCD at the on-vehicle control unit will display a 'FAILED' status.

Figure 21. Car cross the white line

IP Address: 192.168.100.171

data out: 0

Figure 22. LabVIEW GUI display the cross of white line at line 3

It can be apparently seen that the major challenge of the beginner-level participant is to complete the driving parking test within 3 minutes. On the contrary, the results of the study have shown that 80% of intermediate-level participants are capable of completing the parking test within 3 minutes. The beginner level requires a lot of practice in order to make a perfect parking. It can be learned by watching how the intermediate-level participants perform the parking test. In addition, the proposed system can provide an assistive tool to driving instructors and beginner-level participants on what to do to complete the parking test within the specified time. The system is capable of measuring the time spent for each checkpoint as described in the system operation and can trigger the instructor if the vehicle has crossed the parking test white line.

4. CONCLUSION

The fully automated driving test procedure on the parking test is implemented successfully using a wireless communication protocol, microcontrollers, movement sensors, and LabVIEW software. In the study, the wireless communication protocol in LabVIEW is configured correctly to receive data packets from the microcontrollers and sensors. In addition, the LabVIEW block diagram is successfully constructed to produce the parking test status in LabVIEW GUI accurately. The study also shows that the proposed system is capable of evaluating novice and intermediate driving skills based on the duration taken to complete the parking test. Since the proposed system was successfully implemented, for future works, the system can be implemented for other types of parking tests such as slope (incline) parking tests, and reverse parking tests including the S-shaped and Z-shaped road.

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