Development of Laser-Beam Cutting-Edge Technology and IOT-Based Race Car Lapse Time Computational System

B. Thiyaneswaran, E. Ganasri, A. H. Hariharasudan, S. Kumarganesh, K. Martin Sagayam, and Ahmed Alkhayyat

1 Introduction

The objective of racing contest is to determine the winner of the race. The participant who completes the race with predetermined number of lapses in a shortest time will be announced the winner of the race. Racing originated during 1920–1930s in Europe in order to entertain people. The basic set of rules for formula 1 racing was formed according to the FIA standardized racing rules in 1946. Other than the world championship series, many other non-championship races were also held after 1983. Every race has four drivers and the drivers can be switched if the race is long, and along with this, the support staff of each team will also be present who plays a vital role in the team's success.

Each formula 1 racing has its unique characteristics – has iconic tracks or street circuits, has different predetermined set of lapses, and has any specific distance. The number of lapses will be decided according to the length of the racing circuit. At present RF (Radio Frequency) transmitter and receiver are used for calculating the lapse time in a race which makes high cost for fabrication. It can be used for multi car racing but in single car racing this project can be used where it has an advantage

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R. Sharma et al. (eds.), *Data Analytics for Internet of Things Infrastructure*,
Internet of Things, https://doi.org/10.1007/978-3-031-33808-3_8

over the pre-existing system. One major advantage of using embedded systems is data can be transmitted to various devices as they are connected to internet.

In this research, the lapse count, race starting time, race ending time, time taken for each lapse, and their starting and ending time can be calculated using embedded systems and can be uploaded to cloud via internet. The devices that can communicate over internet are known as Internet of Things. As mentioned earlier, time is a very important factor in racing and it should be sensed accurately. For sensing time, we used LiDAR (light detection and ranging) sensor also known as laser sensing.

Existing race car lapse calculation systems have two sensors: one in the car and the other on the track. The exact position of the vehicle is estimated using global positioning system (GPS). Unique sensors on the vehicle enable a signal back again each time when the vehicle crosses the start-finish line. There is the special type of sensors used to track the racing. The embedded system along with the sensors finds the start-finish event. The signal computes the duration of lapse time and increments the lapse count by 1. This is how the lapse and lap times are measured for a car.

Every car running on the track would have similar sensors on board, which give the relative position of the cars. On track, sensors estimate the lap times. But this is costly, and for individual race car lapse calculations, investing large amounts is unnecessary. This ideology is different from the others as it uses a distance calculating sensor to calculate the lapse and it is also precise. Also, the fabrication cost of this project is low. Moreover, LiDAR is a sensing technology and uses air as medium, helps in fast collection of data, and has high accuracy.

Furthermore, the values obtained are not influenced by the amount of light present, but exact values even in darkness and bright light can be calculated using this method. The system will be suitable for fast moving object detection and faster response rate. This system along with the instant display and also has the added advantage of updating the collected data to the cloud. The data can be updated instantly to the cloud and people from different places can view the data without any huge delay time. Thus, using LiDAR and embedded technology in racing is efficient.

2 Literature Review

A vehicle identification framework based on light detection and ranging sensor was proposed by Xianjian et al. [1], which exhibited good stability under simple working conditions and was cost-efficient. Jiaxing et al. [2] proposed a method in which vehicle speed is considered key variable for detection and validation. LiDAR technologies have significant potential in quick detection of fast-moving objects. The method suggested in [2] proposes a tracking framework from roadside LiDAR to detect and track vehicles with the aim of accurate vehicle speed estimation. Chao Deng et al. [3] proposed a model utilizing LiDAR technology for path planning and vehicle control of racing car that ensures safe driving of the car. The result of actual experiment shows that the proposed method [3] can quickly detect the target of the racing car.

Mohamed Zied Chaari et al. [4] proposed an idea of wirelessly charging Internet of Things (IoT) devices. This solution powers up sensors and devices wirelessly via radio frequency (RF) energy. Thiyaneswaran et al. [5] proposed a breathing-level monitoring process that utilizes embedded system. The way of receiving data may useful for developing proposed system. Changyoung et al. [6] proposed that wireless power transmission can be achieved through various methods, but it is important to focus on power transmission distance and efficiency. Their paper deals with multi-antenna design that focuses on the efficiency of power transmission.

Shengnan et al. [7] proposed a model to automatically observe and manipulate vehicle tracking system with time lapse, focuses on the safety of vehicles and lapse calculation. Kenneth [8] proposed a paper on the feasibility of time-lapse ground-penetrating radar for deep excavation works and to identify differences that are usually not notable by naked eye but by signal processed images. Ki-Woong Park et al. [9] have proposed a paper which deals with the problem that the fast-moving object cannot be calculated in time series. It captures the pictures in time-lapse concept which has the great advantage. It periodically captures images of specific point over an extended period and replays it quickly [10].

According to Mingcong Cao et al. [11], autonomous vehicles have widely developed with radars, camera, and LiDAR technology in recent days; however, accurate measurement of data is important for the safety of riders. Q-learning-based Gaussian mixture model is a promising solution for LiDAR fault tolerant. Emil et al. [12] stated that accurate determination of distance between objects and their shapes and sizes using current technologies is highly challenging. This can be overcome by LiDAR system, which utilizes the principle of measuring the time of flight of an optical signal to efficiently calculate the distance between the sensor and object in an effective manner [13].

Kiho Lim et al. [14] stated that for an advanced autonomous driving and vehicular ad-hoc networks, it is important to have effective vehicle-to-vehicle communication. Sharing traffic information collected by sensor with improves driving safety. In this paper LiDAR technology is used in v2v communication. Shuo Gu et al. [15] stated that most of the existing vehicle detection models are of single modal based on either LiDAR or camera. They used multi-modal-based LiDAR-camera fusion to increase the performance of vehicle detection, which works only in the presence of day light, whereas Lidar can work even in the absence of day light [16].

According to Jing Chen et al. [17], autonomous driving has become remarkable in industrial sectors and for personal uses. Using a greater number of LiDARs in order to reduce the blind spot of the LiDAR is cost-effective. So, based on the kinetic behavior of the vehicle, dynamic analysis was performed and the angle of LiDAR detection changes with the rotation of the steering wheel. Jing Huang et al. [18] proposed that since autonomous driving vehicles have been commercialized, it is important to promote more efficient and safer autonomous driving technologies.

LiDAR technologies is one of the most effective sensors utilized for the lane detection of roads and road curbs. To reduce the trade-off between time consumption and object detection, LiDAR technologies can be used [19].

Tao Yang et al. [20] proposed that LiDAR is one of the important technologies used in autonomous vehicles. Thus, as a critical sensor, LiDAR needs to work in terrible weather condition such as rain, fog, and snow. Popular near-infrared (NIR) ToF LiDAR also can be used to obtain accurate results in extreme weather conditions. Birgit Schlager et al. [21] have proposed the fault detection algorithm based on LiDAR sensor used in autonomous driving vehicle. They used an automotive LiDAR sensor to calculate the deviation between the actual distance and the ideal plane representing the target [22].

Lane information is an essential part of high-resolution traffic data, which was proposed by Ciyun Lin et al. [23]. High-density onboard LiDAR cannot be used to process low-density road-side data. Using ground recognition and lane marking point extraction, low density data can also be measured in autonomous driving. Jasmina Zubaca et al. [24] have proposed the system that state the capabilities of the algorithm can be applied to any race track, regardless of their curves, shape of the track, gate position, width etc. It also has the advantage of low computational effort, which enables fast tuning during racing events [25].

Alexander Liniger et al. [26] proposed three different designs to avoid collision accidents during racing games. In the first method, the collision avoidance constraints are followed only by the follower; in the second, the players are conscious about the collision constraints; and in the third, the game is designed to promote blocking. This research shows that the proposed games can have different racing behaviors and generate interesting racing situations. Leyao Huang [27] have proposed the LiDAR-based simultaneous localization and mapping (LiDAR-SLAM). It uses the sensors to build the map of the surrounding environment and observing the environmental features. Localization with high accuracy and practicability is a complex and hot issue in recent years [28].

3 Proposed Method

The method proposed in this chapter is applicable when one car is raced individually and its lapse count needs to be calculated. It can also be used to calculate the speed of the racing car. This system uses LiDAR technology and is advantageous compared to other systems in terms of accuracy and fast detection of objects. The data acquired from racing can also be displayed instantly and can be immediately updated to the cloud so that people from different places can access and view the data. LiDAR technology is advantageous compared to other preexisting techniques such as manual method used to calculate lapses in racing, ultrasonic sensors, fully automatic timing (FAT), radio frequency identification (RFID), and IR transmitter and receiver. The lapse cutting edge calculation of race car performed using laser beam is more efficient compared to other technologies. Unlike other forms of lights such as flashlights, the beam from laser lights stays focused and will not spread out. Thus, laser beams are very narrow, bright, and can travel very long distances. The bunch of laser light waves travel together with their peaks all lined up, or in phase [29].

3.1 Block Diagram

The block diagram of the proposed system is shown in Fig. 1. The microcontroller used for this project is Arduino UNO board, which is an open-source platform used for building embedded projects. It has an Integrated Development Environment (IDE) along with physical programmable circuit [30]. The sensor used for tracking the car is LiDAR (Light Detection and Ranging) sensor, which measures the time difference between the transmitted and reflected pulses, which is used to calculate the distance between the obstacle and the sensing sensor. LiDAR is one of the important components in this project because it emits laser beam which expands less with travel distance. The sensor transmits and receives laser pulse in nanoseconds, so a very large amount of data can be fetched in a very short period of time, which is one of the major benefits of using this sensor in racing.

$$D_{\mathrm{S}} = c \times \frac{T}{2} \tag{1}$$

D_{S} is the distance between the sensor and object.
c is the speed of light in vacuum.
T is the measured time between emitting and receiving the signal.

The LiDAR sensor is a popular sensor that enables the user to know the exact distance of the object present on the surface of the earth. The LiDAR follows a basic principle in which it emits the laser light into the environment which hits an obstacle

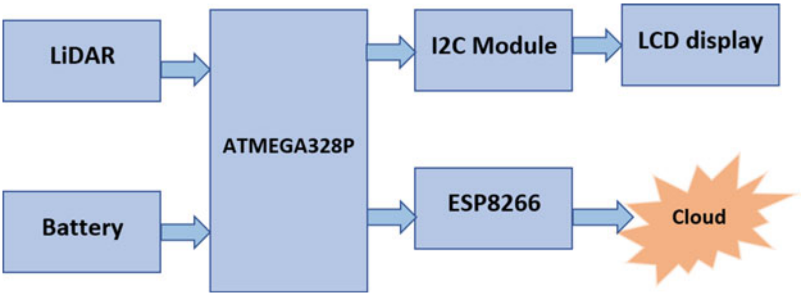


Fig. 1 Block diagram of developed system

on the surface of the earth. The time duration it takes to return to the receiver part of the LiDAR sensor is computed to find the distance. The distance can be calculated using Eq. 1. The performance of the sensor depends on the speed at which the light travels which is about 186,000 miles per second, and the process of measuring the exact distance by LiDAR seems to be unbelievably faster than any other existing technologies.

The LiDAR sensor operates in a range of 0.1–12 m, needs a voltage supply of minimum 5 volts, and has a frame rate of 10 to 1000 Hz. This sensor can be used for obstacle detection, obstacle avoidance, assisted landing, terrain following, vehicle position sensing, etc. It is compact in size and is light in weight. An LCD screen is used to display the output, if this is furnished in real entity then TFT display or any other large display can be used. The data are then uploaded to the google cloud so that people from different places can access them.

When the process is initiated, the LiDAR sensor starts working and gets inputs. When the car cuts the laser beam, the lapse count gets incremented and this will continue until the total number of lapses required to complete the race is reached. Once the race is completed, the LCD displays the output. Initially, two push buttons are used to get the total number of lapse count needed to complete the race.

The flowchart of the proposed system is shown in Fig. 2. It consists of control switch. When the control switch is turned on, the other switch starts taking input. Each time when it is pressed, the lapse count value gets incremented. After counting the total number of lapses, turn off the control switch. Now the microcontroller will have the total number of lapse counts needed to complete the car race.

3.2 Simulation of Proposed System

The simulation of the proposed system is shown in Fig. 3. Figure 3 shows the circuit diagram of the system and is a simple representation of the components of an electrical circuit. It also shows the relative position of all the elements and their connections to one another. Arduino UNO is the central unit of the circuit, which is the microcontroller used in this system. A LiDAR sensor is connected to the system and is used to measure the distance between the car and the sensor. An LCD display along with the I2C module is also interfaced with the microcontroller board (Arduino UNO). Two switches are used to get the input from the user and a 9-volt battery is used to supply power to the system.

4 Results and Discussion

The developed system is tested in a practical environment before launching it in the market to ensure that the system is free of error.

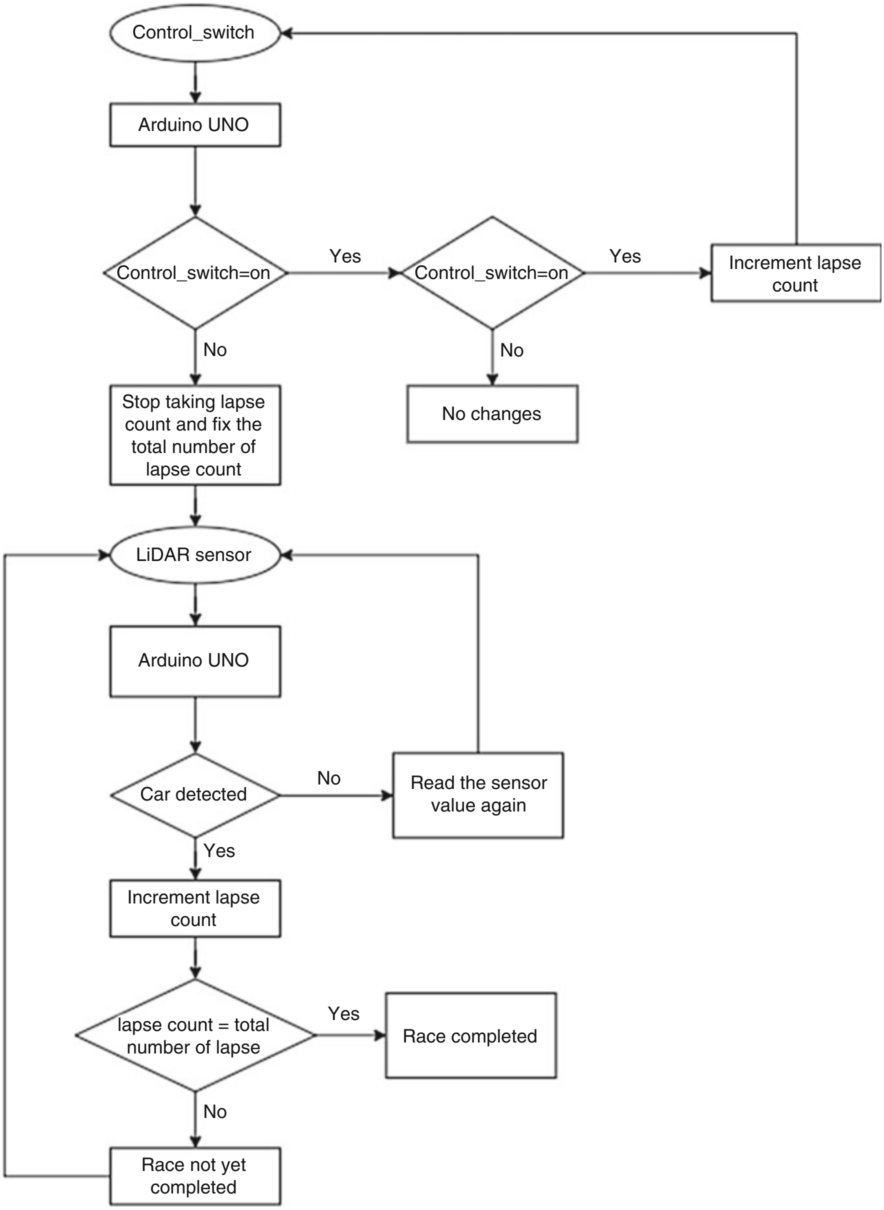


Fig. 2 Flowchart of the system

The hardware of the system shown in Fig. 4 contains two switches for getting the final lapse count needed to end the race. The switches are connected to the resistor for regulating the power supply. Arduino UNO board is used as a microcontroller

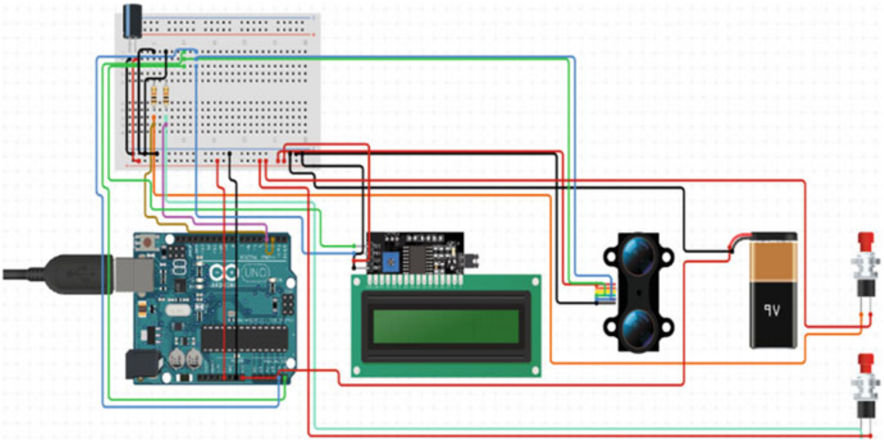


Fig. 3 Simulation of the developed system

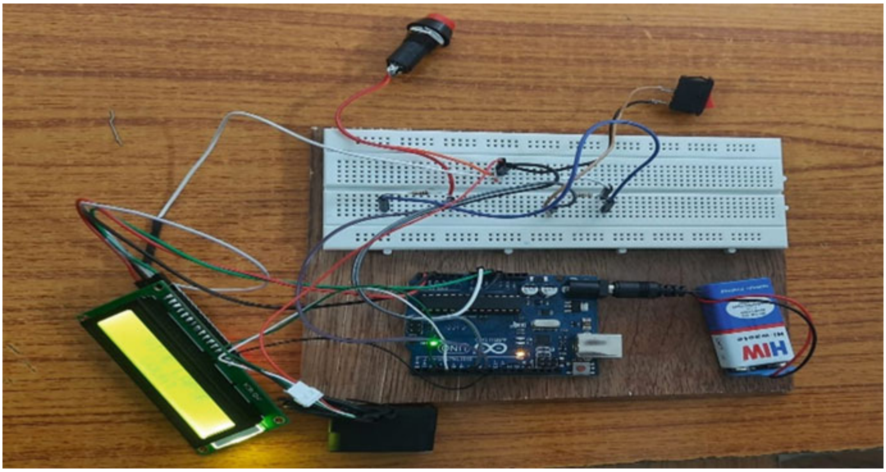


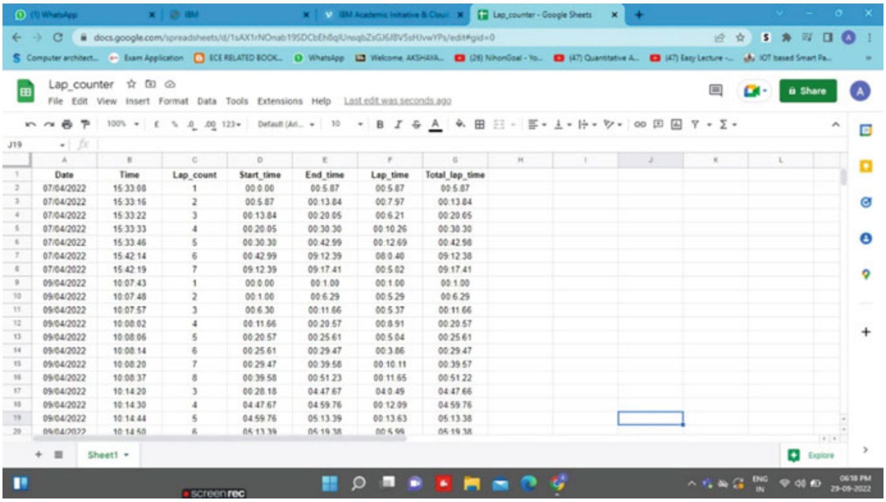
Fig. 4 Hardware implementation of the system

and an LCD display is connected to the I2C module. I2C module is used to establish communication between two or more ICs. This display overcomes the drawback of LCD 16 × 2 parallel LCD display, which intern reduces the number of pins used in Arduino.

The output of the proposed system is shown in Fig. 5. First, the system instructs the user to give the total lapse count (Fig. 5a), on which the user starts entering the lapse count by pressing the push button. Afterward, the count gets incremented and the total lapse count is displayed for reference (see the count 7 shown in Fig. 5b). When the car starts moving, the system starts calculating the lapse count. Every time a lapse is completed, it is displayed on the LCD along with the duration of that lapse.

(a) (b) (c) (d)

Fig. 5 Display Output view of proposed system



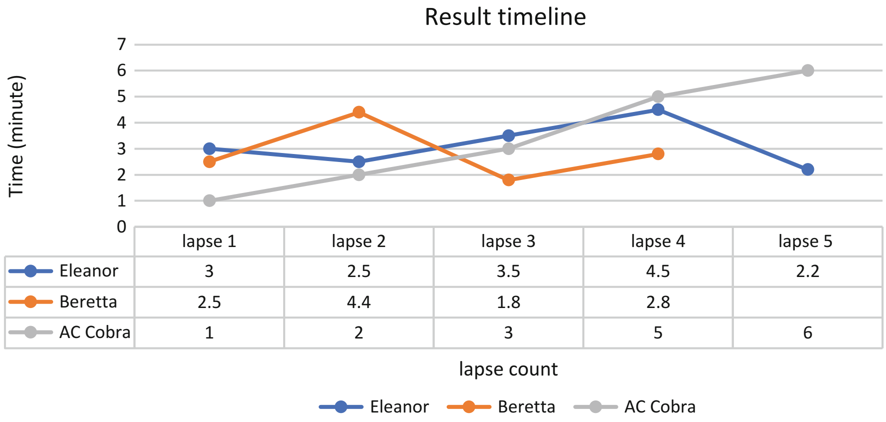
Date	Time	Lap_count	Start_time	End_time	Lap_time	Total_lap_time
07/04/2022	15:33:08	1	00:0.00	00:5.87	00:5.87	00:5.87
07/04/2022	15:33:16	2	00:5.87	00:13.84	00:7.97	00:13.84
07/04/2022	15:33:22	3	00:13.84	00:20.05	00:6.21	00:20.05
07/04/2022	15:33:33	4	00:20.05	00:30.30	00:10.26	00:30.30
07/04/2022	15:33:46	5	00:30.30	00:42.99	00:12.69	00:42.98
07/04/2022	15:42:14	6	00:42.99	09:12.39	08:0.40	09:12.38
07/04/2022	15:42:19	7	09:12.39	09:17.41	00:5.02	09:17.41
09/04/2022	10:07:43	1	00:0.00	00:1.00	00:1.00	00:1.00
09/04/2022	10:07:48	2	00:1.00	00:6.29	00:5.29	00:6.29
09/04/2022	10:07:57	3	00:6.30	00:11.66	00:5.37	00:11.66
09/04/2022	10:08:02	4	00:11.66	00:20.57	00:8.91	00:20.57
09/04/2022	10:08:06	5	00:20.57	00:25.61	00:5.04	00:25.61
09/04/2022	10:08:14	6	00:25.61	00:29.47	00:3.86	00:29.47
09/04/2022	10:08:20	7	00:29.47	00:39.58	00:10.11	00:39.57
09/04/2022	10:08:37	8	00:39.58	00:51.23	00:11.65	00:51.22
09/04/2022	10:14:20	3	00:28.18	04:47.67	04:0.49	04:47.66
09/04/2022	10:14:30	4	04:47.67	04:59.76	00:12.09	04:59.76
09/04/2022	10:14:44	5	04:59.76	05:13.39	00:13.63	05:13.38
09/04/2022	10:14:50	6	05:13.39	05:19.38	00:5.99	05:19.38

Fig. 6 Output in google spread sheet

Once the lapse count gets incremented and reaches the final count, the race gets completed. Fig. 5c shows the display of seventh race lapse. Finally, the completion status of race is displayed on the LCD display. Fig. 5d shows the finished status. The whole procedure is repeated once the system is restarted.

Figure 6 shows the data of the race acquired using the proposed model, i.e., car-lapse cutting-edge technology using laser beam. These data are instantly uploaded to cloud, preferably google sheets, for ease of access, which contains the date and time at which the race took place, the race lapse count, its starting and finishing time, and the duration of each lapse.

Each trail is set with a specific lapse count. The graph is plotted between time in minutes and lapse count. Figure 7 shows the lapse count and time taken for each lapse in three different trails.



	lapse 1	lapse 2	lapse 3	lapse 4	lapse 5
Eleanor	3	2.5	3.5	4.5	2.2
Beretta	2.5	4.4	1.8	2.8	
AC Cobra	1	2	3	5	6

Fig. 7 Sample timeline and table of results

Table 1 Comparison between manual method and ultrasonic and LiDAR lapse technologies

	Manual calculation	Ultrasonic sensor	LiDAR technology
Max distance coverage	Not accurate	4 m	12 m
Time delay	More than a second	20–50 milliseconds	1–10 nanoseconds

Table 1 shows the comparison between manual calculation, ultrasonic sensor, and LiDAR sensor. The table shows that LiDAR technology is superior compared to the other two methods in terms of time delay, accuracy, and maximum distance coverage. This data is instantly uploaded to cloud without any time delay; a link is then created through which people from different regions view these race details precisely.

Using ultrasonic sensor for calculating racing lapses is not a good idea. As the ultrasonic sensor works on the principle of emitting sound waves at very high frequency in which cannot hear it and receives then back. The time gap between transmitting and receiving a signal is used to compute the distance between the sensor and the object. Here, since the signal is a sound wave, a time delay is noted. This can be overcome by utilizing LiDAR sensors, in which the laser beams emitted are used to calculate the distance between the sensor and the object (in nanoseconds of time delay).

Another method used in vehicle tracking is IR ID chip which acts as the key of IR sensor as it has the car identification number. Each IR sensor is fit in the car and it is embedded with one IR ID chip which has the identification number of the vehicle. It also has an RF transmitter that frequently transmits a RF signal through an antenna toward the direction in which the car is moving. The receiver in the control unit fit at a specific point in the race track accepts the signal transmitted by the transmitter and sends the data to the system present in the nearby control room for getting the full details such as lapse count, lapse time etc.

Table 2 Comparison of lapse values calculated using IR transmitter and LiDAR technology

Lapse count	Lap time using IR transmitter (minutes)	Time delay (seconds)	Lap time found using LiDAR technology (minutes)	Time delay (nanoseconds)
1	2:30.18	0.1	2:30.17	0.1
2	3:42.11	0.2	3:42.09	0.2
3	4:11.23	0.2	4:11.21	0.2
4	5:21.33	0.1	5:21.32	0.1
5	6:18.09	0.2	06:18.07	0.1
6	7:37.17	0.1	07:37.16	0.1

Table 3 Comparison of recent technologies and LiDAR technology

Features	Radio frequency identification (RFID)	IR transmitter and receiver	LiDAR technology
Reader range	0–2 m	0–5 m	0–12 m
Integration	Difficult	Difficult	Easy
Memory storage	No	Yes	Yes
IOT enabling	No	Yes	Yes
Response	Identification	Identification + positioning	Identification + positioning + speed
Cost of fabrication	Expensive	Expensive	Affordable

This system has an advantage when it comes to multiple car tracking, but this system is not accurate for single cars and cannot sense fast-moving vehicles. Table 2 compares the lapse values calculated using IR transmitter and LiDAR technology . It is to be noted that LiDAR technology calculates time delay in nanoseconds, whereas IR transmitter and receiver calculates the time delay in seconds.

Table 3 shows a comparison of the recent technologies and LiDAR technologies and shows why LiDAR technologies are advantageous than the other two technologies. An RFID tag, a microchip, is attached to the car to track the position of the vehicle. The tag picks up the signal from an RFID reader and scanner and then returns the signal, usually with some additional information such as start and finish time of the racing vehicle. The main disadvantage of this system is it cannot track fast-moving vehicle like race cars. These show that LiDAR technology more efficiently detects fast-moving objects like racing car with less time delay compared to other existing technologies.

Figure 8 shows a comparison of the efficiency of different technologies used for lapse calculation. The time delay, i.e., the minimum time the object should be present in the sensor range so that the sensor can track its presence, and accuracy of the object are represented in the chart given in Table 4. Radio Frequency Identification (RFID) is an advanced technology that uses wireless transformation of data between the tag or car and a reader or device to automatically track or identify the physical location of each object. The system's transmission range is restricted to few meters from the reader and the tag should be in clear line of sight.

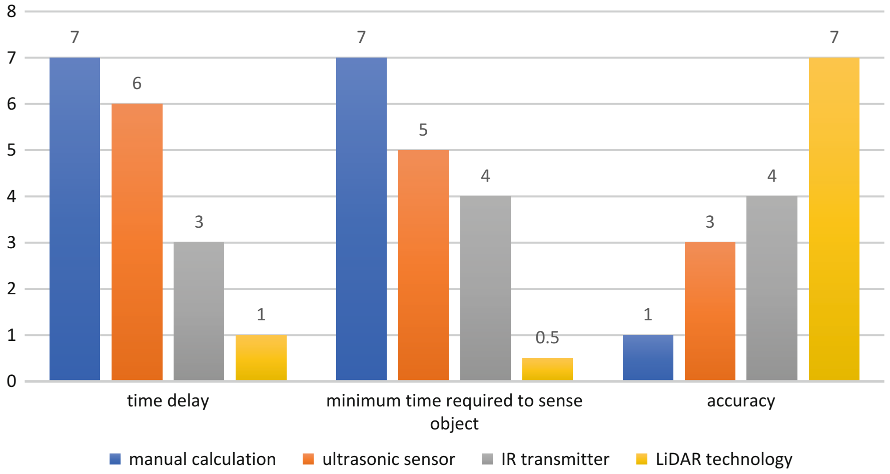


Fig. 8 Comparison of different technologies utilized for lapse calculation

Table 4 Data obtained using the proposed system

S.no	Date	Time	Lap count	Start time	End time	Lap time	Total lap time
1	17/10/2002	15:33:08	1	00:0.00	00:5.87	00:5.87	00:5.87
2	17/10/2002	15:33:16	2	00:5.87	00:13.84	00:7.97	00:1.84
3	17/10/2002	15:33:22	3	00:13.84	00:20.05	00:6.21	00:20.05
4	17/10/2002	15:33:33	4	00:20.05	00:30.30	00:10.26	00:30.30
5	17/10/2002	15:33:46	5	00:30.30	00:42.99	00:12.69	00:42.98
6	17/10/2002	15:42:14	6	00:42.99	09:12.39	08:0.40	09:12.38

Table 4 shows the date at which the event occurred, time, lapse count, start and end time of each lapse, duration of each lapse, and the total race time calculated with this system.

The accuracy and efficiency of the developed system were analyzed by comparing it with a fully automatic timing (FAT) system. Fully automatic timing (FAT) is a popular racing timing system that helps obtain accurate race results, i.e., accurate to 0.01 of a second. This system needs a start signal, running time, and capture device to be digitally synchronized to ensure accuracy. This system is designed in such a way that it is activated automatically by an initiation signal rather than manually. The start signal is generated by a start sensor integrated with a gun that is used to start the race. The finish signal is generated by a ribbon or string and is recorded electronically to remove any human error. The results obtained using the developed system is shown in Table 5, which show that LiDAR technology is accurate and does not need any external activation system for initiation like FAT.

This work addresses the common difficulties encountered during lapse calculation. The proposed system enables uninterrupted monitoring and storing of race-related information, and the data obtained are displayed on an LCD display

Table 5 Accuracy of the developed system compared to FAT

Lapse count	FAT	LiDAR technology
1	00.5.11	00:5.11
2	00:6.45	00:6.45
3	00:4.98	00:4.97
4	00:5.21	00:5.21
5	00:6.11	00:6.10
6	00:5.55	00:5.55
7	00:6.32	00:6.31

for instant viewing. This model is cheap, efficient, and accurate in terms of time measurements.

5 Conclusion

The proposed system was developed by utilizing laser beam-based LiDAR. ATMEGA328 controller was used to access LiDAR technology. When the racing element crossed the beam, LiDAR was activated by triggering. In this work, a laser beam–based cutting-edge technology for calculating race car lapses was fabricated and tested. The results of this system were accurate, and the system was able to detect time delay even in nanoseconds in comparison with fully automatic timing (FAT) system. The data obtained were also uploaded to cloud using Internet of Things (IOT). LiDAR technology finds many advantages in racing sector where even fast moving objects can be detected effectively. The developed system can track a maximum of 12 m track width with maximum 10 ns computation.

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