Chapter 10
Development of Laser Beam Cutting Edge Technology and Iot Based Race Car Lapse Time Computational System

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Introduction

The objective of racing contest is to determine the winner of the race. The participant who completes the race with pre-determined number of lapses in a shortest time will be announced the winner of the race. Racing was originated during 1920–1930s in Europe in order to entertain people. The basic set of rules for formula 10.1 racing was formed by FIA standardized racing in 1946. Other than the world championship series, many other non-championship races were also held after 1983. Every race has 4 drivers where they can switch the drivers if it is a long race and along with this the support staff of each team will also be present who plays the vital role in the team's success.

Each formula one racing has its unique characteristics. It depends on iconic tracks or it may be street circuits, it has different pre-determined set of lapses, it may have any specific distance. The number of lapses will be decided according to the length

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of the racing circuit. At present Rx transmitter and receiver are used for calculating the lapse time in a race which 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 over the pre-existing system. One major advantage of using embedded systems is, it can be connected to the internet and can transfer data to various devices via internet all over the data.

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 the cloud via internet. Thus, the devices can communicate over the internet and it is known as the internet of things. As mentioned before time is a very important factor in racing and it should be sensed accurately. For sensing time, here we use LiDAR (light detection and ranging) sensor and it is also known as laser sensing.

At present, the race car lapse calculation techniques will have 2 sensors in it. One in the car and the other on the track. The exact position of the vehicle is estimated using the Global positioning system (GPS). Unique sensors on the vehicle enables a signal back again each time the when the vehicle crosses the start-finish line. There is a special type of sensors which is embedded on the track of the racing on the start-finish line which in turn signal computes to reset the duration timing of the lapse 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. This gives the relative position of the cars. On track, sensors estimate the lap times. But this is cost prohibitive 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 is low for this project. LiDAR is a sensing technology which uses air as medium which helps in the fast collection of data and it has high accuracy.

The values are not influenced by the amount of light present, it gives exact value even in presence of dark and bright light. If you are trying to detect something moving quickly, the fast update rate will allow you to detect those targets as well. This system along with the instant display it 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 various places can view the data without any huge delay time. Thus, using LiDAR and embedded technology in racing is efficient.

Literature Review

A vehicle identification framework based on light detection and ranging sensor was proposed by Jian et al. (2022). This shows that the system has good stability under simple working conditions and it is cost efficient. Zhang et al. (2020) have proposed method that the vehicle speed is a key variable for detection and validation. LiDAR technologies have significant potential in quick detection of fast-moving objects. It proposes a tracking framework from roadside LiDAR to detect and track vehicles with the aim of accurate vehicle speed estimation. Deng et al. (2021) have proposed a paper that deals with path planning and vehicle control of racing car and realizing the safe driving of the car using LiDAR technology. The result of the actual experiment shows that the thesis can quickly detect the target of the racing car.

Chaari and Al-Rahimi (2021) have proposed a paper that deals with the idea of wirelessly charging internet of things (IOT) devices. It gives the solution to power up sensors and devices wirelessly via radio frequency (RF) energy. The breathing level monitoring process used the embedded system proposed by Thiyaneswaran et al. (2020a). The way of receiving data may useful for developing proposed system. Changyoung et al. (2020) have proposed that wireless power transmission can be achieved through various method but it is important to focus on power transmission distance and efficiency. This paper deals with multi antenna design which focus on the efficiency of power transmission.

The automatic observation and manipulation of automated vehicle tracking system with time-lapse was proposed by Dong et al. (2018). It works on the safety of vehicles and lapse calculation in racing. Kenneth et al. (2018) have proposed a paper that studies about the feasibility of time-lapse ground penetrating radar in deep excavation works and it helps to identify differences which are usually not notable by naked eye but by signal processed image. Park et al. (2018) have proposed a paper which deals with the problem that the fast-moving object cannot be calculated in time series as a solution to it taking pictures in time-lapse concept has been a great advantage. It periodically captures images of specific point over an extended period and replays it quickly (Thiyaneswaran et al. 2020b).

Vo et al. (2021) have proposed that autonomous vehicle has widely developed with radars, camera, and LiDAR technology in recent days, however, accuracy of measuring data is important when concerned about the safety of riders. Q-learning based gaussian mixture model can achieve a promising solution for lidar fault tolerant. The accuracy, false acceptance rate and other metric parameters are elaborated for testing out the system by Thiyaneswaran et al. (2023) and Kumarganesh et al. (2016). Sachan et al. (2021a) have stated that determining the distance between objects their shape and size in practical aspects with accuracy in current technologies is one of the challenging tasks. To overcome this LiDAR system uses the principle of measuring the time of flight of an optical signal to calculate the distance between the sensor and the object in an effective manner.

Ghanem et al. (2021) have stated that the advancement of autonomous driving and vehicular ad-hoc networks it is important to have vehicle to vehicle communication in an effective manner. Sharing traffic information collected by sensor with each improves driving safety, in this paper to increase the performance LiDAR technology is used in v2v communication. Sachan et al. (2021b) have stated that most of the existing vehicle detection models are single-modal based either LiDAR or camera. In this paper to increase the performance of vehicle detection multi-modal-based LiDAR-camera fusion is used. This multi-modal system works only in the presence of day light and only Lidar works in the absence of day light.

Azad et al. (2021) have proposed that autonomous driving has become remarkable in industry and private uses. Using a greater number of LiDAR's 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. Priyadarshini et al. (2021b) have proposed that the autonomous driving vehicles have been commercialized so it is important to promote more efficient and safer autonomous driving technologies. LiDAR technologies is one of the most effective sensors in lane detection of roads and road curbs. To reduce the trade of between time consumption and object detection LiDAR technologies can be used.

Priyadarshini et al. (2021c) have proposed that LiDAR is one of the important technologies used in autonomous vehicle. Thus, as a critical sensor lidar needs to work in terrible weather condition such as rain, fog, snow, etc. using popular near-infrared (NIR) ToF LiDAR it shows that the sensor gives accurate results in extreme weather conditions also. Singh et al. (2021) have proposed that the fault detection algorithm in LiDAR sensor used in autonomous driving vehicle. Here an automotive LiDAR sensor is used to calculate the deviation between the actual distance and the ideal plane representing the target.

The lane information is an essential part of high-resolution traffic data was proposed by Sahu et al. (2021). Usage of high-density on board 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. Zubaca et al. (2021) 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.

Liniger and Lygeros (2019) have stated three different aims of racing are proposed to avoid collision accidents. In the first game the collision avoidance constraints are only followed by the follower. In the second game both the players are conscious about the collision constraints. The third game is designed to promote blocking. This research shows that the presented games can have different racing behaviors and generate interesting racing situations. Huang (2022) has proposed this paper which shows about the LiDAR-based simultaneous localization and mapping (LiDAR-SLAM) uses the sensor to build the map of the surrounding environment by observing the environmental features. Localization with high accuracy and practicability is a complex and hot issue in recent years.

Proposed Method

This project is applicable when one car is raced individually and its lapse count need to be calculated. It can also be used to calculate the speed of the racing car. This system has an advantage over other systems in terms of accuracy and fast detection of objects as we use LiDAR technology. The data which is acquired from the racing can also be displayed instantly and it can be updated in the cloud instantly for people to access and view the data from various places. LiDAR technology has an advantage over other pre-existing techniques like manual calculation of lapse in racing, ultrasonic sensors, fully automatic timing (FAT), Radio frequency identification (RFID), IR transmitter and receiver. The race car lapse cutting-edge calculation using laser beam is more efficient than the other technologies. Laser lights are not like other types of light forms such as flashlights. The beam stays focused and it will not spread out. Thus, laser beams are very narrow, bright and can travel for very long distances. The laser's light waves travel together with their peaks all lined up, or in phase.

Block Diagram

The developed system block diagram is shown in Fig. 10.1. The microcontroller used for this project is Arduino UNO board which is an open-source platform used for building embedded projects by Thiyaneswaran et al. (2022). It has Integrated Development Environment (IDE) along with a physical programmable circuit (Priyadarshini et al. 2021a). The sensor used for tracking the car is LiDAR (Light Detection and Ranging) sensor. It measures the time difference between the transmitted and reflected pulse and with this time difference the distance which is in between the obstacle and the sensing sensor can be calculated. LiDAR is one of the important components in this project because it emits a laser beam which has less expansion with travel distance. The sensor transmits and receives laser pulse in nano seconds of time 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.

$$D_s = c \times \frac{T}{2} \tag{10.1}$$

D_s is the distance between 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 famous sensing method which enables the user to know the exact distance of the object which is present in the surface of the earth. The LiDAR follows a basic principle in which it emits the laser light into the environment at an obstacle on the surface of the earth and calculates the time duration it takes to return to the receiver part of the LiDAR sensor. The distance can be calculated using the Eq. (10.1). The working of the sensor depends on the speed at which the light travels which is about 186,000 miles per second, the process of measuring the exact distance through LiDAR seems to be unbelievably fast than any other existing technologies.

The operating range of the LiDAR sensor is 0.1–12 m. It needs a supply voltage of minimum 5 V. The frame rate of this sensor is 10–1000 Hz. This sensor can be used in obstacle detection, obstacle avoidance, assisted landing, terrain following,

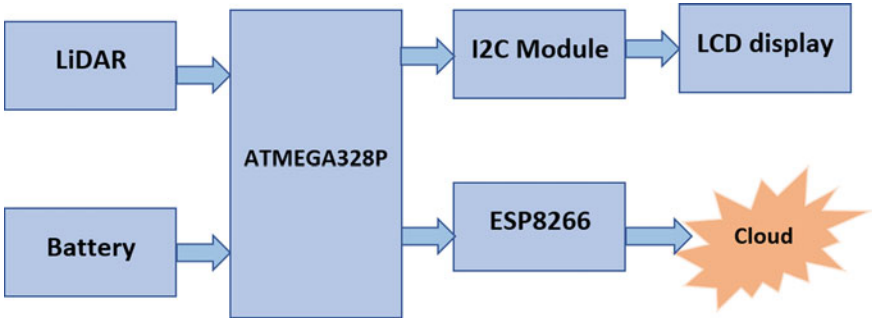


Fig. 10.1 Block diagram of developed system

vehicle position sensing, etc. It is compact in size and it is light weight. An LCD display is used to display the output in this project, if this is furnished in real entity then TFT display or any other large display can be used. The data is also uploaded to the google cloud so that people from various places can access the data with systems.

The lidar sensor starts working and gets the input, when the car cuts the laser beam the lapse count gets incremented this will continue until it reaches the total number of lapses required to complete the race. Once when this is completed, the LCD displays as the race is completed. Initially two push button switches are used in order to get the total number lapse count needed to complete the race.

The flow chart of the system developed system in Fig. 10.2 which one control switch when turned on, the other switch starts taking input and each time it is pressed, the lapse count value gets incremented. Once when we have done with giving the total number of lapse count, now turn off the Control switch. Now the microcontroller will have the total number of lapse count needed to complete the race by the car.

Simulation of Proposed System

The simulation system of proposed system is shown in Fig. 10.3. It shows the circuit diagram of the system which gives the simplified 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 which is used to measure the distance of the car from the sensor. An LCD display along with the I2C module is also interfaced to the microcontroller board (Arduino UNO). Two switches are used to get the input from the user and a 9 v batter is used as the power supply for the system.

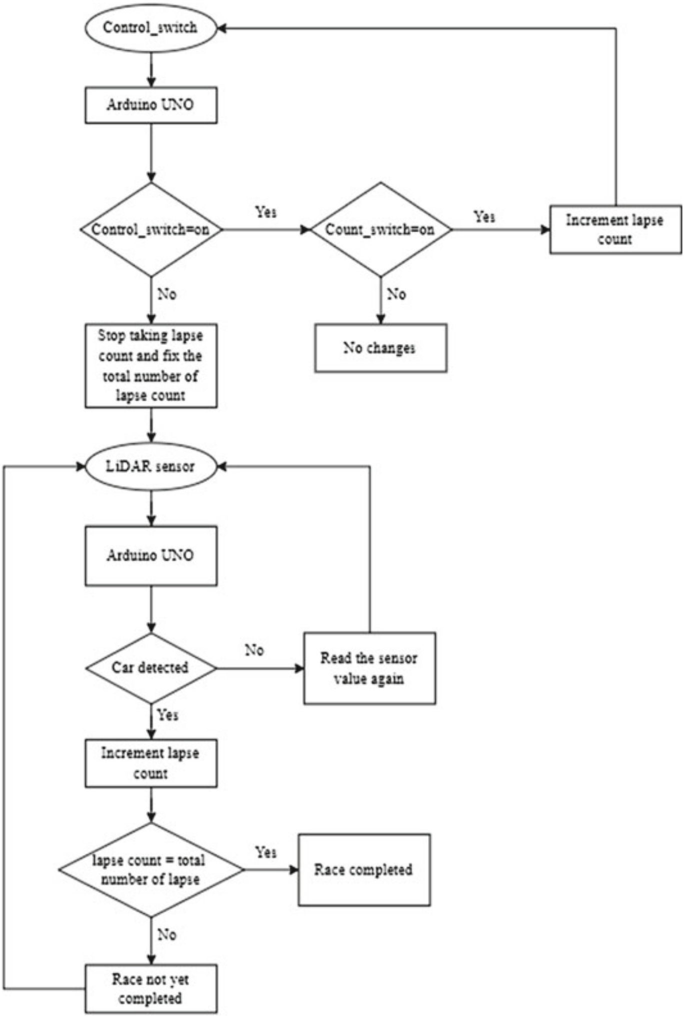


Fig. 10.2 Flow chart of the system

Results and Discussion

The developed system is tested in the practical environment before releasing the system into the market to ensure error free working of the system.

The hardware of the system shown in Fig. 10.4 has two switches for getting the final lapse count that is needed to end the race. The switches the connected with the resistor for regulating the power supply. The Arduino UNO board is used as a microcontroller and a LCD display is connected with the I2C module. I2C module is used to establish communication between two or more IC's. This display overcomes

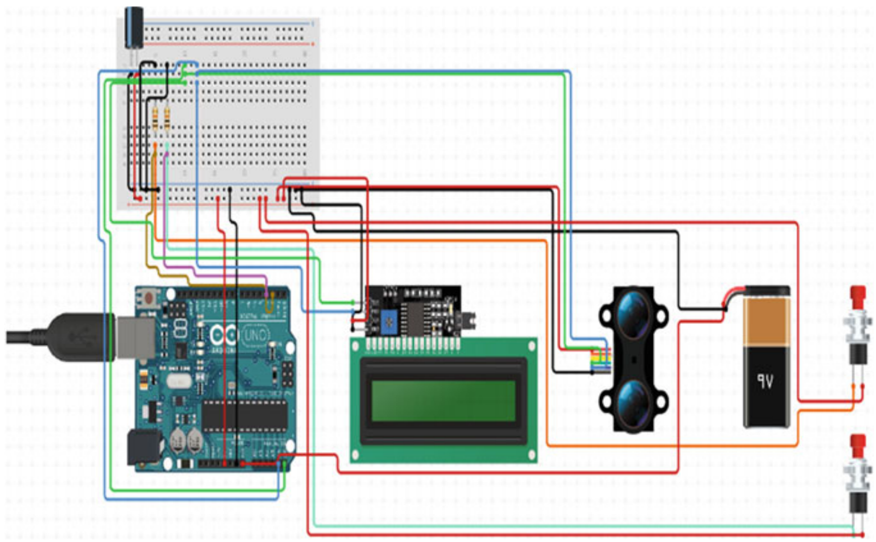
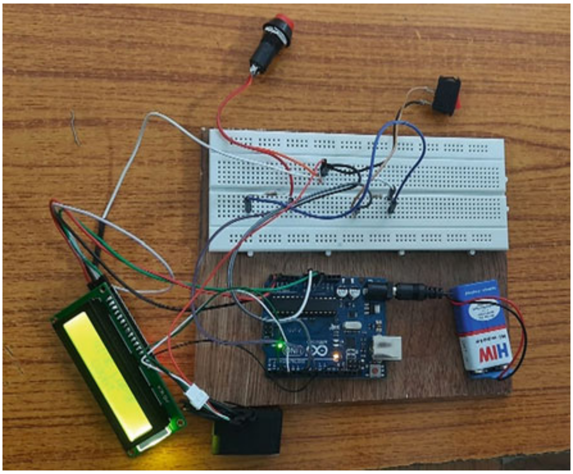


Fig. 10.3 Simulation of developed system

Fig. 10.4 Hardware implementation of the system



the drawback of LCD 16 × 2 parallel LCD display in which you will waste about 8 pins on your Arduino for the display for the display to get working.

The display progress of the developed system is shown in Fig. 10.5. Initially the system initiates the user to give the total lapse count as shown in Fig. 10.5a. The user starts entering the lapse count by pressing the push button switch. After the user enters the count, it gets incremented and the total lapse count is displayed for reference. The test system shows the entered values as 7 as shown in Fig. 10.5b. When the car starts moving the system starts calculating the lapse count. Every time a lapse

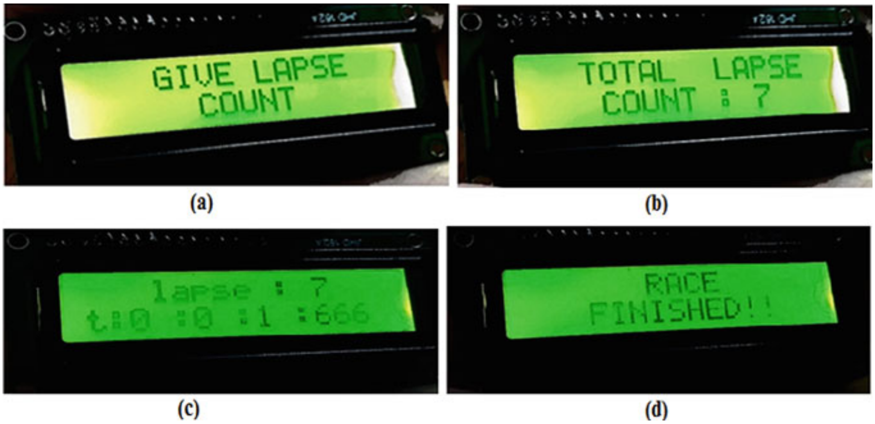


Fig. 10.5 Display of progress of developed system

is completed it is displayed on the LCD along with the duration of that lapse. Once the lapse count gets incremented and reaches the final count the race gets completed. Figure 10.5c shows the display of 7th race lapse. Now the race completion status is displayed on the LCD display. Figure 10.5d shows the race finished status in LCD display. Once the system is restarted this procedure takes place again from the start.

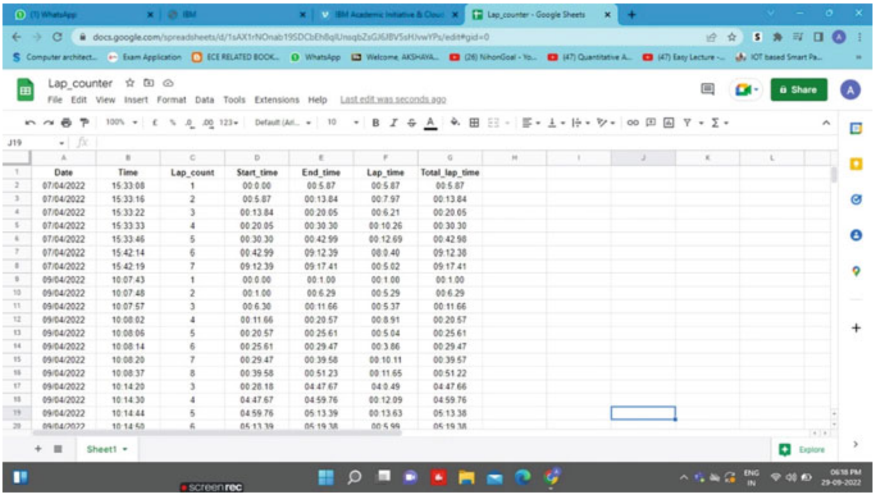
Figure 10.6 shows the data of the race which is acquired using race car lapse cutting edge using laser beam. These data are uploaded to cloud preferably google sheets for ease of access. It contains the date and time at which the race took place, the race lapse count, its starting and finishing time, and the duration of each lapse is also uploaded instantly.

Each trail is set with a specific lapse count. The graph is plotted between time in minutes and lapse count. Figure 10.7 represents the lapse count and time taken for each lapse in three different trails.

Table 10.1 shows the comparison between manual calculation, ultrasonic sensor, and LiDAR sensor. Through which we can conclude that LiDAR technology has an benefit over the other two methods in means of time delay, accuracy, and maximum distance coverage. This data is instantly uploaded to the cloud without any huge time delay and a link will be created by which the people even not in the racing region can view these race details precisely.

Using ultrasonic sensor in racing lapse calculation is not an effective idea. As the ultrasonic sensor works on the principle of emitting sound waves at a very high frequency in which one cannot hear it and receives them back. The time gap in between transmitting and receiving the signal is used to compute the distance between the sensor and the object. Here since it is a sound wave there will be a time delay in order to overcome this LiDAR sensors are used where it emits laser beam to calculate the distance between 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. Every IR sensor is fitted in the car



	Date	Time	Lap_count	Start_time	End_time	Lap_time	Total_lap_time
2	07/04/2022	15:33:08	1	00:0.00	00:5.87	00:5.87	00:5.87
3	07/04/2022	15:33:16	2	00:5.87	00:13.84	00:7.97	00:13.84
4	07/04/2022	15:33:22	3	00:13.84	00:20.05	00:6.21	00:20.05
5	07/04/2022	15:33:33	4	00:20.05	00:30.30	00:10.26	00:30.30
6	07/04/2022	15:33:46	5	00:30.30	00:42.99	00:12.69	00:42.98
7	07/04/2022	15:42:14	6	00:42.99	09:12.39	08:0.40	09:12.38
8	07/04/2022	15:42:19	7	09:12.39	09:17.41	00:5.02	09:17.41
9	09/04/2022	10:07:43	1	00:0.00	00:1.00	00:1.00	00:1.00
10	09/04/2022	10:07:48	2	00:1.00	00:6.29	00:5.29	00:6.29
11	09/04/2022	10:07:57	3	00:6.30	00:11.66	00:5.37	00:11.66
12	09/04/2022	10:08:02	4	00:11.66	00:20.57	00:8.91	00:20.57
13	09/04/2022	10:08:06	5	00:20.57	00:25.61	00:5.04	00:25.61
14	09/04/2022	10:08:14	6	00:25.61	00:29.47	00:3.86	00:29.47
15	09/04/2022	10:08:20	7	00:29.47	00:39.58	00:10.11	00:39.57
16	09/04/2022	10:08:37	8	00:39.58	00:51.23	00:11.65	00:51.22
17	09/04/2022	10:14:20	3	00:28.18	04:47.67	04:0.49	04:47.66
18	09/04/2022	10:14:30	4	04:47.67	04:59.76	00:12.09	04:59.76
19	09/04/2022	10:14:44	5	04:59.76	05:13.39	00:13.63	05:13.38
20	09/04/2022	10:14:50	6	05:13.39	05:19.38	00:5.99	05:19.38

Fig. 10.6 Output in google spread sheet

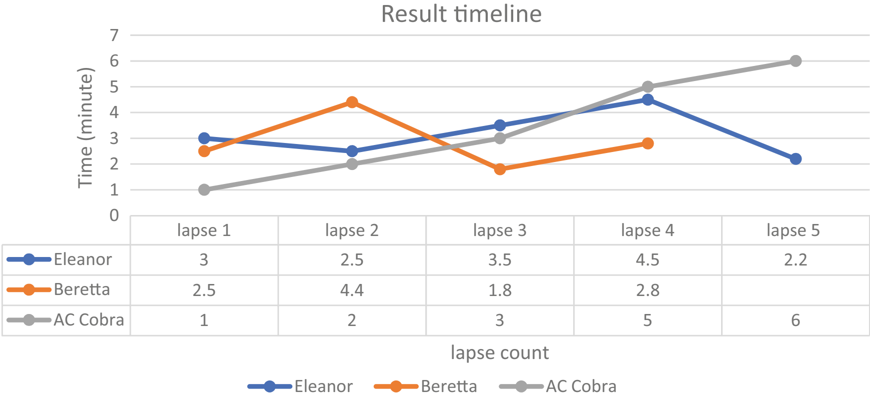


Fig. 10.7 Sample timeline and table of results

Table 10.1 Comparison between manual, ultrasonic and LiDAR lapse technology

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

Table 10.2 Comparison between IR transmitter and LiDAR technology in lapse calculation

Lapse count	Lap time using IR transmitter (min)	Time delay (s)	Lap time found using LiDAR technology (min)	Time delay (ns)
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

and it is embedded with one IR ID chip which has the identification number of the vehicle. It also has a RF transmitter fitted to the car and it frequently transmits the RF signal toward its moving direction through the antenna. The receiver which is fitted in the control unit at specific point in the race track accepts the signal which is 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.

This system has an advantage when it comes to multiple car tracking but while single car is raced this system will not be accurate and cannot sense fast-moving vehicles. In LiDAR technology only have nano seconds of delay time. Table 10.2 shows the comparison between the IR transmitter and LiDAR technology in lapse calculation for racing. To be noted that the LiDAR technology gives the time delay in nanoseconds whereas the lapse time calculated using the IR transmitter and receiver has the time delay in seconds difference.

Table 10.3 shows the comparison between the recent technologies and LiDAR technologies and why LiDAR technologies has an advantage over the other two technologies. An RFID tag is a microchip which is attached to the car to track the position of the vehicle. The tag picks 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 the fast-moving vehicle like race cars. From the given information it is known that the LiDAR technology has more advantages over the other technologies for detecting fast-moving objects like a racing car with less amount of time delay.

Figure 10.8 represents the comparison between the different technologies that is used in lapse calculation for racing. The time delay, the minimum time that the object should be present in the sensor range so that the sensor can track its present and accuracy of the object are represented in the chart given below. The Radio Frequency Identification (RFID) is the advanced technologies that use wireless transformation of data between the tag or car and a reader or device to automatically trach or identify the physical location of each object. The system's transmission range is restricted to a few meters from the reader and the tag should be in a clear line of sight.

Table 10.4 shows the sample set of values obtained while using this system. The date at which the event occurred, time, lapse count, start time of each lapse, end time

Table 10.3 Comparison between recent technologies and LiDAR technology

Features	Radio frequency identification (RFID)	IR transmitter and receiver	LiDAR technology
Reader range (m)	0–2	0–5	0–12
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

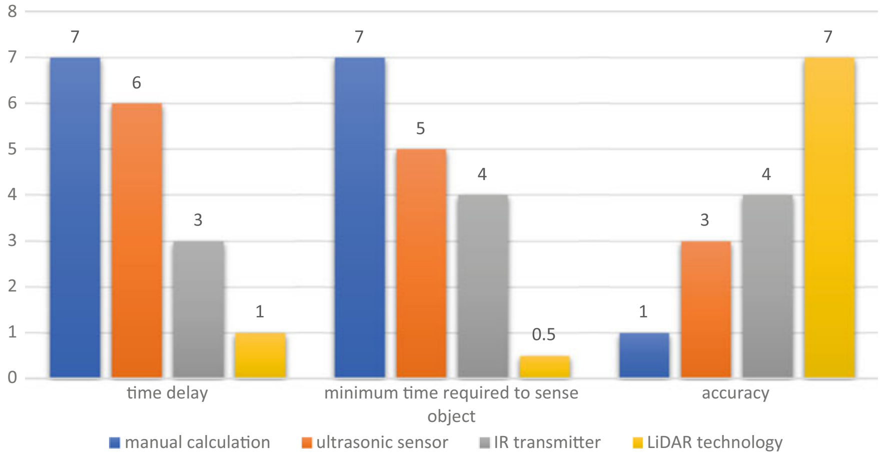


Fig. 10.8 Comparison between different technologies available in lapse calculation

Table 10.4 Information that was obtained with this 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

of each lapse, duration of each lapse, and the total race time was calculated with this system.

This system was tested against the fully automatic timing (FAT) system to check its accuracy and efficiency. Fully automatic timing (FAT) is a famous type of racing

Table 10.5 Accuracy of the system when compared against 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

timing system that helps to get the race results that are 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 a initiation signal, rather than manual initiation. In this the start signal is generated by the start sensor which is integrated with a gun which is used to start the race. The finish time must also be recorded electronically to remove any human error. The finish signal is generated by the ribbon or string. The sample readings that have been acquired in this system is shown in Table 10.5. The readings in the table shows that LiDAR technology can be accurate and it does not need any external activation system for initiation like FAT.

The common issue of difficulty in lapse calculation is directed in this paper in an efficient manner. This system enables uninterrupted monitoring and storing of race-related information. This data is displayed through LCD display for instant viewing. It is cost friendly, efficient, and accurate in terms of time measurements.

Conclusion

The proposed system was developed and hardware configuration was implemented. The laser beam-based LiDAR was suitably utilized in the developed system. The ATMEGA328 controller was used to access the LiDAR technology. The perfect triggering was performed to activate the LiDAR when racing element crossed the beam. The race car lapse cutting edge using laser beam had fabricated and tested. The results of this system were accurate and even nano seconds of differences can be calculated and this was compared with the precision model which is the fully automatic timing (FAT) system. There are no huge differences which states that the system is accurate. The data was also uploaded to cloud using internet of things (IOT). LiDAR technology has many advantages in racing sector where fast-moving objects can be detected effectively. The developed system can able to track the maximum of 12 M track width with maximum 10 ns computation.

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