JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

PERFORMANCE AND SAFETY ENHANCEMENT IN HIGH-SPEED VEHICLES

[1]Prof. Pratibha Joshi, [2]Kunal Patkar, [3]Anvesh Lokhande, [4]Manas Mendon, [5]Vignesh Marla

[1]Professor, [2]Student, [3]Student, [4]Student, [5]Student
[1]Department of Electronics and Telecommunication,
[1]SIES Graduate School of Technology, Navi Mumbai, India

Abstract : The main objective of the project is to improve the safety measures of vehicles and to enhance the performance of high-speed vehicles in various racing sporting events. The project includes concepts such as data acquisition of vehicles, live speed detection of competitors, and safety distance measurement. The DAQ system which is used here gives the user various readings such as temperature, distance, etc. For live speed detection of other vehicles, we have opted for cameras to click photos of cars around the user's car. Thus, by calculating the distance from the user's vehicle at different times we got a change in the speed of cars behind. This data is provided to the driver and it helps the driver to know what speed is required for maintaining the pole position in a race and to prevent accidents because of collisions.

The paper consists of systems that can be used to improve performance and security measures in vehicles. Also, it includes the detection of the speed of vehicles using OpenCV and Deep Learning. It also shows how this new way of implementation is better than the traditional way.

***IndexTerms* - Data Acquisition, Speed Detection of vehicle, Safety, Performance, Security, Deep Learning, Open CV.**

I. Introduction

F1 racing is getting more popular day by day and many companies are getting attracted to participate with their own designed vehicle, after spending a huge amount of money in manufacturing a vehicle, the driver's safety and performance play an important role. Our project is based on a real-time auto vehicle monitoring system. We have built a project which helps to improve and optimize the performance and safety of high-speed vehicles as well as help the driver to avoid any accidents/collisions. The basic need of this project is to keep the drivers updated about their surroundings and make sure that the driver has every information which is required for optimum performance as well as safety. Therefore, the project will not only increase the driver's safety but also reduce the accidents which may cause damage to the vehicles resulting in loss of money and, in some cases, loss of life.

Jackie Stewart, a three-time world champion, was instrumental in the fight for safety during some of Formula One's most hazardous seasons. She pushed for the use of full-face helmets and seatbelts as well as stronger barriers and qualified medical personnel. In more recent years, the deaths of Ayrton Senna and Roland Ratzenberger in 1994 and Jules Bianchi's eventual fatal incident in 2014 served as the catalysts for two major rounds of safety advances.

In Formula 1, a driver's helmet is still one of the most crucial pieces of safety gear. Since their initial release in 2001, carbon fiber helmets have undergone extensive impact and fire resistance testing. Modern headrest padding was first used in Formula One in 1996, and it serves to lessen the tremendous strain that the high g-force puts on drivers' heads and necks. During turning, F1 drivers can face lateral g-forces of up to 6G, thus even with headrests, they must build up their neck muscles significantly to withstand the stress. As technology develops, helmets become more impact-absorbing on the inside and more resistant on the outside. The late Professor Sid Watkins believed that the headrests, which are made of a material intended to help with impact absorption during a crash and to avoid whiplash, saved Jos Verstappen's life during an accident in the first year that F1 cars were equipped with the device. The Head and Neck Support (HANS) device, which has been required since 2003, restricts the head and neck's motion inside the vehicle to reduce the risk of harm in the event of a collision. The tool attaches to the driver's helmet and fastens it to the carbon fiber collar to stop the head from moving and the neck from hyperextending, which is a major cause of fatality in motorsports when it leads to a basal skull fracture. Although the HANS device wasn't immediately well received when it was originally introduced, it has since become a standard piece of gear in motorsport. In order to accurately measure the forces imposed on the driver, which is crucial following a collision, F1 drivers carry accelerometers in their earpieces. The ear was chosen as the non-invasive location for the device when it was first introduced in 2014 because it also exhibits the precise movements of the head during an impact. In order to see exactly what happens inside the cockpit following a crash, F1 cars starting in 2016 have been equipped with a camera facing the driver. Also, it provides a close-up view of the HANS device, headrest, and seatbelt in use, assisting with the assessment of any flaws.

The data acquisition system is one of the most important systems for a Formula Society of Automotive Engineers (FSAE) for monitoring and analyzing various systems and parameters of the car [1]. The DAQ system samples real-world signals using transducers and further conditions, the signal finally converting the conditioned signal to digital format for data handling by a computer and logging the data streams for analysis and storage. A DAQ system for motorsport applications should be rugged and capable of real-time performance.

With the rapid development of computer vision and artificial intelligence technologies, object detection algorithms based on deep learning have been widely investigated. Such algorithms can extract features automatically through machine learning; thus, they possess a powerful image abstraction ability and an automatic high-level feature representation capability [3][4].

The vehicles in use are increasing from year to year. It leads to more fuel/energy consumption, and more carbon dioxide or other exhaust gases are released into the environment. The emissions norms have become stricter than before. To adhere to such stringent requirements, some advanced technological solutions need to be developed to reduce fuel consumption and emissions from vehicles. The consumption of Fuel can be reduced if the energy wasted in the coolant or the exhaust gases will be reduced. The engine cooling system ensures that the engine works at its optimal temperature, which is around 80°C-90°C.[4]. These are the technologies that are already implemented but how the proposed system provides more efficiency will be reflected throughout this paper.

Literature Review

Formula One racing is a great spectator sport. It includes high-speed cars and with high speed comes high risks of not only critical injuries but also death. Overcoming the risk without losing the sport's essence is an important aspect; care should be taken to achieve these various strategies and techniques. The safety measures, driving strategies, safety equipment, and rules and regulations are responsible for the safety of the people on the track

The method proposed by A Banerjee, A V Jindal, A Shankar, V Sachdeva, and M Kanthi describes the design and working of a motorsport data acquisition, logging, live telemetry, and display system developed using the Controller Area Network (CAN) communication protocol as the backbone of the arrangement. The main controller of the CAN system is the myRIO which was programmed using LabVIEW. A Formula One car hosts over a hundred sensors during each of its races [2]. The data acquisition/logging system, although does not directly affect the car's performance, is indispensable when it comes to the testing and design phase of the car. Data acquired by the proposed system [2] helped in making sure that the car achieves the goals that were envisioned when it was designed. The data helps in ensuring that maximum performance is obtained without compromising the safety and reliability of the car in the project.

Object detection attracted the attention of the research industry lately. Researchers are trying to explore the topic to reach to an accepted accuracy level. Machine learning is used to detect objects. There are many techniques doing this job but in order to identify the best model among the suggested models, this thesis is going to explore the topic of how to detect the objects while at the same time comparing two suggested models and suggesting the best one which yields highest accuracy and performance as suggested by Sipan Masoud Mustafa. In this paper [5] the aim of this thesis was to develop two algorithms, SVM and Decision Tree to detect vehicles in images and videos. We have used the SVM technique only as a part of our project.

One of the main tasks in robotic vision is to find the position and orientation of the objects surrounding the robot in 3D space, relative to the reference frame. Determining the camera's tilt angle in a vertical plane and the object-to-camera distance (the distance between the camera and the objects) is essential for localizing, navigating, and performing some high-level task planning. There are two common methods to calculate the object-to-camera distance [1]: i) using the object's given size and the camera's focal length, and ii) using the height of the camera and the point of contact where the object meets the ground. Unlike in the first method, the dimension of the object in the second method is unknown as stated by Peyman Alizadeh. To calculate object distance for a moving object, the object must first be tracked by a camera. Object tracking can be classified into four main categories: model-based, appearance-based (region-based), feature-based, and contour-based methods. This technique has been used in our project for the detection of the vehicle approaching from behind using the single fixed camera method.[6]

Presently Implemented Systems

There are lots of systems and techniques which are prevailing in F1 racing nowadays. F1 cars are incorporated with various advanced sensors to Monitor and measure various aspects of car like Engine Temperature, Acceleration, fuel flow, pressure, G-Force etc. These readings from the sensors are stored and used in the analysis and enhancement of the vehicle for better performance. Also, during the race this telemetry data is transmitted from car to their respective pits, and after analyzing it engineers convey this data to drivers through an earpiece this process of transmitting data from car to pit and pit to car takes a few seconds thus based on this data drivers take live decisions in the race in order to improve or maintain their position and speed in race.

Proposed Systems to Overcome these problems

Many things are already implemented to improve the safety of the driver, there is still some scope for improvement which can further minimize the risk of vehicle mishaps. So, the proposed Data Acquisition Systems (DAQ) further enhance the driver's safety in many ways. Earlier the vehicle machinery monitoring and speed of different vehicles were tracked only by the pit members and it was later conveyed to the driver. So, with the help of Data Acquisition Systems (DAQ) [2] and Support Vector Regressor Model [6] F1 companies can cut off the loop and directly inform the driver about uneven temperature rise, speed of the vehicle behind, and many other features. Also, one of the main improvements in the system is cost reduction which is a very important factor in this expensive sport. Also, this enhanced system can help in temporary prevention or delay of accidents because of temperature increase by indicating to start the coolant in order to reduce the temperature of the engine.

Race Track Explanation

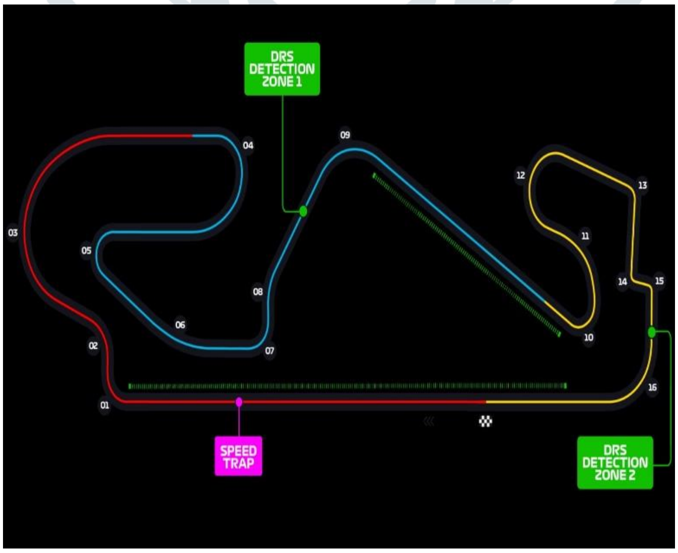

Fig. 1. Race Track

All the data recorded by the data logger at the time of the practice race can be analyzed and used for enhancing drivers' performance in the actual race.

As it can be seen the picture given above represents a race track that is divided into 16 parts. The patch from the start point and point number 1 is a straight path so the driver can drive the vehicle at its maximum speed and acceleration for improving his position but there is a turning patch from point 1 to point 2 where the driver needs to slow down his vehicle to ensure there is no collision with other vehicles and he takes a safe turn but with safety, he also needs to maintain his position so here data analytics plays an important role. The data collected from practice races can be used to calculate the maximum speed at that the driver can drive the vehicle at the turning point without any collision so that he can maintain or improve his rank.

This is how data can be used to enhance the vehicle's performance in a race by keeping drivers' safety as the number one priority.

II. METHODOLOGY

This section involves the working and understanding of the project model and also the methods to be followed for it implementation.

The use of a Hall effect sensor has been done to build a tachometer that displays the RPM of the wheel and the Speed of the vehicle. MLX90614 Non-Contact temperature sensors which work on the principle of infrared rays have been used to monitor the temperature of the Engine whose readings helped us to activate the feedback loop if the temperature exceeds the threshold. Accelerometer is interfaced in order to obtain the acceleration of the vehicle at different parts of the track to do further analysis to improve the vehicle's performance. G-Force and Gyroscope readings of vehicles are obtained using an accelerometer. DS3231 RTC module has been used to log data with real-time stamps. Data logger and SD card store all the readings from various sensors which are incorporated with Arduino [2]. All the real-time readings from the sensors and the speed and the distance between the vehicle approaching are displayed using Nextion intelligent display. A camera module is interfaced with Raspberry Pi to obtain video/photo of the vehicle which is approaching from behind this video/photo and undergoes image processing and machine learning algorithms in order to display the distance and speed of the approaching vehicle which is explained below in detail [4].

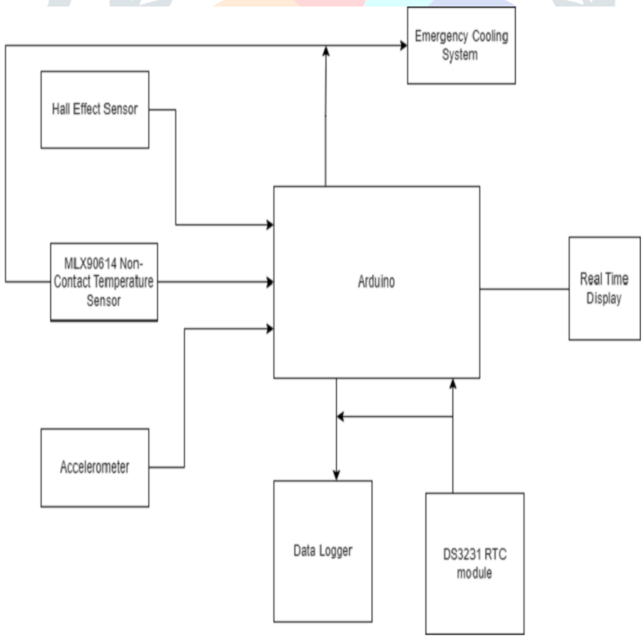

Fig. 2. Block Diagram of Arduino

So, UDM was used to measure the distance between our vehicle and the vehicle approaching from behind and by using Image Processing and OpenCV, the speed of the car was predicted. This was done by measuring distance at different times and getting the vehicle's speed. But the major problem we faced was not getting datasets for training the model as it included images of real-time racing vehicles and it was not possible and practical to collect those images at that stage. So, we created our own datasets by using a certain object. After capturing nearly 150 images of that object at different distances which will act as an approaching car. So, when these images were applied to the Image processing model, we received the width and height of the object at that particular distance.

So how does this object size algorithm work?

Before proceeding with the measurement, we need to find the object in space and obtain its coordinates. We used a for loop to extract the arrays with all points delimiting the identified objects. Not having perfect geometric shapes, we must reduce the delimitation of the object to a simple rectangle, as in this case. Now we have the coordinates of the object and thanks to the rectangle we can already show the dimensions in pixels. Still, by converting this measurement to centimeters we would not get real data because we need a reference on the dimensions.

For this purpose, we use Aruco Marker. It has the huge advantage of not having to calibrate the camera because we know it is an exact square of 5cm X 5cm. Beyond this OpenCV recognizes it and does not need complex operations for integration. The marker only needs to appear in the video along with the objects. Within the for loop relating to the contours of the objects, among other things, also two parameters h and w that correspond to the height and width are extracted. Like this, we applied image processing on nearly 100 images of that object and calculated the width and height of the object at that particular distance.

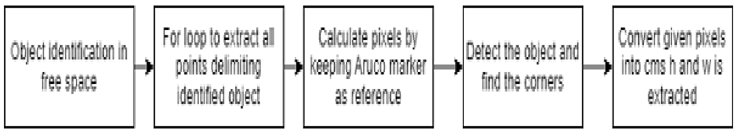

Fig. 3. Object Size Detection

Then we feed these datasets obtained to the support vector regressor as it gives us the highest accuracy of distance. SVR works on the principle of SVM with a few minor differences. Given data points, it tries to find the curve. But since it is a regression algorithm instead of using the curve as a decision boundary it uses the curve to find the match between the vector and position of the curve. Support Vectors help determine the closest match between the data points and the function used to represent them. After all this, we can feed any images of the object and get the distance for that object from the camera. Now we must calculate this distance at different time stamps and based on them we can calculate the relative speed of the approaching vehicle. In this way, the distance and speed of the approaching vehicle will be conveyed to the driver and thus will help the driver to improve his/her performance.

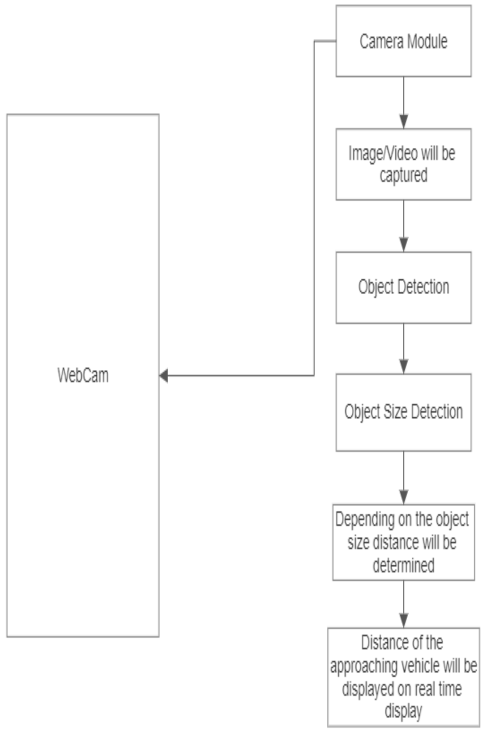

Fig. 4. Block Diagram of Distance Measurement

III. EXPERIMENT

In this section, the Experimentations performed are tried to be explained in detail.

A. DAQ.

So, for collecting the data from the vehicle, the DAQ system was used, which consists of various sensors for collection and monitoring different parameters of the vehicle. While interfacing the sensors with the microcontroller, we faced many problems, such as the data rate we were getting was not enough for analysis, so an advanced version of the microcontroller than the one we were using before was used, due to which the problem related to the data rate was solved, and, we were able to connect multiple sensors at a time due to the availability of extra pins in the microcontroller. After getting the required data rate, the next target was to save this data, which is data logging, so an SD card module was used by interfacing it with a microcontroller so that data could be logged that was collected by different sensors, but for better understanding and doing further analysis on the data, it is important to collect the data with a timestamp of every second. For example, the speed of the car at 12:32:12 is 54, and the temperature of our engine at the same time is 156°C, so for this, an RTC module was used, which is a clock for a microcontroller, which solved our issue related to the time stamp. After getting the data at a particular rate and logging it onto the SD card, the next target was to showcase the vehicles' real-time data to the driver, so for this, the Nextion touchscreen display was used. This display was used to show various vehicle parameters and warnings based on the sensor readings, but when it was interfaced with the microcontroller, the data rate at which the data was getting logged was reduced due to increased load on the microcontroller. After doing research on the internet and after some trial and error, we were successful in displaying the real-time data with a considerable amount of data rate.

B. Distance Measurements

So, we applied hundreds of images to the image processing model to get the size of the object in the given image. By using this method and support vector regression we found an optimum technique to find the distance of that object in that image. By using this technique, we can find the actual distance of the vehicle behind our vehicle. Also, we faced the problem that what we will do when images get cut down so we found a solution that will fix a threshold so that images don't get cut which means that we will bother the driver for a fixed distance of 50 inches to 8inches (According to our prototype.).

Also, the driver gets to know about the distance of the vehicle behind as well as many other data regarding his vehicle

C. Feedback Loop (For Engine Overheating)

The MLX90614 is a non-contact temperature sensor that uses the infrared (IR) radiation emitted by an object to measure its temperature without physical contact was used for measuring the temperature of the engine and the body temperature of the vehicle as this sensor has the dual capability of sensing the target body temperature and the surrounding temperature as well. It was integrated with the Data Acquisition System.

The aim of integrating the MLX90614 sensor was to make the driver aware of their engine temperature and have a feedback loop that can be useful in avoiding accidents. So, three cases were taken into consideration keeping a fixed value of temperature as the threshold.

Note - The threshold values used below are for demonstration purposes only. The values can be changed depending on the type of vehicle and engine.

Case 1 - When the temperature of the engine is between 0 to 34 degrees Celsius which is normal Temperature thus the message "Optimal temperature engine running smoothly" will be shown on the display.

Case 2 - When the vehicle starts competing in the race the engine temperature will start rising exponentially so if the temperature is between 34 to 100 Celsius, a message will be displayed as "Temperature above optimal range". So that the driver is aware that the temperature is rising rapidly this temperature is also considered as normal Temperature for the engine to run smoothly as an engine of any vehicle emits enormous heat while working.

Case 3 - As the temperature is rapidly increasing it will be controlled by a liquid or air coolant system installed around the engine to stop the engine from overheating but if the engine starts going above the normal threshold which is above 100 in our case, a message will be displayed to alert the driver regarding the abnormal behavior of the engine which is as follows "!!!Alert, Engine temperature increasing rapidly, slow down or stop the vehicle!!!.

CO-EXISTENCE WITH REAL SYSTEM

The system developed with respect to the paper plays a very crucial role in drivers' safety and performance. The wide variety of sensors provide different information at the same time to the driver themselves which drastically reduces the manual errors or communication problems from the engineer's side present in the pits during the races. Also, the system used is comparatively of very lower prices as compared to that of the present system which also helps the teams to invest their money in other different sectors too. Also, the dependency of drivers on their team's response will also get reduced. Even with such advantages, this study has a huge scope for improvement ahead. High-speed processors can be used so that data can get transmitted at a much higher speed. High qualities cameras and speed detection of the approaching vehicle can be introduced to this system.

The system can be used while testing or monitoring New Vehicles/Machines. Data collected from previous races can be used for analyzing and optimizing drivers' and vehicles' performance in upcoming races. The aim is to prioritize drivers' safety without compromising their chances of victory. In F1 racing this system can be used to know the position of the approaching vehicle from behind. This will help the driver avoid any possible collisions by increasing the speed or having an idea about the lane of the approaching vehicle.

Present-day industries use highly expensive and Hi-tech machines. Any damage to these machines can cost the companies a hefty sum of money and may lead to fatalities and accidents. Any such damage may also affect the quality of the product the company is manufacturing. Hence to avoid such complexities this system can be used for monitoring the conditions of various machines and robots in factories, industries, etc. The advancement of data acquisition and processing techniques should be the key to facilitating the development of biology and medicine.

IV. LIMITATIONS

All the problems faced and limitations are mentioned in this section below.

One of the limitations of the work is that as it is based on a real-time high-speed vehicle application, the datasets needed for the work were the images of real cars on the F1 field which is not possible at this level. So, the use of a normal toy car as a dataset was done, and thus performed the SVR model on these datasets.

Some problems were faced while transferring the value of distance to the display connected to Arduino. Earlier it was expected to send these distance values to Arduino from Raspberry Pi using serial communication. But because of the failure in implementing Raspberry Pi, that data was transfer was not possible.

Code and the systems need a very high-speed processor as the application in hand is a high-speed application. But because of cost restrictions, it was not possible to execute the work at that high speed, and thus image processing is applied on frames at fixed regular intervals.

V. RESULTS

As the work is segregated into two parts; the first is a Data Acquisition system & second is image processing the first part which consists of various sensors which are interfaced with a microprocessor like a Hall effect sensor to measure the Rpm of the vehicle. A Hall effect sensor is a type of transducer that uses the Hall effect to measure magnetic fields. It typically consists of a thin semiconductor material, such as gallium arsenide (GaAs) or indium antimonide (InSb), that is attached to a conducting material to form a Hall element. When a magnetic field is applied perpendicular to the Hall element and a current is passed through it, the Hall effect generates a voltage across the element, known as the Hall voltage, which can be measured to determine the strength and polarity of the magnetic field and using this readings speed of the vehicle is calculated and displayed on the real-time display installed on the dashboard of the vehicle.

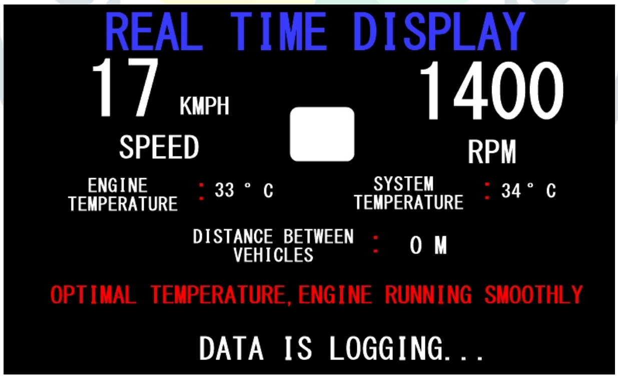

Fig. 5. Desired Result on Nextion Display

The MLX90614 is a non-contact temperature sensor that uses the infrared (IR) radiation emitted by an object to measure its temperature without physical contact. It is used for measuring the temperature of the engine and the body temperature of the vehicle as this sensor has the dual capability of sensing the target body temperature and the surrounding temperature as well.

As per Fig. (4.1) these readings will be used for safety purposes as the temperature is segregated into three different thresholds depending on the behavior of engine temperature.

Case 1 - When the temperature of the engine is between 0 to 34 degree Celsius which is normal Temperature thus the message "Optimal temperature engine running smoothly" will be shown on the display. This is shown in Fig. (4.2)

Fig. 6. Message (Optimal temperature engine running smoothly)

Case 2 - When the vehicle starts competing in the race the engine temperature will start rising exponentially so if the temperature is between 34 to 100 Celsius, message will be displayed as "Temperature above optimal range" as shown in Fig. (4.3). So that the driver is aware that the temperature is rising rapidly this temperature is also considered as normal Temperature for engine to run smoothly as engine of any vehicle emits enormous heat while working.

Fig. 7. Message (Temperature above optimal range)

Case 3 - As the temperature is rapidly increasing it will be controlled by a liquid or air coolant system installed around the engine to stop the engine from overheating but if the engine starts going above the normal threshold which is above 100 in our case shown in Fig. (4.4), a message will be displayed to alert the driver regarding the abnormal behavior of the engine which is as follows "!!!Alert, Engine temperature increasing rapidly, slow down or stop the vehicle!!!.

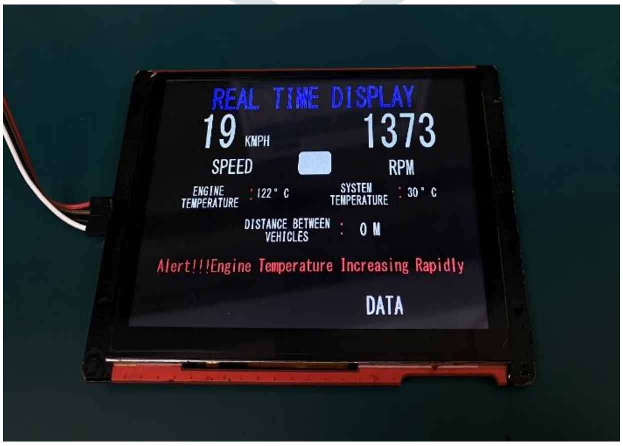

Fig. 8. Message (!!!Alert, Engine temperature increasing rapidly, slow down or stop the vehicle!!!)

Note - The threshold values used above are for demonstration purposes only original values depend upon the type of vehicle and engine.

Accelerometer MPU6050 is a device that measures acceleration, which is the rate of change of velocity with respect to time. Accelerometers are commonly used for various purposes such as Motion sensing, Navigation, and positioning, Structural health monitoring which is essential for performance analysis of vehicles it helps data scientist to study various behavior of vehicles on different parts of the track, and with the help of this analysis, they can use the vehicle at it best for performance enhancement.

All the data from various sensors will be logged into an SD card or a data logger which is also known as a data recorder or data acquisition system, which is a device or instrument that collects and records data from various sensors or sources over time. Data loggers are widely used in various applications to capture, store, and analyze data for research, monitoring, and analysis purposes.

The second part of the work involves image processing operations on multiple image frames captured by the camera.

So, with the help of this function initially multiple image frames are getting captured of the object or the vehicle that is been approaching from behind. Then these frames are processed through a support vector regression model in order to get the height and width of the object in the given image and based on that the distance is been estimated these distances can be displayed on the serial monitor or as well as can be extracted in an excel sheet and can be further sent to the display which is connected to the microcontroller.

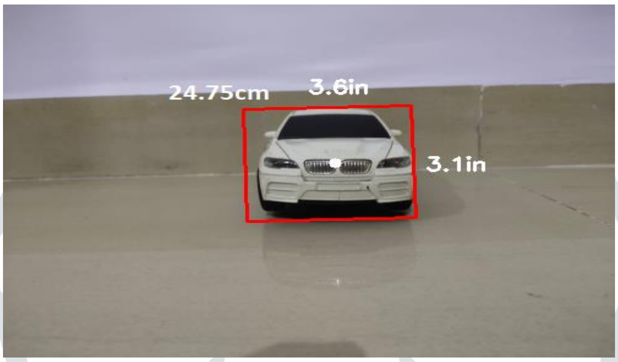

Fig. 9. Output of Object Size Detection

VI. CONCLUSIONS

In this paper, detailed information about how to improve the vehicle's safety measures and how to enhance the vehicle's performance is given. It includes concepts of Data Acquisition Systems, Image Processing, Data Logging, Machine Learning, WebCam, and Live Speed detection in order to complete these objectives. Also, through the work, a cheaper and more reliable alternative to the existing system of High-Speed Vehicles is tried to be provided which also reduces the delay of this process and directly informs the drivers about various details of the race.

REFERENCES

[1] Mateus Eloi, Vitor Yeso Freitas, Richardson Menezes, Helton Maia Peixoto. "Vehicle Speed Detection and Safety Distance Estimation Using Aerial Images of Brazilian Highways."https://www.researchgate.net/publication/344447322_Vehicle_Speed_Detection_and_Safety_Distance_Estimation_Using_Aerial_Images_of_Brazilian_Highways.

[2] A Banerjee, A V Jindal, A Shankar, V Sachdeva , M Kanthi. "Motorsport Data Acquisition System and Live Telemetry using FPGA based CAN controller." https://iopscience.iop.org/article/10.1088/1742-6596/2161/1/012041/pdf

[3] Mallikarjun Anandhalli, Vishwanath P.Baligar. "A novel approach in real-tim[2] A Banerjee, A V Jindal, A Shankar, V Sachdeva , M Kanthi. "Motorsport Data Acquisition System and Live Telemetry using FPGA based CAN controller." https://iopscience.iop.org/article/10.1088/1742-6596/2161/1/012041/pdf e vehicle detection and tracking using RaspberryPi.

[4] Shubham R. Ugle, Shweta D. Kate, Dhananjay R. Dolas. "Formula One Safety: A Review." https://www.IRJET-V2I766.pdf

[5] Sipan Masoud Mustafa. "Vehicle detection and tracking using Machine Learning techniques." http://docs.neu.edu.tr/library/6812355026.pdf

[6] Peyman Alizadeh. "Object Distance Measurement Using a Single Camera for Robotic Applications." https://zone.biblio.laurentian.ca/bitstream/10219/2458/1/Peyman%20Alizadeh%20MSc.%20Thesis%20Corrected_2_2.pdf