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SMART TECHNIQUE FOR EV DETECTION BASED ON THERMAL CHARACTERISTICS

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Abstract **-** The key objective of this project is to develop a User Interface (UI) product that can scan the thermal images of the vehicles, acquire their thermal characteristics and compare the thermal characteristics of vehicles' exteriors to detect and classify which types of vehicles these are. Based on thermal parameters and applying signal processing we will detect and classify Electric and Conventional Vehicles. Collection of vehicles data is important for traffic management, smart city implementation, giving a concession of free parking and toll to electric vehicles. As compared to any conventional methods thermal cameras give the better result of detection and recognition. For achieving this aim, we will be using embedded hardware and software for real-time image signal processing of thermal data and extracting the thermal characteristics as per the requirements. With the help of image processing techniques and algorithms, we could classify conventional and Electric vehicles using their thermal signature.

Index Terms **- Thermal signature, Vehicle Detection, Intelligent Transport Systems, embedded hardware and software, interpolation, front-end sensor, inter-integrated circuit, embedded system, smart city feature, histogram, user interface**.

I. INTRODUCTION

Recently, issues like congestion, traffic accidents, and air pollution increased due to the rapid increase in combustion vehicles. Many countries are now implementing Intelligent Transportation Systems (ITS) to classify and detect vehicles for combating and controlling the increase in combustion vehicles. There are various approaches that are employed to detect vehicles. These approaches are the use of infrared cameras, visible spectrum video cameras, vibration sensors, acoustic sensors, etc. In recent past decades, surveillance cameras were largely utilized for monitoring traffic on roadways. For fulfilling the smart city mission, it is required to detect and categorize vehicles types as per their emissions standards. This is required for giving concession in tollway, providing special track and parking for E-Vehicles. Conventional approaches lack accuracy during bad weather, But Infrared thermal cameras have the almost same accuracy in all weather conditions. Infrared videos and images of vehicles are able to give real-time detection of vehicles.

Yun-cheol Nam and Yunyoung Nam proposed classification and detection of vehicles based on images captured in thermal and visible light cameras in the 2018 EURASIP Journal on Image and Video Processing. These approaches could be utilized for continuous smart surveillance purposes. In these methods grille areas and headlight areas were extracted from IR thermal and visual light images, then the extracted images were used for detecting and classifying vehicles. They validated these methods experimentally and achieved 92.7% accuracy in visible image classifier and 65.8% accuracy thermal image classifier.

In 2016, Mahendra R. Bhutiyani, Lokesh K. Sinha and Asheesh Kumar Gautam proposed a novel method for the detection of armored Vehicles in Airborne thermal imagery by the use of morphological processing and extraction of texture feature in De Gruyter, published online on 21 April. They proposed an algorithm that could detect tanks in higher and lower resolution imagery. Thermal image segmentation using mean shift was the basis of the algorithm, that could detect possible targets in the field other than the background. A pre-processing morphological algorithm was applied to minimize uneven illumination and clutter in the thermal images.

In 2015, Yoichiro Iwasaki, Masato Misumi, Toshiyuki Nakamiya proposed Real-time Detection of Vehicles Using an IR Thermal Camera under diverse atmospheric conditions for Traffic Surveillance. They advocated two methods of detection by utilizing thermal IR camera images. The 1st method utilized pattern recognition to detect vehicles for the windshields and their surroundings and this method decreases accuracy in winter. The 2nd method utilized thermal energy reflection from tire areas to detect targets and this method had high accuracy for two center-lane but low accuracy for vehicles on sides. By combining both methods 92.1% accuracy could be achieved.

Miroslav Ruzicka, David Svorc, and Tomas Tichy advocated a technique to detect and classify electric and combustion vehicles by utilizing their thermal properties in 2020, the Smart Cities Symposium Prague. In this technique, thermal signatures of both types of vehicles were taken and compared for identification of vehicles type.

II. CURRENT DETECTION METHODS

In many countries, various techniques are currently in use to detect and classify Electric and combustion vehicles. These are:

1) Detection of Vehicles by using their acoustic signature
2) Detection of Vehicles by using their dynamic behaviours
3) Detection of Vehicles by using their electromagnetic emissions
4) Detection of Vehicles by using radar sensors
5) Detection of conventional Vehicle by infrared analyzer for detecting emission components.
6) Detection of Vehicles by the combination of Visual camera and thermal camera.

III. PROPOSED METHOD FOR DETECTION

In this project, a new way of detection of E-vehicles (EV) and Combustion Vehicles is proposed. Here we utilize the benefits of an IR thermal sensor to assess temperature patterns of exteriors of vehicles to generate the algorithm for identification of the E-vehicles and combustion vehicles in traffic.

3.1 Working Principle

When an object is heated above absolute zero temperature, it emits infrared electromagnetic radiation. The radiated infrared frequency is proportional to the temperature of the body. The infrared camera/ sensor senses the temperature based on radiated electromagnetic infrared frequency. Every vehicle generates heat during its operation. Even electric vehicle also generates heat but very little as compared to combustion vehicles. The heat generated in the engine or wheel easily spread through its metallic body and heat is emitted from all over the body. Areas that are directly in contact with the engine become more heated as compared to areas that are not directly in contact with the engine. So, areas such as mask, grille area, hood are heated more as compared to other areas. This is the basic concept which paves the way to use thermal characteristics of vehicles to detect and classify vehicles. Electric engines (motors) are likely to generate heat which is much less than that generated with combustion engines. The region particularly of the right bumper above the front wheel and grille area is the region of interest of examination.

3.2 Constructions

3.2.1 Hardware Requirements

Table.1. Hardware Requirements

SI.NO	Minimum Hardware Requirements
1	PC features: Processor – Intel i3 minimum RAM – 4 GB Hard disk – 100 GB Monitor Screen Size – 14 Inch
2	Melexis MLX90640 Sensor
3	ESP32 Micro-Controller Unit
4	ILI9341 LCD Controller with LCD (Optional for additional display)

3.2.2 Software Requirements

Table.2. Software requirements

SI.NO	Software Requirements
1	MATLAB 2016 or Higher Version
2	GUI toolbox
3	Image Processing Tool Box
4	OS – WINDOWS 7 or Higher Version

3.3 Black diagram and Descriptions

Below shown is the setup for the front-end hardware to acquire thermal data.

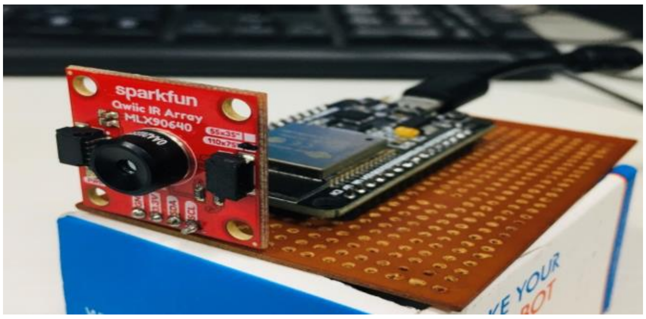


Figure 1: Front-End Hardware Setup

For detecting E-Vehicles and combustion vehicles we used embedded hardware and software for real-time image signal processing of thermal data and extracting the thermal characteristics as per the requirements. We further applied image processing techniques and algorithms for the classification and detection of vehicles.

Here we used the Melexis MLX90640 IR camera Sensor as the front-end sensor to take the real-time IR images. The output of this thermal camera produced 32x24 pixels IR array data which contains 768 FIR pixels. Each pixel contains the thermal signature as data in the range of -40°C to+300°C. We also used IR sensor AMG8833 (8x8 pixel) and FLIR Lepton 3.5 (160x120 pixel) for comparing the result. Below shown is the Melexis MLX90640 Sensor.

Figure.2. Melexis MLX 90640 IR Sensor

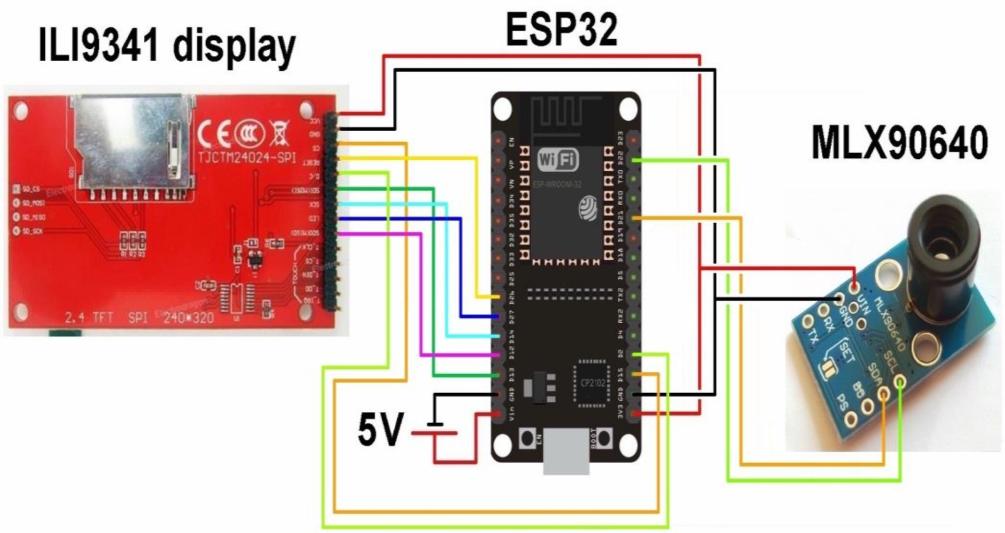
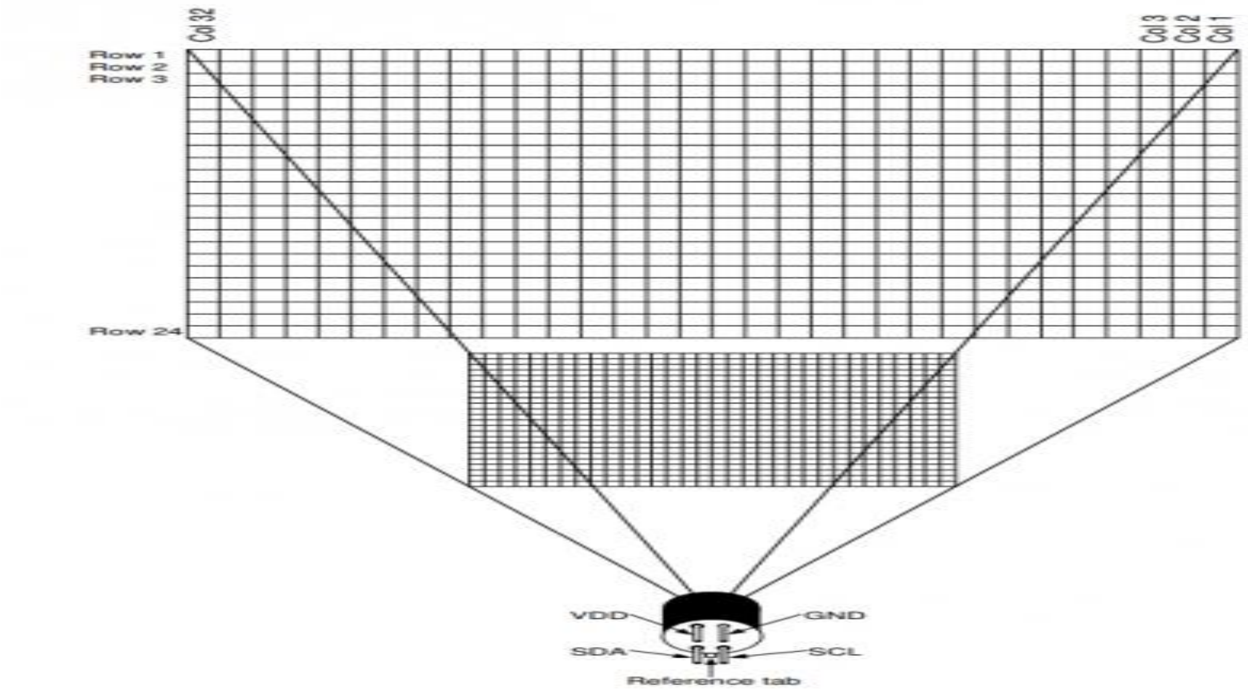


Fig.3. Embedded System Setup

Melexis MLX90640 comprises 768 IR sensors (also known as pixels). Every single pixel is recognized with its rows and column location as Pix [i,j] where "i" is the row position from 1 to 24 and "j" is its column position from 1 to 32. The below figure illustrates the pixel position of the Melexis MLX90640 sensor.



Figurce.4. Pixel position of the sensor

Through the I^2C communication using an ESP-32 Micro Controller Unit (MCU), the retrieved serial data was made in a suitable parallel format which was required by the PC or Laptop. The signal processing aspects like noise reduction, interpolation of the image/ data, thermal calibration of data with respect to the surroundings, and averaging were developed using a toolbox available in MATLAB. The post-processed filtered and conditioned image data were further analyzed with the help of the image processing method and using the suitable algorithm we successfully detected E-Vehicles and Combustion vehicles. For display, we could also use an (optional) ILI9341 LCD controller with low-cost LCD in parallel with PC or Laptop for conforming taking of complete image of the vehicle before capturing it.

IV. RESULT AND ANALYSIS

We developed an interface for communication between the embedded microcontroller and the PC. Once the thermal captured data was fetched into the microcontroller, the user could visualize or debug the data through a serial port via COM port in the terminal from the PC end. This was achieved with the UART Communication protocol, which is the common standard interface between an embedded platform and a desktop computer/ PC. To Establish a UART interface, it is required to set some parameters such as baud rate, parity, etc on either side i.e., the transmitter and the receiver. Here microcontroller is a transmitter and the Desktop/PC is the receiver. The microcontroller is sending the PC the real-time thermal data serially. In our design, we set the baud rate at 115200 bits/seconds. The COM port varies from one USB port to another USB port and PC to PC. Hence it is always advised to figure out the correct port number from the device manager in Windows OS PC/ Desktop. If the configuration is correctly set, one will be able to see the real-time serial data in the terminal port.

For better result, we carried out test after at least 30 minutes running of engine in normal road and images were taken from side and front. In order to extract the thermal data from the IR camera, a suitable micro-controller (ESP32 by espressif system) was used. A Standard digital protocol was followed for establishing proper handshaking between micro-controller and IR camera and an interface with which camera sensor data could completely be uploaded into the microcontroller memory. In the normal mode of operation real-time measurements were constantly running and through I^2C interfacing, the micro-controller was able to configure the IR sensor parameter such as to select frame rate fps (frames per second) in the control register, and accordingly, it updated the IR pixels data and Time in RAM each 1/Fps seconds. Camera data were read and stored in the resistors in MCU. Here frame rate could be taken between 0 to 32 Hz. Out of two FOV (Field of View) 55°x 35° and 110° x 75°, one could be selected. For our project, we took 2Hz (frames per second) as the sampling rate. For camera resolution, we took 18 bits resolution. We used the Tera-term terminal to view received data in CSV files (Excel file).

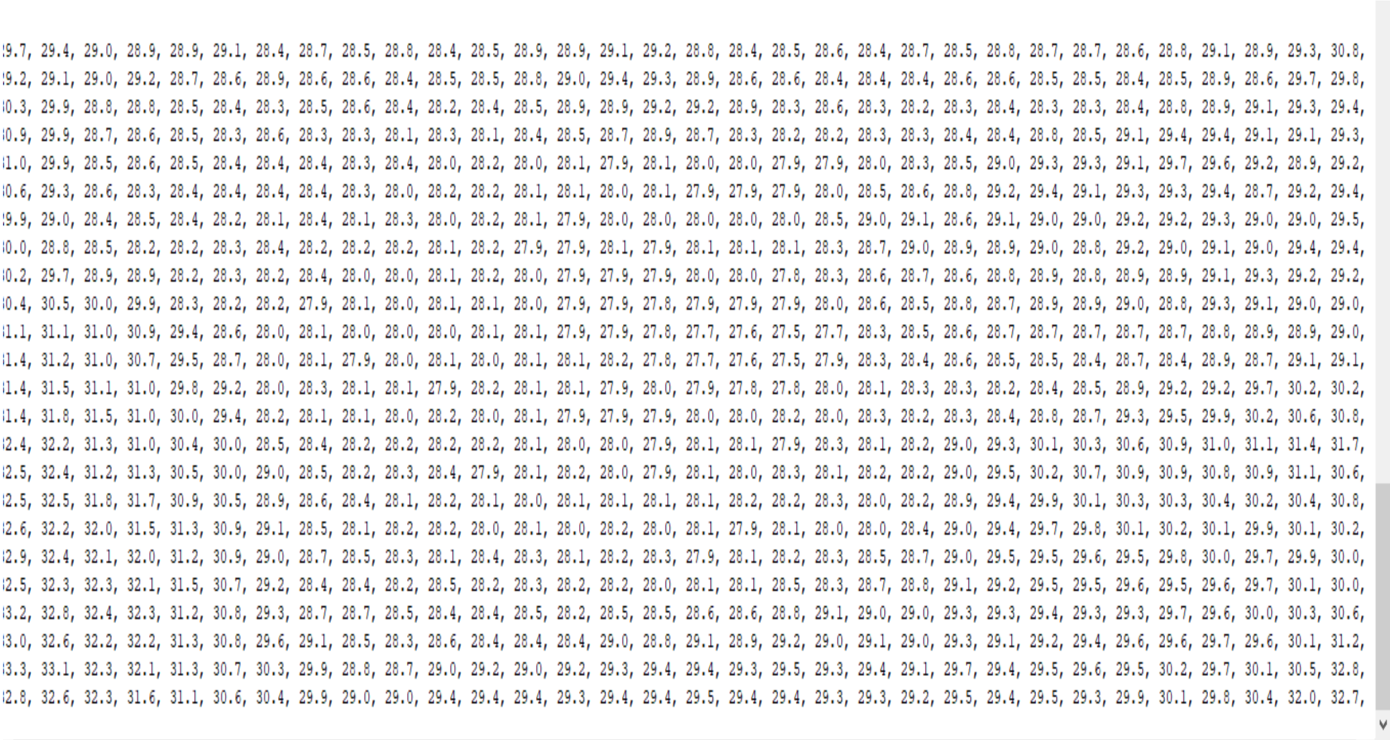


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Fig.5. One frame of MLX90640 IR sensor in Tera-term terminal

Using MATLAB, we produced raw images and 3D images from CSV file data. Again, these raw images and 3D images were converted to smoothen raw images and smoothen 3D images using MATLAB for a better quality of images. We interpolated these smoothened images to get better clarity images.

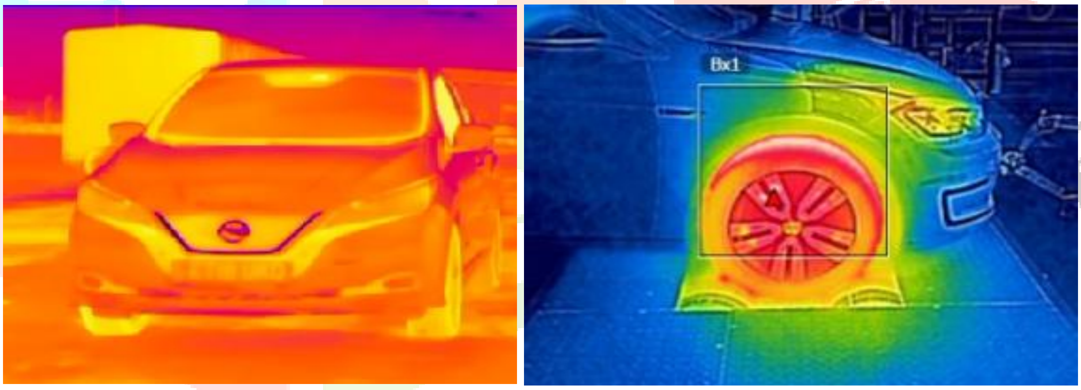

Fig.6. Typical front view and side view of Electric vehicle

Fig.7. Typical front view and side view of Combustion vehicle

Now we converted these temperature data into histograms. We took histograms for temperature data for all three IR sensors. It was found that histograms of front images of all electric vehicles taken in all three IR sensors were approximately identical in shape and follow Gaussian curve and histograms of front images of all combustion vehicles taken in all three IR sensors were approximately identical in shape and don't follow Gaussian curve and having a larger number of temperature intensities.

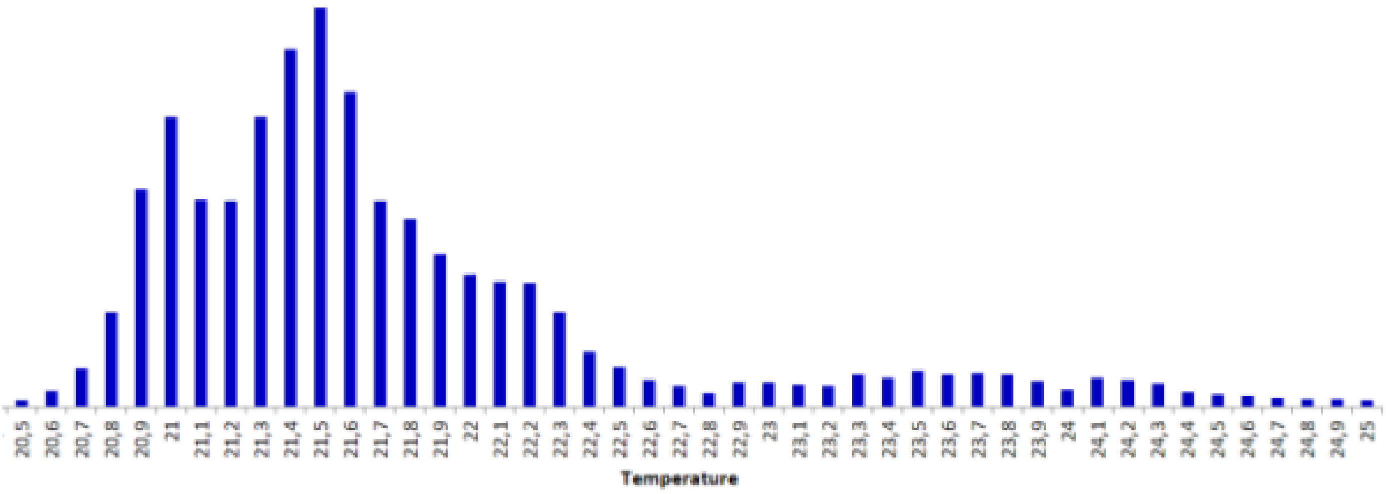

Fig.8. Typical histogram of interpolated thermal data of Electric vehicle

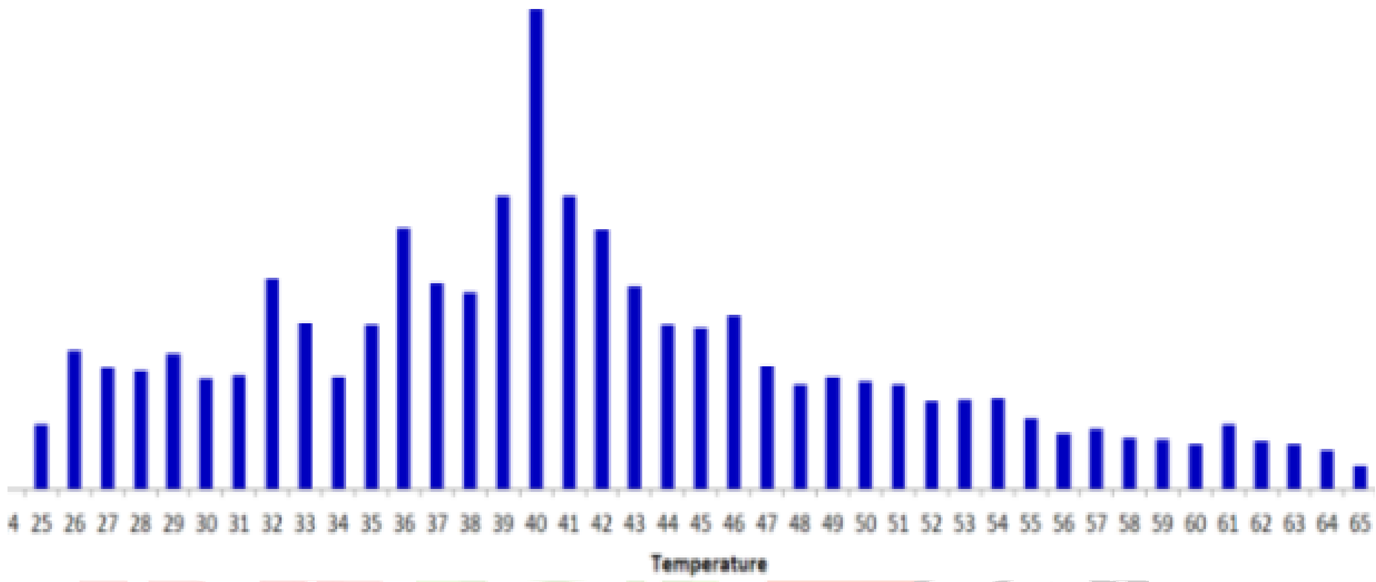

Fig.9.Typical histogram of interpolated thermal data of Combustion Vehicle

The following results were found from the tests and it was concluded that

1). Temperature patter of both electric vehicles and combustion Vehicles are different.

2) Emitted temperature ranges were different. In the case of Combustion Vehicles, temperature more than 40° above the atmosphere is observed in a larger area whereas in the case of Electric vehicles, temperature more than 20° above the atmosphere is observed in a small area.

3) Area of maximum temperature emitted are different in both vehicles. In the case of Combustion vehicles, the front grille area and the hood or bonnet areas were the affected areas. In the case of Electric vehicles, wheel areas were affected areas due to friction with road and brake disks.

4) Average temperature found from histograms shows that in the case of electric vehicles average temperature is less than 5° above atmospheric temperature, whereas in the case of combustion vehicles average temperature of the vehicle is more than 10° above atmospheric temperature.

5) Histograms of E-Vehicles followed the Gauss Curve whereas, histograms of Combustion vehicles did not follow the Gauss curve and had a large number of irregular temperature intensities.

These were the results to confirm whether the vehicle was an Electric or a Combustion vehicle.

V. CONCLUSIONS

This approach shows reliable methods to detect electric vehicles. The reliability of detection depends on the pixels values of the IR sensor used. Higher the pixel value higher the accuracy of reliable detection. It is also possible to detect Electric vehicles in all weather conditions without compromising the accuracy of results. This approach can be successfully employed in the implementation of Smart city features.

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