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High-Resolution Fuel Monitoring System using Machine Vision for Motorbikes

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Abstract A motorbike has a coarse fuel level indicator (with five to six levels), which might prove to be risky, as the motorbike rider may not be aware of the actual level of fuel left in the tank. Due to this, he or she might get stranded at a place far away from the nearest petrol station. To solve this major issue, there are facilities such as a reserve petrol tank in the bikes too. In developing countries, motorbikes are used by lower or middle-income individuals. As a result, some people are hesitant to fill the petrol tank even after it reaches the reserve level. There are chances that such riders may fail to predict the last level of petrol in their tanks and get stuck in a position wherein they need to tow their bike. To solve this issue, we have proposed a system that uses image processing techniques to keep the rider informed about precise fuel status up to 0.1 liters. Our system captures images with the help of a 5-megapixel camera and further processes them to estimate distance with accuracy in meters per ml. Also, a voice alert (using text to speech) is generated in case of a sudden drop in the fuel level. These drops can occur due to leakage or theft of fuel. We could achieve accuracy up to 94.87 % in the prediction of KM per liter of fuel. The potentiality of the system to work on a real-time basis makes it more deployable on the motorbike. The proposed high-resolution level measurement system is portable and can even be used for the detection of other liquids such as oil, water, etc.

Keywords Motorbike fuel monitoring · Raspberry Pi · Image processing · High-Resolution fuel monitoring

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1 Introduction

Our system particularly targets motorcycles as they most often have a vague bar representation of fuel levels in the tank. The use of motorcycles is high in middle-class families and they suffer from fuel related problems many times. This scenario inspired us to develop a new and useful system for motorcycles to manage fuel use. The system can overcome the manual monitoring of fuel level. This may avoid the chances of inefficient results. In normal circumstances, when we go to the gas station to fill up our tank, we have no opportunity to determine whether or not what they state is true. It's possible that the fuel tank isn't filled to capacity. Due to the use of an analog gauge, it is difficult to detect the exact level of fuel in the tank [1]. The proposed system prevents the driver from getting into situations wherein he or she has to push the motorcycle due to assumed value of fuel. There are few systems available that deploy a digital meter using a floating sensor to detect the fuel level in the tank. In case of wobbling, the float sensor cannot produce an accurate result and can mislead the driver.

Usage of float sensors in the detection of fuel level is one of the popular techniques. The system consists of a sending unit and a gauge. A float sensor connected to a metal rod is placed inside the sending unit. It is resistive. The output that is the resistance varies with respect to the level of fuel. The gauge consists of a bimetallic strip that heats, curves, and moves the needle on the fuel gauge in case of high fuel level. On the other hand, in the case of low fuel level, the strip cools down and straightens, thus moving the needle down. This method has displayed low accuracy and high complexity [2]. Another fuel level indication system [3] included the use of ultrasonic and fluid level sensors along

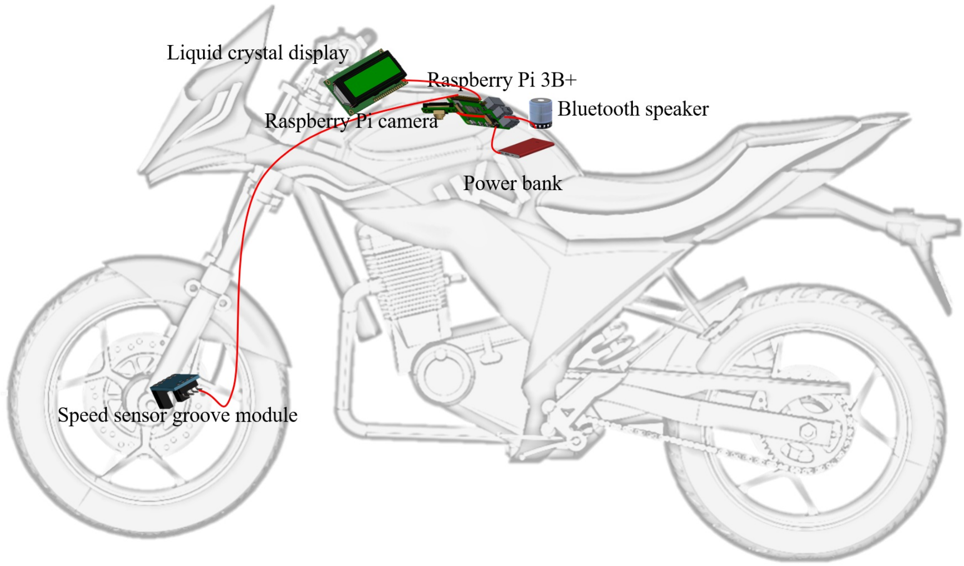

Fig. 1 Concept diagram of the proposed system. The system was powered with the help of a power bank. A Raspberry Pi camera was placed in such a way that it faced the fuel. Images captured were sent to Raspberry Pi 3B+ and processed. The speed sensor groove module kept a constant check on the rotations of the wheel. Desirable parameters were displayed on the liquid crystal display. The display was placed in front of the rider and alerts if any were generated using a Bluetooth speaker.

with web applications. These methods deployed a system which required a stable network connectivity.

Motorcycle fuel monitoring system is a portable system used to monitor the fuel. Due to its portability, the system can be easily installed on any motorcycle that runs on liquid fuel. As shown in figure 1 the implementation includes the setup of a small system. The liquid crystal display is placed in front of the rider so that it is well in the line of sight. The Raspberry Pi camera is placed so as to face the fuel. A speed sensor groove module monitored the rotations of the wheel. It is used to predict the distance covered by the motorcycle. The Bluetooth speaker was used to generate alerts in case the level of fuel goes below a threshold. The whole system was powered by a power bank. Our fuel monitoring system aims to counter the drawbacks of the above-mentioned technology and enhance the precision of the fuel indication system. Our system has the added advantage of also making the rider aware about the exact quantity of fuel that is being refilled at the petrol pumps thus eliminating the chances of being conned. The display of both the amount of fuel as well as the approximate distance that can be traveled with it proved to be advantageous to the rider. Additionally, our system can detect and alert the driver about any possible fuel leakage and hence ensuring the safety of the rider. A voice alert was also integrated which informed the rider about the remaining fuel and the distance that can be covered using that amount of fuel. This feature was activated when the fuel level went below the threshold value.

2 Literature Review

Divakar [2] elaborated and compared the conventional methods used in fuel level detection. One of the methods used consisted of a sending and gauge unit. The sending unit further consisted of a resistive float sensor, with a thin metal rod. The tip of the metal rod was attached to a variable resistor. The resistance and flow of current changed with the variations in fuel levels. A bimetallic strip was used in the gauge unit. The strip heated with the increase in fuel level and moved the needle on the fuel gauge. Low fuel level would lead to less generation of current which further cools and straightens the strip, thus moving the needle on the fuel gauge down. The fact that the float remains at the full stage even after a long time due to its limitation in movement makes this system inefficient. Another practice used for fuel detection was the usage of a microprocessor for monitoring the output of variable resistor, communicating with gauge unit, and then displaying the amount of fuel. Divakar suggested the utilization of capacitive level sensing technology. This technique used two conducting electrodes. The gap between these electrodes was fixed. The fuel level was measured by the capacitance between the electrodes which was in turn directly proportional to the dielectric constant. The rise

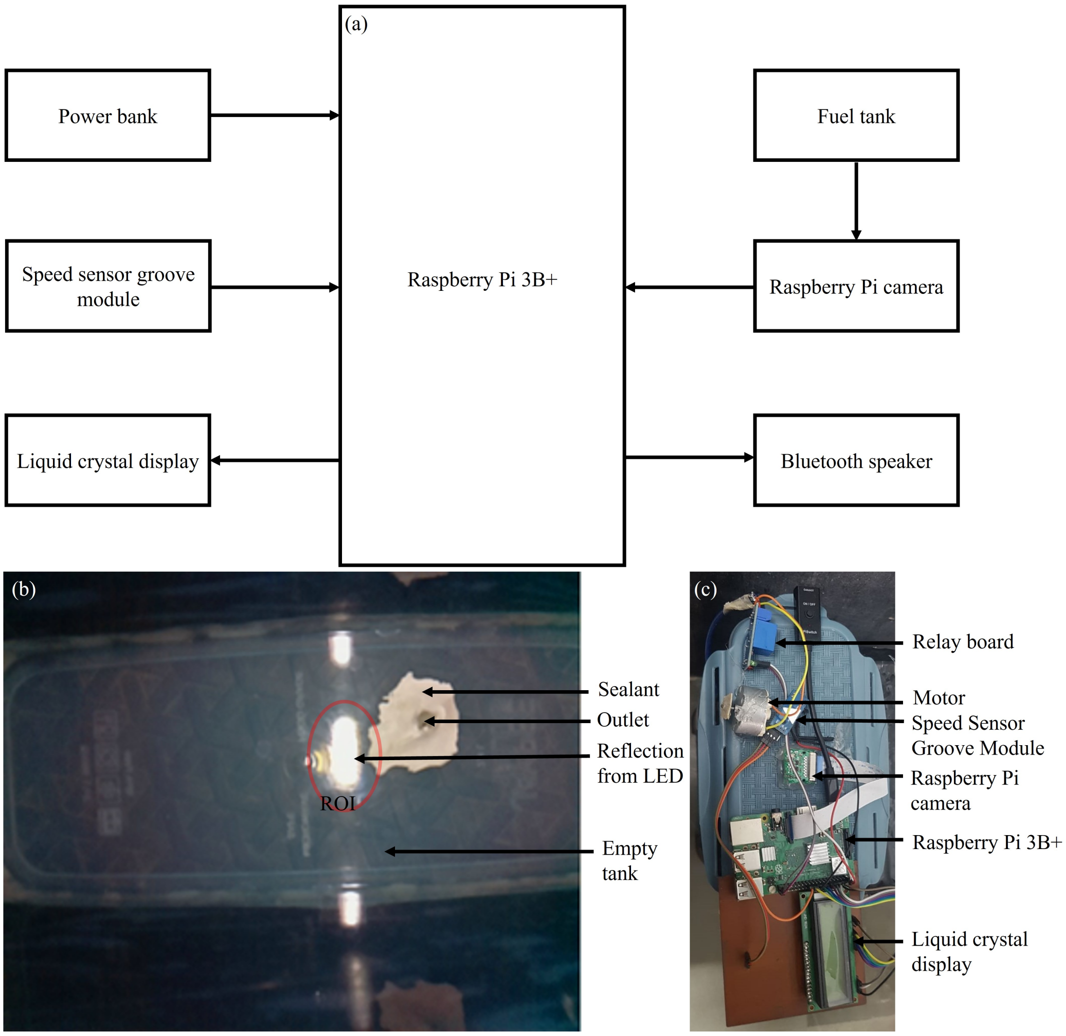

Fig. 2 (a) Figure showing the block diagram of the proposed system. Inputs were fed into the Raspberry Pi 3B+ through the speed sensor groove module as well as the Raspberry Pi camera. Images of the fuel tank were captured by the Raspberry Pi camera and sent to the Raspberry Pi 3B+ for further processing. The speed sensor groove module LM393 was used to keep a track of the rotation of the wheel for the calculation of distance. The central unit of the system that is the Raspberry Pi processed the inputs to display the remaining amount of fuel and the distance that can be traveled. The results were displayed on the 16X2 liquid crystal display and alerts were generated using the Bluetooth speaker.(b) The figure shows the real image of a tank. A reflection of the LED light can be seen in the image. The reflection is treated as the region of interest. In order to show the consumption of fuel, a outlet was created which was sealed from the side to avoid excessive leakage of water. (c) The figure shows the system implementationon the top of the tank. It consists of a LCD, Raspberry Pi 3B+, Raspberry Pi camera, speed sensor groove module, motor to show the rotations of the wheel and a relay module to drive the motor.

in fuel level led to an increase in capacitance. The accuracy of this system was moderate.

From the last few decades, immersed work has been done in the field of fuel level analysis to avoid fuel theft and fraud. The rates are increasing day by day so it is becoming important to save fuel and stop its theft. To avoid fuel fraud, Ali *et al.* [4] invented a innovative technique. In this technique, they designed and implemented an automatic fuel monitoring, tracking, and theft detection system. The system was implemented with the help of a fuel level circuit, GPS, and GSM module. The system was executed with the help of an Arduino module which was connected to an ultrasonic sensor that sensed the waves that came back after hitting the surface of the fuel. The readings of detected fuel levels and location of the vehicle were sent to the owner's mobile using a GSM and GPS network respectively. The software part of this system comprised of LabVIEW which stored certain features such as vehicle plate number, total volume of the tank, remaining amount of fuel in the tank, and many more. This system utilized a mixture of networks but at the same time lacked vision in case of failure in connectivity. In remote areas where connectivity is low, this system may cause issues.

Raja *et al.* [3] developed a system that deployed a wireless network with GPS so that the owner is aware of the location of the vehicle. A float sensor was used to detect the level of fuel. In addition to this, GSM was deployed which sent SMS alerts once the fuel tank is opened along with the time details. The system was authenticated with the help of a password that was known to the driver and owner only.

Vignesh *et al.* [5] had developed a digital fuel level indicator using two flow sensors and an Arduino. The flow sensors were placed linearly. The first flow sensor was used to measure the amount of fuel entering the tank while the second one was connected to the Arduino UNO. The data was actively stored in the dynamic memory of Arduino and displayed on the LCD. A solenoid valve acted as a carburetor that controlled the flow of fuel. In the case of low fuel, the rider was informed about the same. When the fuel level entered the critical state, the alarm was activated.

Walleback [6] used a Kalman filter for fuel level estimation in heavy vehicles. The fuel level was detected using a Kalman filter which proved to be disadvantageous in terms of memory allocation, response time, and the number of inputs required.

A real-time fuel mileage indicator for motorbikes along with the driver's information was developed by Varghese *et al.* [7] which was cost-effective. The system consisted of a flow meter that was responsible for the connection between the fuel tank and the engine. A control unit was also deployed which included a speed sensor module that recorded the distance traveled. The results were displayed on an LCD screen. The testing phase included driving the motorbike at various speeds ranging from 10 km/hr to 70 km/hr. The mileage was recorded at single and double load conditions too.

3 Methodology

3.1 Components and equipments

The Raspberry Pi kit that included Raspberry Pi 3B+, its casing, and power supply was ordered from an online platform. A power bank of 10000 mAh was used. The power bank delivers up to 18 watt of power output. The 5 megapixel Raspberry Pi camera, LM393 speed measuring sensor module was purchased from Visha World, India. Other components such as a 16 X 2 LCD screen, Bluetooth speaker, LED light lamp, resistors, motor, jumper wires were bought locally.

3.2 System design

The proposed system was made to be portable and consisted of a plastic container which represented the fuel tank in motorcycles. The 5 megapixel Raspberry Pi camera module was placed so as to face the fuel. The 16 X 2 LCD, displaying value of fuel in millilitres and as well as distance that can be covered (in kilometers), was situated in front of the owner. The speed sensor groove module was used to keep a track of the rotations of the wheel. The rotations were demonstrated by the motor in the proposed system. This speed sensor module aided the system to display the approximate distance that can be travelled. Figure 2 depicts the flow of inputs from the sensors to the central unit that is the Raspberry Pi 3 Model B+. Outputs were generated through two sources namely an LCD screen and a Bluetooth speaker. Figure 3 shows the connections for the proposed system. A motor was being monitored by the LM393 module for the rotations. Meanwhile, images were captured by the Raspberry Pi camera and sent to the Raspberry Pi 3B+. The Raspberry Pi module processed all the inputs to display the desired parameters on the LCD screen. The system was powered using a power bank of 10000 mAh.

The proposed technique used an image processing tool for determining the level of fuel in the fuel tank. An image was captured by the camera module and processed. A frame was extracted from the captured image. The background was subtracted from the image and the level was detected by subtraction done on two consecutive images. Figure 4 depicts the images captured by the Raspberry Pi camera. Figure 4 (a) shows the image of the tank when 150 ml of fuel was present in the tank. Following that are the images of tank when 150 ml of liquid was incremented each time as shown in 4. This technique provided cost effective solution for fuel level detection and monitoring system without compromising the accuracy of measurement. The sensor and web camera were chemical resistant, and did not change it's physical characteristics. The Raspberry Pi displayed the quantity of fuel to the nearest accurate value. While the motor was in motion, the speed sensor module monitored the distance covered.

In case of leakages, a sudden decrease in the fuel level was witnessed. This abnormal reduction in the tank was again captured by the Raspberry Pi camera module. The LCD screen displayed the remaining fuel and distance that can be travelled. In addition to this, a voice alert was also generated when the fuel level dropped to a stage below the threshold level.

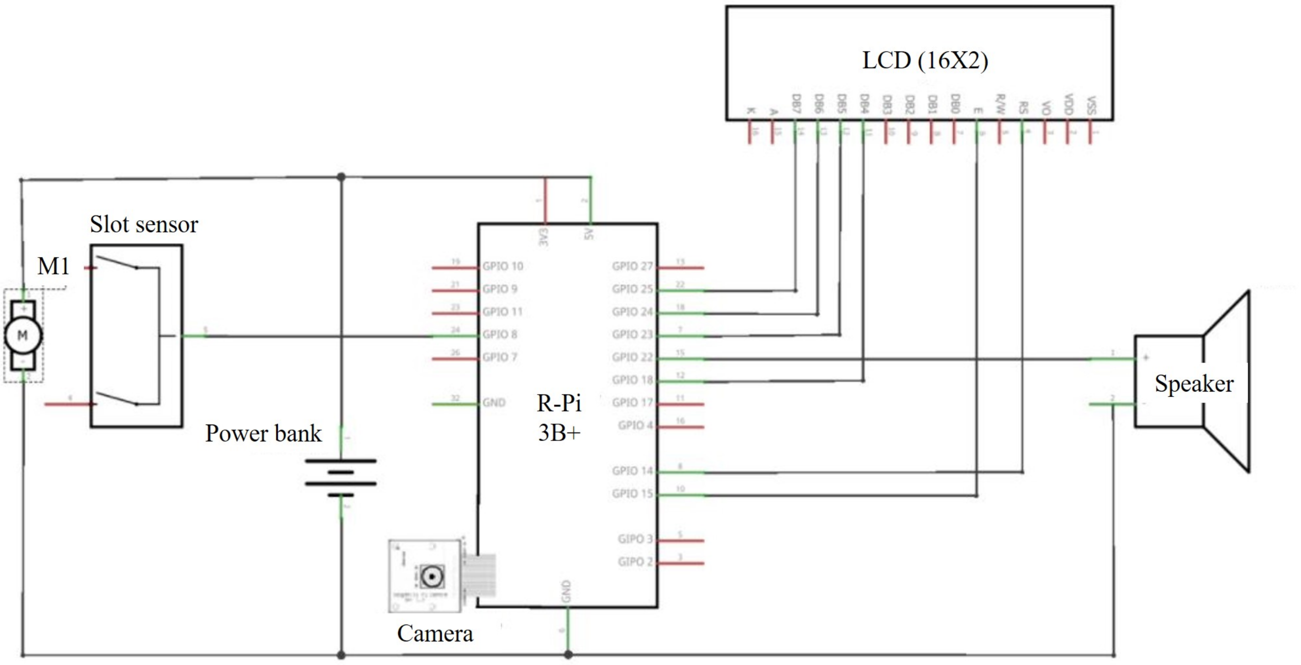

Fig. 3 Circuit diagram of the proposed system. The Raspberry Pi 3B+ was powered using the power bank. The 5 megapixel Raspberry Pi camera captured images of the tank and sent it to the Raspberry Pi which in turn processed the images. The speed sensor grove module kept a track of the rotations. Results were displayed on the 16 X 2 LCD screen. Alerts were generated using Bluetooth speaker.

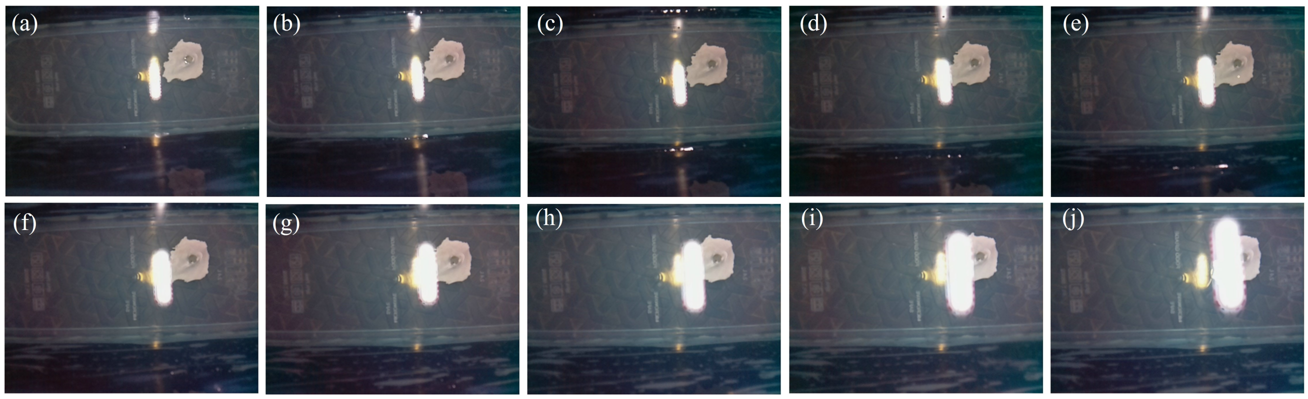

Fig. 4 Figure depicts the images captured by 5 megapixel Raspberry Pi camera. A USB powered LED light lamp was used to illuminate the tank. The light reflection can be seen on bottom surface of the tank. The part highlighted by the red circle is the region of interest. It can be seen from the figure that the reflection of the LED light changes with the addition of fuel to the tank. (a) The figure shows the image of tank with 150 ml of fuel. The following images are captured when 150 ml of fuel was incremented each time.(b) 150 + 150 = 300 ml. (c) 300 + 150 = 450 ml. (d) 450 + 150 = 600 ml. (e) 600 + 150 = 750 ml. (f) 750 + 150 = 900 ml. (g) 900 + 150 = 1050 ml. (h) 1050 + 150 = 1200 ml. (i) 1200 + 150 = 1350 ml. (j) 1350 + 150 = 1500 ml.

4 Results and discussion

Figure 5 shows the results that were obtained after the images were captured and processed by the system. Images were captured by the Raspberry Pi camera. Image subtraction methods were used. The results were displayed on the LCD screen as shown in figure 5. Figure 5(a) displays the remaining amount of fuel as 1020 milliliters and the distance that can be traveled as 52 kilometers. On the other hand, after the owner of the vehicle has traveled a particular distance and used up some of the fuel, the system recognizes the change on a real-time basis and displays the new reading as shown in 5(b)

Figure 5 (c) depicts a bar graph of experiment number versus the calculated petrol and actual petrol present

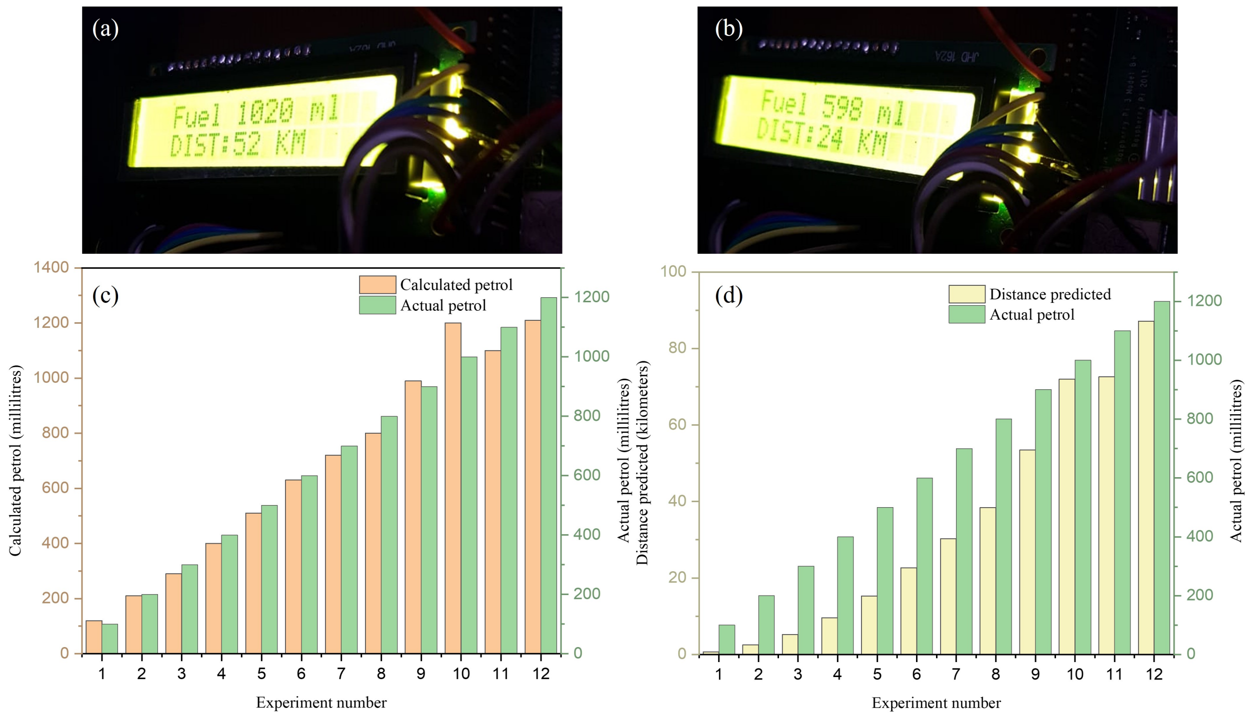

Fig. 5 Results are displayed on the LCD screen. The remaining amount of fuel in millilitres and the distance that can be traveled with that amount of fuel was displayed. (a)The remaining amount of fuel was 1020 ml while the distance that can be traveled was 52 km. (b) After travelling a certain distance and consuming fuel, the latest recording was 598 ml fuel remaining and distance that can be traveled was 24 km. (c) The graph shows the amount of petrol calculated by the proposed system and the actual amount of petrol present in the tank with respect to the experiment number. (d) The graph displays the distance that can be traveled with the remaining amount of fuel in the tank as well as the actual petrol with respect to the experiment number.

in the tank in milliliters. On the other hand, figure 5 (d) shows the distance predicted by the system as well as the actual petrol present inside the tank with respect to the number of the experiments conducted. For experiment number 10, the calculated petrol is 1200 millilitres while the actual petrol present inside the tank was 1000 millilitres. The corresponding distance traveled was recorded was 72 kilometers. Minute deviations were observed in the figure 5(c) reading displayed by the system and the actual recordings. Also, the distance was predicted by the system with respect to its calculated readings. The actual distance that can be traveled with the remaining amount of fuel might vary since, in the case of experiment number 10, a variation in the readings of calculated petrol and actual petrol was witnessed.

The existing practices are put forward in Table 1. The table compares the contemporary systems based on the techniques used, accuracy, and response time. The system proposed by Vignesh *et al.* [5] and Jade *et al.* [14] displays the same range of accuracy but different techniques. Vignesh *et al.* [5] used flow sensors while Jade *et al.* [14] used various sensors such as speed, density, temperature sensors. However, our system utilizes image processing approach to detect the amount of fuel remaining and the distance that can be traveled in that amount of fuel.

The overall accuracy of 85 % was acquired by Varsha *et al.* [15] when the fuel level was detected using an ultrasonic sensor. The wear and tear of sensors inside the fuel tank might prove inefficient. Due to this, the accuracy of the system might drop which in turn can mislead the driver. Our system implements an image processing approach with an overall accuracy of 94.87 %.

The system developed by Walleback [6] showcased the results after several minutes. The usage of the Kalman filter for fuel level estimation delayed the response of the system. In addition to this, memory allocation, processor speed, and the number of inputs needed are some factors that have proved disadvantageous for this system. Our proposed system displays the results and issues alerts on a real-time basis so that the owner remains constantly updated with the current status of fuel in his/her tank.

Table 1 A comparison table with the existing systems, based on the techniques used during fuel level detection and alert system. The table also shows comparison based on the accuracy and response time.

Method	Accuracy (%)	Response time	Technique
Farzana *et al.* [8]	80 %	Real-time	Arduino Mega and sensors
Vignesh *et al.* [5]	95-98 %	-	Arduino and flow sensors
Raja *et al.* [3]	-	Real-time	Float sensor, GPS and GSM modules
Avinashkumar *et al.* [9]	95-98 %	-	Digital Fuel Level Indicator In Two-Wheeler Along With Distance To Zero Indicator
Ahmed *et al.* [10]	-	Delay of 1 second is present	Ultrasonic and fluid level sensor, web application
Jibia *et al.* [11]	98.2 %	-	Microcontroller
Walleback[6]	-	After several minutes	MATLAB simulation and Kalman filter
Singh *et al.* [12]	95-98 %	-	Monitoring and Alert System using IoT
Saravanan *et al.* [13]	-	-	Ultrasonic sensors
Jade *et al.* [14]	95-98 %	-	Density, temperature and various other sensors
Varsha *et al.* [15]	85 %	-	Arduino and ultrasonic sensor
Proposed system	94.87 %	Real-time	Image processing

5 Conclusion

Our approach for fuel level detection and alert system used image processing and achieved an overall accuracy of 94.87 %. The camera captured images and sent them for processing. The system performed image subtraction on two consecutive images captured and displayed the remaining amount of fuel in real-time. Rotations of the motor were recorded by the speed sensor and distance traveled was displayed accordingly. Our system was capable of not only detecting the fuel level but also cross verifying the amount of fuel refilled at the petrol stations. The chances of being exploited are reduced. In addition to this, the apparatus deploys an alert system. The alert system was activated as soon as the fuel level dropped below a threshold. The system warned the owner about the current fuel level status and the distance that can be traveled with that amount. Our image processing technique can be used in various other applications such as oil tanks, dams, fuel, or any liquid adulteration detection. Liquids having different densities can be segregated using our proposed system. Overflowing of dams can be avoided if a level detection mechanism is kept in place. Also, the sensors used in the proposed system did not touch the surface of fuel or liquid and thus did not undergo any damage. Altogether, our system proved to efficient, reliable, portable, and inexpensive.

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Declarations

Funding information

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Conflicts of interest

Authors G. Purandare and N. Mehendale declare that there has been no conflict of interest.

Code availability

All the codes used in this study are provided in the supplementary material.

Authors' contributions

Conceptualization was done by Ninad Mehendale (NM). All the experiments/code executions were performed by Gauri Purandare (GP) and NM. The formal analysis was performed by GP and NM. Manuscript writing-original draft preparation was done by GP. Review and editing was done by NM. Visualization work was carried out by GP and NM.

Ethics approval

All authors consciously assure that the manuscript fulfills the following statements: 1) This material is the authors' own original work, which has not been previously published elsewhere. 2) The paper is not currently being considered for publication elsewhere. 3) The paper reflects the authors'own research and analysis in a truthful and complete manner. 4) The paper properly credits the meaningful contributions of co-authors and co-researchers. 5) The results are appropriately placed in the context of prior and existing research.

Consent to participate

This article does not contain any studies with animals or humans performed by any of the authors. Informed consent was not required as there were no human participants. All the necessary permissions were obtained from Institute Ethical committee and concerned authorities.

Consent for publication

Authors have taken all the necessary consents for publication from participants wherever required.

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