Fuel Theft Prevention Utilizing IoT Technologies

Ragavantiran Gurumoorthy
MSc in Electronics and Computer Technology
Dublin City University (DCU)
Dublin, Ireland
krraghav2501@gmail.com

***Abstract*- To solve the common problem of fuel fraud at gas stations in India, which involves incident like wrong fuel dispensing and adulterartion, I propose a solution. This project uses an Arduino Giga R1 WiFi microcontroller with an Arduino Giga Display to create a real time dashboard inside vehicles. The dashboard features an easy to use graphical interface that displays accurate pH levels, helping to identify any water in the fuel. The ultrasonic sensors will measure the tank's volume, and flow rate sensors will monitor the how much the petrol is dispensing from the gas station, ensuring customers getting correct fuel.Additionally, I use Ardunio Cloud platform to create a dashboard and display the readings of ultrasonic sensor in form of Guage and chart to retrive information of fuel consumption for period of time.**

Keywords: Arduino Giga R1 wifi, Arduino Giga Dsipaly, pH sensor, Fuel Fraud Prevention, Cloud.

I. Introduction

Fuel prices in India are increasing periodically due to trade issues, and many people are getting into fuel scams at gas stations. This fraudulent behavior usually means that fuel pumps display wrong amounts, making customers pay for more fuel than they actually get. The problem is that consumers dont have particular tools to measure the fuel they receive, as car dashboards only show fuel levels in gauge type, which makes it hard to detect errors. These issues remain unnoticed until it's too late, resulting in financial losses over time.

There have been many reports in India about fuel being mixed with water to increase its volume, tricking customers. This practice not only affects consumers but also produce a risk to their vehicles. Water in fuel can lead to engine damage, lower efficiency, and expensive repairs. Even though there have been efforts to address these problems with regulations and awareness programs, the issue persists, and need some technology to identify that was attached within the car so the people will have confidence in their car rather that the gas station readings.

In 2020, an incident occurred when a man was billed for 11.5 liters of petrol for his bike, even though it could only hold 8.5 liters. After a thorough investigation and collecting enough proof, the gas station owner was apprehended.This situation shows that there are fuel fraud is happening and waraness was required within the community. Sadly, it is troubling to see that such fraud persists, indicating that these cases are not just one-off incidents but part of a larger issue. It is neccesary to take stronger measures to fight fuel fraud and protect consumers nationwide.

My project aims to solve these problems by creating a easy to use system that helps consumers check the amount and quality of fuel they receive. The core of this system is the Arduino Giga R1 WiFi microcontroller, which I am connecting with other components. The flow meter displays readings of the fuel being dispensed in real time, while the pH sensor detects any fuel contamination by measuring the pH level and quickly notifies in the dashboard if the fuel is substandard. Additionally, the ultrasonic sensor monitors the fuel level in the tank, ensuring that the dispensed amount matches the vehicle's capacity. All sensors data, such as fuel dispensed, fuel level, and pH readings, is shown in a user friendly dashboard on the Arduino Giga Display.

The Arduino Giga R1 WiFi microcontroller will be the main part of the system, working with the Arduino Giga Display to display important information in an easy to read dashboard. Additionally, the system will use Arduino Cloud for data logging, enables the users to monitor fuel levels and view charts of fuel consumption over time. This allows for simple tracking and analysis, even when users are away from their vehicle.

I plan to use this advanced system to fight fuel fraud and protect consumers from fraud practices. This project will keep vehicles safe from damage due to bad fuel, increase consumer confidence, and improve regulatory control. It will also promote environmental sustainability by encouraging better fuel use and reducing the chance of harmful impurities, helping to lower emissions and create a cleaner future.

Traditionally, finding fuel fraud has to rely different methods that use special tools for measurements. A popular approach is to use a fuel storage tank to check how much fuel is dispensed. In this method, people would take petrol from their cars and measure it against the expected amount in the tank to find any differences. Although this technique is effective in controlled environments, it is not practical for everyday use because it is inconvenient and time consuming.

A common method used in the oil and gas industries is manual dipsticks for measurement. However, these dipsticks are not good at detecting fuel fraud in vehicles. Their short in size make it hard to guarantee accurate fuel dispensing at gas stations, so they are not an effective way to find fuel fraud identification.

Station audits, usually done by government agencies, focus on calibrating fuel dispensing equipment and make sure it is well maintained. These audits are supposed to be maintain the equipments provide certification but due to improper ethical issues, there is no guarantee that all audits are free from tampering or that they always meet high standards.

CCTV cameras are used to check fuel levels at gas stations, but they may not be very useful for spotting fuel fraud. The video footage can be hard to match with the actual amount of fuel dispensed, making it difficult to get accurate results. Because of this, CCTV alone is not very effective for detecting fraud.

Many consumers monitor their fuel use by filling up when their tanks are almost empty and then keeping track of the miles they drive. While this method gives some control, it can be boring and prone to errors. Logging and analysis take a lot of time, and there are chances to prone to data loss, so this method is not effective to identify fuel fraud.

In conclusion, There are traditional methods are used to identify fuel fraud, but it will take a lot of time, which also known as time consuming, this project aims to support identifying fuel fraud within the vehicle and boost the consumers sustainability and avoid fuel fraud and adulteration.

II.Related Work

In recent years, various methods have been implemnted to detect and monitor fuel fraud which highlights the need for effective solutions that ensure accurate fuel dispensing and reduce fraudulent activities. This section reviews current research and the proposed project, showing how it improves on earlier efforts.

Yamini et al. [2] created a smart IoT-based system designed to monitor and detect fuel theft and errors during refueling. Their system uses IoT technology for real time monitoring, which is similar to the approach in this project. However, while their main focus is on detecting theft and inaccuracies, this proposed project expands on this by adding more sensors to evaluate both the amount and quality of fuel, offering a more comprehensive solution.

Kanade [3] shows how ultrasonic distance sensors work with Raspberry Pi in civil engineering, showing they can measure distances accurately. This research is important for the current project, which uses ultrasonic sensors to monitor fuel levels in vehicles. By using these sensors, the project aims to make sure the fuel dispensed matches the vehicle's capacity, fixing the issues found in Kanade's study.

BinMasoud and Cheng [4] developed a vehicle monitoring system based on IoT with Raspberry Pi, looking at different vehicle parameters, which fits with the current project's aim to use IoT technology. However, this project focuses specifically on fuel monitoring by adding a flow meter, pH sensor, and ultrasonic sensor, providing a clearer approach to detect fuel fraud and ensure quality.

Sreenivas and Manoj [5] study shows how improper regulating fuel prices in India affects regulations. Their provide valuable information about the overall regulatory environment, but this project focuses on the detecting fuel fraud. It is a combination of sensors and data logging technologies to make sure that it provides accurate measurements and prevent fraud.

Adella et al. [6] research introduces a system for monitoring fuel consumption in real time using IoT technologies. Like this project, it enhance the importance of real time data for managing fuel and preventing fraud. However, the proposed system enhances this by adding sensors that identify fuel adulteration and guarantee precise fuel dispensing, making it a more complete solution.

Yamini et al. [7] present an IoT method for monitoring fuel, encouraging sustainability. Similarily in the suggested system, it employs IoT sensors for detection, showing a shared technology approach. However, this project specifically addresses fuel fraud in India and includes a detailed real time dashboard for quick feedback to users, which is not clearly outlined in Devi's research.

Iswanto et al. [8] talks about a pH meter system that uses a Raspberry Pi and a user interface made with Python. The project includes a pH sensor to check fuel quality, but it also adds features like monitoring flow rate and volume. Additionally, this project aims to use these technologies to stop fuel fraud.

The proposed project is made based on the previous research by combining the advanced technologies used inn the previous research papers into a single system aiming at detecting fuel fraud and ensure accurate fuel dispensing. By using flow meters, pH sensors, ultrasonic sensors, and Arduino cloud, this prototype could offers more comprehensive and user friendly solution compared to current methods, effectively tackling both quantity and quality issues in fuel monitoring.

III. System Architecture

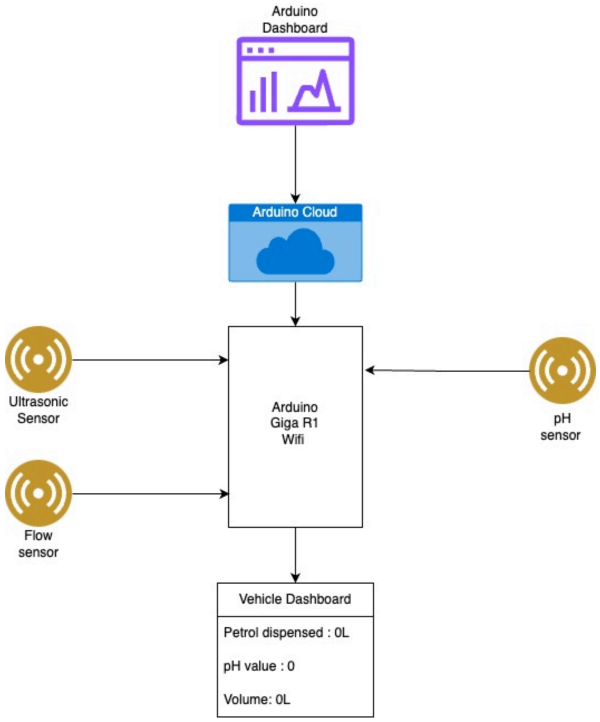

Fig.1 System Architecture

Figure 1 shows the layout of the system. The main part is the Arduino Giga R1 WiFi microcontroller, which acts as the central processing unit for the whole system. This microcontroller is essential for handling data collection, processing, and sending information to the cloud.

The Arduino Giga R1 WiFi connects with and gathers input data from several sensors associated with the system, such as a flow sensor, a pH sensor, and an ultrasonic sensor. These sensors display essential information about fluid flow, pH levels, and distance measurements, respectively.

The system is designed to interface with three primary sensors:

Ultrasonic Sensor: The main function of this component is to calculate the fuel level within the reservoir. Operation is based on ultrasonic sound waves being emitted and measuring the time before these waves return after hitting the fuel's surface. Situated high up in the tank, a sensor measures their distance to come with an estimate of fuel level and therefore gives out calculation about how much fuel is left. After grabbing the fuel level data, it then sends this information to an arduino Giga R1 WiFi microcontroller. Data is processed by the microcontroller and sent to Arduino Cloud with its WiFi connectivity. In a cloud-based manner for remote monitoring and storage A user-friendly dashboard is provided which displays fuel level readings on devices connected to the internet, in real-time. Figure 15: The dashboard that conveys the status of the fuel tank allows consumers to remotely monitor levels, and receive alerts or updates as required.

Flow Sensor: Located in the fuel dispensing line, the flow sensor measures the rate at which petrol is dispensed. It accurately tracks the volume of petrol that flows through it, providing essential data for billing and ensuring that customers are charged accurately for the fuel they receive.

pH Sensor: This device checks the quality of fuel by measuring its pH level. While petrol is a hydrocarbon and doesn't have a standard pH, the sensor can detect any water or other contaminants that may change its pH. It sends an electrical signal to the microcontroller, which examines the data for any signs of fuel contamination.

The Arduino Giga R1 Wifi processes data from different sensors in real time. It then sends this information to an external display unit that works well with the Arduino Giga board. This display acts as the vehicle's dashboard, enabling drivers to easily track the tank volume, petrol flow rate, and the fuel's pH level.

The system uses a modular design. The Arduino Giga R1 Wifi handles processing, and an external display shows important information to the driver. This setup allows for easy addition of sensors and features, making it flexible for various vehicle monitoring needs. With a display made for the Arduino Giga board, the system can share key data with the driver without needing complex integration with the vehicle's dashboard.

IV. Implementation

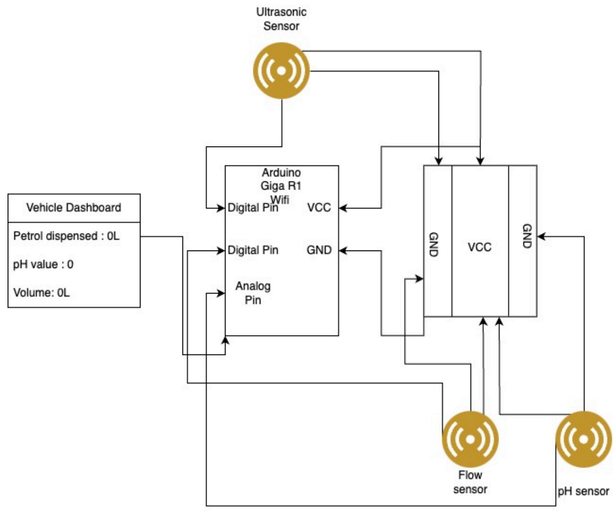

Fig.2 Circuit Diagram

Fig.2 Circuit Diagram of the Fuel Theft Prevention and Monitoring System with Numerous Sensors Integrated to Arduino Giga R1 Wifi Microcontroller Fig. 2 Circuit diagram for fuel theft prevention & monitoring system in which multiple sensors are integrated using an arudino giga r1 wifi microcontroller The system features flow rate and pH value as well monitoring, plus fuel volume measurement. However, it only sends the fuel height data captured by ultrasonic to Arduino Cloud. The best part is you can watch, control and monitor in real time through your mobile app. Tank Cloud Dashboard showing capacity, and an indication for furthers of current fuel levels they can monitor remotely Each component above will be described in more detail regarding its implementation.

Sensors	Specifications
HC-SR04	5V input, 15mA output current, 40KHz frequency
YF-S201	5-18V input, 15mA output current
SEN0161-V2	3.3V to 5.5V, 5-10mA

Fig.3 Sensors Specifications

In Fig. 3 are the sensor specifications describing the model number and their voltage and current.

1. Flow Sensor Implementation:

The YF-S201 flow sensor has a plastic body and a rotor with a magnetic hall-effect sensor. It measures fuel flow by producing pulses that match the amount of fuel flowing through it. Each pulse indicates a certain volume of fluid. This sensor connects to a digital pin on the Arduino, and an interrupt service routine (ISR) counts the pulses.

To find the flow rate, you can use the formula:

Flow Rate = Volumetric Flow / Area;

where,

Flow Rate (L) = Pulse Count Pulses per Liter

The flow rate will be displayed in the Arduino display, but it will not senf the data to cloud where I set only the to send the ultrasonic sensor data .

2. pH Sensor Implementation:

The SEN0161-V2 pH sensor from DFRobot's Gravity measures the pH level of fuel, showing its acid/base balance. It sends an analog voltage that matches the pH level, which the Arduino reads through an analog pin. The pH value is calculated from the raw analog data using a calibration equation.

The following is the calibration equation to determine pH from raw analog readings:

pH Value=(Sensor ReadingsXCalibration Slope)+ Calibration Offset

It will then Displays the data in the Arduino Giga Display with color-coded lighting for warnings of readings outside normal range. This allows users to detect possible contamination and give immediate feedback on fuel quality.

3. Implementation of Ultrasonic Sensor:

The HC-SR04 ultrasonic sensor checks the tank volume by sending out ultrasonic waves. It measures how long it takes for the waves to bounce back after hitting the fuel surface. This time is turned into a distance, which helps find out the fuel volume.

The distance is calculated using the formula:

Distance (cm) = ((Duration/2)*0.0344.

By calculating the distance, the volume of the tank is measured by using the formula,

Remaining Volume (mL)=Remaining Height (cm)×Tank Height (cm)Tank Volume (mL)

The filled volume is subsequently also utilized according to the formula total tank volume-less remaining volume filled up space. The Arduino Giga Display presents this data, and is updated in real-time on the Web so it can be checked from anywhere.

4. Cloud Communication:

The system gets updates via Wi-Fi with fuel volume information, refreshing every few seconds in the Arduino Cloud. This cloud platform shows real-time tank capacity and fuel level data in clear visual formats. Users can access these metrics online, allowing for quick responses to changes in fuel volume, theft, or leaks, even outside of operating hours.

With the help of cloud communication users can be continuously provided with real-time and historical data, which helps to increase efficiency in fuel fraud detection and prevention.

V. Result and Evaluation

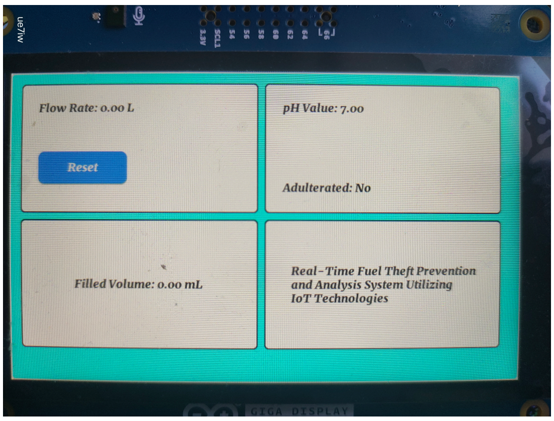

Figure 3 Display Output

In the Figure 3, the Arduino Giga Display outputs real-time data from the embedded sensors The display is divided into four major areas: Flow Rate, pH Value, Ultrasonic Reading Easily, and Cloud Status. The top-left quadrant incorporates the flow rate with a 'Reset' option to clear your current reading. The top right section, under the pH Value, includes a label denoting whether or not the fuel is compromised. The section blinks a red and white light whenever adulteration is detected, and the last box is the project topic.

1. Calibrating and Integrating Sensors:

This included calibration of every sensor to produce accurate measurements and good system performance. Details of calibration processes and integration are as follows:

PH Sensor Calibration: he SEN0161-V2 pH sensor was set up using lemon water and clean water for calibration. This process was included in the Arduino program, where the calibration offset and slope were adjusted to align with the sensor's reaction to these reference liquids. This calibration made sure the sensor measured the pH of the fuel correctly and gave trustworthy readings.

Calibration of Flow Sensor: The flow rate sensor was set up by changing the pulse count per liter based on the sensor model. This change made sure that the flow rate readings matched the real fuel flow accurately and consistently.

Calibration of Ultrasonic Sensor: The ultrasonic sensor was adjusted based on the tank's height and volume specified in the code. This adjustment enabled the system to correctly change distance measurements into fuel volume readings.

2. Functionality And Display Of The System

The Arduino Giga R1 WiFi microcontroller effectively handled data from all sensors and showed important information on the Arduino Giga Display. Key features and display options include:

Flow Rate Measurement: The display showed the current flow rate in liters per minute. A reset button was included in the flow rate section, allowing users to reset the total flow volume to zero for easier tracking of fuel usage over time.

pH Value Tracking: The fuel's pH level was constantly checked and shown on display. A label called "Adulterated" was added to the pH value section. This label indicated "Yes" if the pH level fell outside the acceptable range of 6.2 to 8.0, suggesting possible fuel tampering. When adulteration was found, the whole pH value section flashed red and white, giving a clear warning about fuel quality problems.

Ultrasonic Data: The ultrasonic sensor readings for the tank volume were displayed on the screen in real-time. The sensor data was sent to the Arduino Cloud and registered as a “thingProperties. h” file. The data was then processed by a cloud platform, which rendered the fuel-level information in the form of gauge GUIs that could be monitored remotely.

3. Integration with cloud and remote monitoring

Real-time monitoring and data visualization using Arduino Cloud for integration with the system:

Data Transmission: The data of the ultrasonic sensor was transmitted to Arduino Cloud via Wi-Fi and the connection was initialized using “thingProperties. h” file. This made certain that the information remained up-to-date in the cloud platform.

Dashboard on cloud: Through the dashboard user can see real-time fuel volume parameters and historical trends. In addition, the Arduino IoT Cloud app which made graphical representations of sensor readings possible and hence improved remote monitoring.

4. Power Supply and Connections

For the Power supply and sensor connections.

Supply: The VCC and GND are connected to the common in the breadboard and connected to the Arduino board to avoid extra wiring.

Signal pins: Signal connections between each sensor and the appropriate pin on an Arduino board were direct to avoid errors during data acquisition & processing.

The system showed that it could effectively combine different sensor data, allowing for accurate and immediate tracking of fuel flow rate, pH levels, and tank volume. It also includes features like a reset button for flow rate and an alert system for adulteration, which not only provided essential information but also improved user engagement and ease of use. Visual signals, such as blinking alerts for pH issues, helped users quickly spot problems, enhancing the system's practical use.

Connecting with cloud services enabled remote monitoring, allowing users to check fuel levels and quality when the vehicle is in an idle state, which then can make sure they have enough petrol to travel This remote access, along with real-time data display, gave a complete view of fuel status, making it a useful tool for managing fuel and preventing theft. Overall, the successful setup of sensors and reliable data display and cloud communication shows the system’s potential as a strong solution for maintaining fuel quality and avoiding fraud.

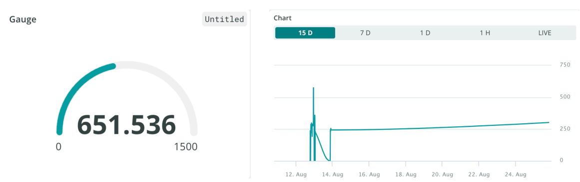

Figure 4 Cloud Output

Figure 4: The Arduino Cloud dashboard shows the ultrasonic sensor data using a gauge interface. This gauge allows users to monitor fuel volume from a distance and visually represents how much fuel is in the tank. The display provides consistent readings, showcasing the system's impressive ability to send data and update the cloud platform in real time.

VI. Conclusion

The project effectively shows how IoT technologies and sensors can work together to track fuel quality, flow rate, and tank volume in real time. By adjusting the pH and flow rate sensors and using an ultrasonic sensor for tank volume, the system delivers precise and useful data. The display's visual interface, which includes a reset button and an alert for fuel adulteration, improves user experience and makes the system easy to use.

However, the Arduino Giga R1 WiFi module has limited memory, which prevented me from adding more features or functionalities in the designated area on the display that I named the project topic. This points out a restriction in the current setup of the system.

In the future, using a more advanced microcontroller or connecting the system to a real-time car dashboard with better automotive sensors could greatly improve its functions. These upgrades could help combat fuel fraud and adulteration more effectively by offering more accurate measurements and extra real-time monitoring options. Enhancing the project with these changes would make it even more applicable for fuel management and theft prevention.

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