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DEVELOPMENT OF A FUEL ADULTERATION DETECTION SYSTEM USING IoT BASED SENSOR TECHNIQUE

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Abstract: Fuel is very important in our everyday activities, it has been used in companies, industries, organizations and automobiles. It also serves as a means for generating electricity. Adulteration of petroleum products is hard to detect because the existing components of the fuel constitute the adulterants. The adulterants alongside other cheap hydrocarbons are mixed with the base fuel to degrade its quality and for the monetary benefits of the business vendors. This makes the adulterated fuel to pose a very serious danger to the consumers. This research project developed an IoT-based fuel adulteration detection system using a weight sensor-based technique. The IoT-based system helps to notify and give information about the fuel adulteration to the user immediately on a registered website called thingspeak. The average detection accuracy and response time of the system are 96.37% and 1.34 seconds respectively. These results emphasize the crucial function of adulteration detection system in fuels, as it detects adulteration of liquids effectively and accurately for automobile users and thereby reducing the risk of adulteration in fuels.

Keywords: *Adulteration, Arduino, Kalman filter*

1. Introduction

The importance of crude oil all over the world cannot be overemphasized as it has contributed immensely as a means of energy for modern technological devices [1]. In no doubt, almost all the fractions obtained from crude oil find application in several aspects of technological advancement but one of the fractions which have gained popularity all over the world is gasoline also known as petrol [1].

The adulteration of the gasoline is brought by the different tax regime imposed by various countries making some of the hydrocarbon products inexpensive and consequently, a good choice as the adulterant [2]. The adulteration was possible because the adulterants and the based fuel possess very similar characteristics that makes the mixture seamless. The negative effects of this nefarious activity include tailpipe emission, increase in indoor air pollution, ill-health effects on the environment and the residents, non-availability and high cost of the adulterants for the legitimate consumers [3]. The aforementioned negative effects of the fuel adulteration among other things, allude to the fact that there is need to develop an effective system for the monitoring of fuel quality at the distribution points [4] [5]. Technological advancement over the years leads to the discovery of vehicles, airplanes, generators, etc. In all over the world today vehicle is being used as a means of transportation to transport human and goods[6]. These vehicles usually make use of gasoline as a means of energy to ignite their combustion engine. In other, for a vehicle engine to work properly, the gasoline used in it must be free from any form of impurity also referred to as adulteration. Adulteration of gasoline is very rampant in Nigeria because products of comparable quantities have different prices[7]. One of the major reasons behind the adulterations of fuel is profit-making [8]. These acts are been carried out by dealers without considering the damages they will do in vehicles. In most cases, Kerosine is being adulterated with petrol which is very inflammable and risky as it can lead to the loss of human life[9].

2. Review of related works

The aim of this project is to develop a fuel adulteration detection system using IoT based sensor technique. There have been several developments of fuel adulteration detection systems, but none have used a weight sensor. To this effect, the reviews of related works are presented below:

This work [1] leverages the use of image processing technique in the detection of fuel adulteration by the measurement of the quantity of product generated upon the application of heat on the adulterated fuel using a photodetector. The voltage output and the quantity of left-over liquid were compared to ascertain the extent of adulteration by the microcontroller which was based on the premise of appearance and disappearance of liquid between the IR receiver and the transmitter. The image of liquid level before and after it was subjected to heat and was captured by camera lens of resolution 320*240 pixels for the Raspberry pi. The image was processed by the raspberry pi and the quantity of detected liquid was converted to a percentage and displayed for visualization.

A waveguide sensor that functions on the principle of Frustrated Total Internal Reflection (FTIR) was used by [10] to detect and validate the variety of contaminated items. It was discovered that there exists a strong correlation between the predicted values and the developed system's output. It was found out that the developed approach performed better due to its high sensitivity.

A group of researchers [11] developed a system for the detection of kerosene presence in gasoline using a complimentary split-ring resonator. The sensitivity of the sensor was so good that 10, 20 and 30% concentration of kerosene in gasoline were measured and displayed by the developed system. This indicated that the system possessed the ability to measure the level of adulteration as low as 10% minimum. The sensor has a lot of advantages including affordability, repeatability and great downsizing that makes it a good candidate for automobile industry and also, can be used for car engines.

Three researchers [12] developed a 3D printed micro viscometer that can accurately measure the automobile fuel's adulteration level based on fuel viscosity. The idea was that the 3D system should be able to differentiate and measure the variation in viscosities between petrol, kerosene and diesel and used the measurement to detect the adulteration. This is based on the premise that petrol, kerosene and diesel have different viscosity levels. An accuracy of up to 95% proves that the developed system was versatile and would have a wide range of applications where viscosity is the monitoring parameter.

A researcher [13] used an optic fiber sensor to develop a new approach for the detection of adulterated fuel where he created and tested a prototype that used an evanescent wave absorption technique to successfully identify percentage adulteration in diesel and petrol by kerosene, with the goal of developing a rapid and precise fuel adulteration mechanism. The developed system performed better as compared to the existing approaches. In the same vein, researchers in [14], in their bid to differentiate various adulterants, they utilized a 3D optical microfluidic to estimate viscosity in fuels. This had wide applications including biofuels and milk for the detection of adulterants in them.

For quick identification of kerosene in gasoline, a group of researchers [15] experimented with a centrally controlled No-Core Fiber Sensor (NCFS), whose working principle is based on transitory wave absorption. According to their findings, the NCFS sensing head was created by striking the NCFC between two multi-fibers, resulting in sensitivity of 390nW/% and 110nW/% for high-level and low-level adulteration, respectively. By using the finite element method, they demonstrated the theoretical verification of confinement loss and intensity change.

Some researchers [16] recommended the use of single channel fiber optic sensor for use in the automobile industry due to its size and its stress-free fabrication.

Using a new fiber optic sensor based on Surface Plasmon Resonance SPR, a group of researchers [3] created a new method for detecting kerosene adulteration of gasoline and diesel. Their experiment was based on the assumption that the refractive index of gasoline and diesel would change linearly when kerosene was added. Furthermore, using the SPR in the Kretsch Mann arrangement, a systematic detection of adulteration level was accomplished. The device displayed electromagnetic interaction immunity, which is a crucial feature for the development of SPR-based optical fiber sensors in petrochemical research.

An optical sensor was used by a group of researchers [6] to screen counterfeit diesel oil. The goal was to distinguish between the mismatch between the refractive index of the fuel sample and the refractive index of the glass. The apparatus also looked at how fuel film interacts with the surface. The most significant mismatch was found between the glass and diesel oil, while the smallest was found between the glass and 15% contaminated diesel oil.

The refractive indexes of binary fuel mixtures were measured using an Anne Refractometer by a researcher [17]. The goal was to use extinction coefficients to differentiate adulterants. The transmittance spectrum was initially measured in the visible and near-infrared (NIR) ranges. It was required for the determination of binary mixes' excess permittivity. Excess permittivity was critical in interpreting data from liquid interactions, particularly in binary liquid mixtures. Using imaginary optical qualities, it was possible to discriminate between 5 to 10% adulteration and 15% adulteration. Adulterants could be removed from kerosene or diesel fuels, which is strength. It works well in liquids with high permittivity.

To screen contaminated diesel oil, a researcher [18] developed a simple, reliable, and inexpensive handheld refractometer. The goal is to use permittivity to detect kerosene adulteration in diesel. With the use of a temperature correction table, the handheld refractometer evaluated the refractive index and consequent excess permittivity, allowing for refractive index estimation at different temperatures. The real and ideal permittivity of diesel was then calculated using the refractive index. The method was successful in detecting adulteration of diesel by kerosene as little as 5%, making it an excellent screening mechanism for contaminated fuel.

A new planar metallic waveguide sensor has been proposed by a few researchers [19]. The goal of this study was to detect contaminated gasoline in automotive fuel. Petrol and diesel were tested for adulteration using a constructed metal-clad planar waveguide with substantial electromagnetic radiation film containment and a hollow prism. When compared to other similar existing sensors, this one had a higher sensitivity. The maximal sensitivity of 105.24 degrees/RIU for contaminated gasoline and 182.68 degrees/RIU for diesel is very similar.

Some researchers [20] developed a fiber optic linked with an opto-electric detecting method to create a simple, inexpensive, small, and sensitive gadget. Its purpose was to detect kerosene adulteration in gasoline. They used the technique to detect kerosene adulteration in gasoline at levels as low as 5%. The results demonstrated that the approach can identify a 1% difference in kerosene adulteration in gasoline.

To investigate gasoline adulteration, this team of researchers [21] used a combination of thermal image processing and the Gray Level Co-occurrence Matrix (GLCM) technique. Thermal imaging processing was to be used. The thermal camera, which consisted of an optical lens and an infrared emitter, emitted infrared light to the object (fuel mixture) enabling the detector to form a thermogram image. The signal processing element, according to their research, processed the electrical pulses produced by the thermogram, which were then translated into image data. They used the GLCM characteristics to extract the effective zone from the image, which revealed the spread of the adulteration. Adulteration detection levels of 5 and 10% in fuel were detected with 98 percent accuracy, according to the study's findings.

For petrol adulteration investigation, a group of researchers [2] presented a dual-core Photonic Crystal Fiber. The goal was to create a sensor that could detect fuel adulteration. The sensing probe was numerically studied using the finite element approach. For the numeric investigation, the sensing probe with a single analyte channel used the finite element method. At the center of the fiber, where the gasoline sample is injected, there are two solid light guiding cores. Using various amounts of gasoline adulteration, they studied the sensitivity as well as the mode coupling pollution of the environment. The simulation, which shows exceptional sensitivity for small probes at 20,161.2nm/RIU, demonstrates the work's strength. The study indicates that the technology might be utilized to create a portable adulteration detection sensor for environmental contamination research. Pollution of the environment

From the reviewed related works, these works prove to be very expensive and requires more laboratory experiences. The techniques used are very time consuming due to its technicality. Most of the sensors used in adulteration detection are very expensive coupled with low availability in many countries. This proposed work uses a cheaper and cost-effective approach, using a weight sensor technique to determine the mass, density of fuels.

3. Proposed model

This project is designed for automobile-specific fuel adulteration detection. It is designed to tackle incidents of adulteration in automobiles and as well receive data through a web-based application. This proposed method of development as compared to other adopted works seeks to give the owners of automobiles the advantage. The following are the main advantages users derive from the use of the adulteration detection system developed:

1. Easy and accurate detection of fuel adulteration.
2. Applicable to automobiles.
3. Cost effective.
4. Time management.

4. Research Methods

The system is made up of two modules namely hardware and software. The hardware module is made up of various units that are used to build the fuel adulteration detection system while the software module contains the C++ programming language for detecting adulteration as well as the mobile web app known as thingspeak for feedback.

4.1 System Hardware.

The following are the various components required for the development of the proposed system:
Weight sensor (Hx711 + load cell), Arduino Uno, 16x2 LCD module, and Wi-fi module, Buzzer, Led, Fuel tank.

4.2 System Block Diagram.

The adulteration detection unit consist of a weight sensing device known as weight sensor. It is used to sense the weight/ density of fuel; these values are then retrieved by the Arduino; it is the brain of the system that interconnects all the units and helps in processing the various functionalities that are to be implemented in the system. This unit is in charge of the overall system's operation. The communication and security unit consist of LCD, wi-fi module, led, and buzzer. The Arduino shows the parameters through the communication and security unit which is the LCD. Security unit is activated depending on the result displayed by the LCD.

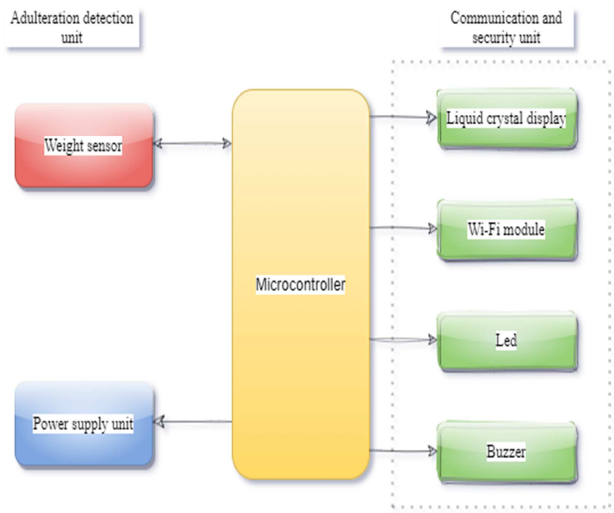

Figure 1: System Block Diagram.

In Figure 1 when the system is turned on for the first time, it initializes the adulteration detection unit which consist of the weight sensor. It then senses the weight of liquid for adulteration detection. The system acts depending on the result of the sensed fuel. If the sensed weight/density of fuel is greater than the known density, it is adulterated, the buzzer and red led is activated. The result of the sensed fuel is sent to a web-based application called thingspeak for feedback.

4.3 System Block Diagram.

The Figure 1 shows the system circuit diagram shows how all the components used in designing the system are used in Figure 2

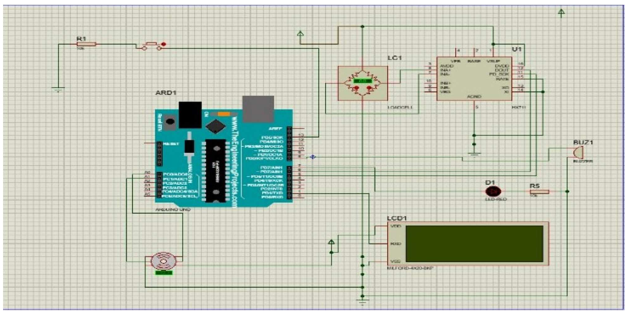

Figure 1: System circuit diagram.

4.5 *Design Calculation.*

A 5V battery was used to power the system. The adulteration detection equipment was powered by a 5V battery. There are no separate calculations for the power supply, communication, or security units because they are all powered by the control unit.

4.6 Control Unit Design Calculation.

The power rating for the control unit and the current rating for other components is calculated using equations 1 to 3
P*cu* is the total power of the control unit,
V*cu* is the operating voltage of the control unit,
Icu is the current rating of the control unit
T_{cu} represent the total lasting time of control unit
Where,

$Pcu = Icu * Vcu$ (1)
From the datasheet of Arduino uno
$Icu = 2A$
(2)
$Vcu=+5v$
$Pcu = 2 * 5$
$Pcu = 10W$

$$Ampere\ hour = \frac{power \times time}{voltage} \quad (4)$$

$$Amphr = \frac{10.0 \times T_{cu}}{5}$$

$$Amphr = 2.0T_{cu}\ Ahr$$

A 4600mAh 5V battery will power the Adulteration unit for T_{cu} hours
$46Ahr = 2.0T_c Ahr$
$T_{cu} = 2.33hrs$
$T_{cu} = 2hr\ 20mins$

4.7 Adulteration Unit Design Calculation.

I. Statistical model

Signals from strain gauges are routed through a HX711 signal amplifier to an Arduino Mega328 microcontroller for data collecting. The following formula can be used to compute weight:

$$W(t) = (V - Z)/C, \quad (1)$$

where W(t) is the weight obtained from the measurement (g), V is the signal voltage perceived by the weight sensor (mV), Z is a signal correcting variable (mV), and C is a measurement accuracy correction factor [22]. Consider the influence of temperature on the measurement in Equation (1). We get the following equations as a result:

$$W(t) = (V - Z_T - e_T)/C, \quad (2)$$

$$x = T - T_{0,} \quad (3)$$

$$e_T = y = a_0x^1 + q_0x^2 + a_2x^3 + a_3x^4 + \cdots a_nx^\beta + b, \quad (4)$$

where Z_T is Z at the measured mass T, y or e_T, is an error signal at T, T_0 is a known calibration mass, and x is the difference between the initial mass and the measured one. By using the regression equation, Eq. (4), with a set of standard weights for calibration consisting of 200, 1000, and 2000 g for 1000 data points, we can determine the coefficients of regression, a_i and b_i, where $i = 0, 1, ..., n$ [22].

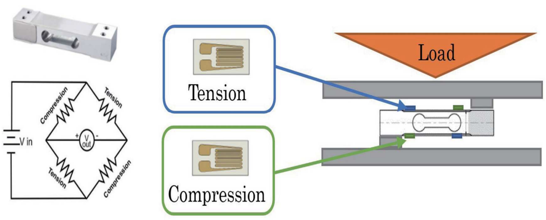

Fig. 2: (Color online) Schematic diagram of the components and installation configuration of a single-point load cell [22]

II. Kalman Filter

In comparison to the moving average filter, the Kalman filter has the advantage of being able to smooth, filter, or predict data. We may easily build the filter in two main sections, prediction and updating of prediction values, by describing it in a state space form at discrete time k and previous time k_1. This is how the algorithmic loop is broken down into three steps. It's worth noting that for real-time weight measurement and calculation, we use a single measured value:

Calculate Kalman Gain:

$$K(k) = [P(k) + R(k)]^{-1},\ 0 \le K(k) \le 1, \quad (5)$$

Update Current Estimate:

$$X(k) = X(k-1) + K(k)[W(k) - X(k-1), \quad (6)$$

Update New Error in the Estimate:
$P(k) = P(k-1)[1 - K(k))]$. (7)

K stands for Kalman gain, P for estimation error, $R(k)$ for measurement error, W for weight sensor measurement value, and X for estimated weight.

5. The System Flowchart

The System shows the operational flow of sequence of the Fuel adulteration detection system in steps. The flow sequences are explained and shown in Figure 2 below:

1. Start.
2. Initialize a Wi-Fi connection using a router
3. The system waits and is ready to execute further commands.
4. Check if the command is received.
5. If the command is received, check if it measures density. Else go to step 5.
6. If the command received measures density, then check if the density is not between the range of quality fuel. Display adulterated and trigger buzzer.
7. If the density is between fuel quality range. Display okay.
8. Stop.

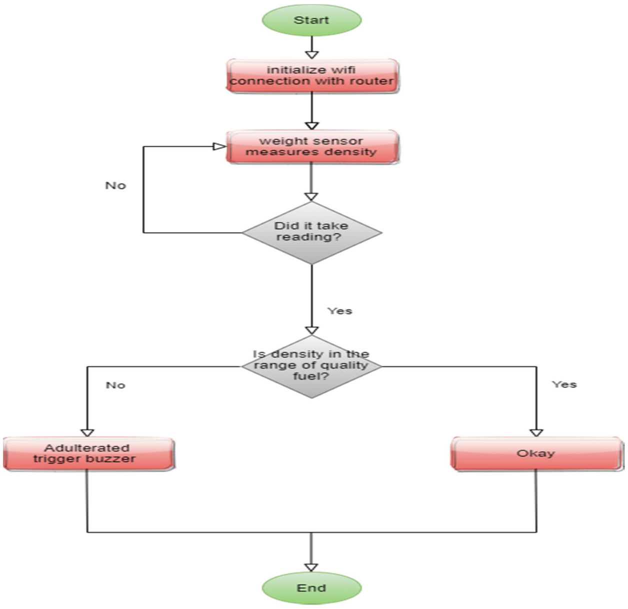

Figure 3: Flowchart of the system.

The Figure 3 shows the accomplished steps in the design system, when the system is powered, the detection unit is initialized, it is ready to detect adulteration of fuel, if it does not sense the weight of the liquid it does not give reading until it does. The LCD displays the results of sensed weight of liquid. Buzzer is triggered when it senses weight out of the range of fuel.

6. Performance Evaluation

The performance of the system is based on the accuracy and response time according to the stated objectives. The response of the adulterated detection unit concerning fuel adulterated with liquids such as water, kerosene, and diesel was evaluated, and the response time it takes to give accurate and stable reading.

7. Results and Discussions.

This section discusses the result obtained after designing, developing and testing of the IoT fuel adulteration detection system. It will include the Hardware development, Software development and System performance evaluation. Figure 4 shows image of the final developed system.

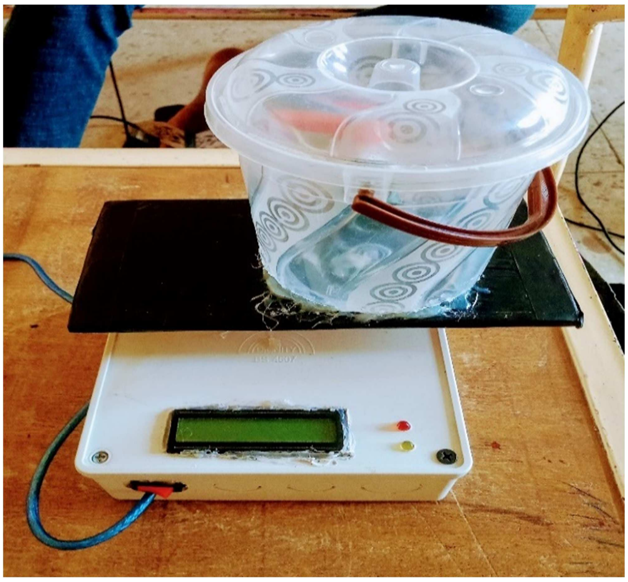

Figure 4: Overall view of fuel adulteration detection system.

C++ was used to program the system and to configure the web-based application to the system developed. The system is made of a PVC (poly vinyl chloride) box integrated with a flat wood surface and a plastic bucket hinged on the flat wood. The flat wood helps to maintain a stable reading from the weight sensor. The weight sensor operates on the Kalman filter technique which maximizes accuracy. The system is powered by a 12-volt battery that has been regulated to 5 volts by an LM7805 integrated circuit.

The result obtained from the construction, development, and testing of the system is discussed and evaluated in this section. The method of evaluation used for this project was based on the accuracy and the response time of the system. The graph in Figure 5 implies the adulteration detection unit of the system which is a weight sensor that easily detects adulterants such as water and diesel.

Results in Table 1 obtained shows the result gotten by the system after few trials. The average response time it takes to sense the weight of the measured liquid is 1.343seconds, according to Table 2. Figure 6 shows the graph of the response time.

The Table 1 shows the density of fuel and it's within the range of unadulterated fuel at different times it was measured in column 1. Column 2 and column 3 shows the density of fuel that is mixed with water and kerosene adulterant respectively. When fuel is adulterated with other adulterants, the density increases as the case maybe in Table 1.

Table 1: Result of fuel and adulterants

S/N	Petrol (Kg/m^3)	Water adulterant (Kg/m^3)	Kerosene adulterant (Kg/m^3)
1	544.01	573.17	562.11
2	542.12	574.15	563.14
3	537.03	572.98	561.02
4	540.03	581.05	566.57
5	544.06	573.04	564.19
6	533.17	571.78	568.18
7	532.08	570.65	565.13

To determine the accuracy of the system, equation 8 was used as metric to evaluate the inputted value and the measured accurate value from the adulteration detection unit.

$$\sigma = \frac{N_c}{T_i} \quad \text{(Lepton, 2013)} \quad (8)$$

Where,
σ = Accuracy
N_c = Number of accurate measured values
T_i = Total number of times it was measured
To determine the precision of the system is how close the values are when repeated several times.

$$\text{Accuracy} = \frac{\text{Measured accurate value}}{\text{total meeasured value}} \times 100 \quad \text{(Lepton, 2013)}$$

Accuracy = 96.37%

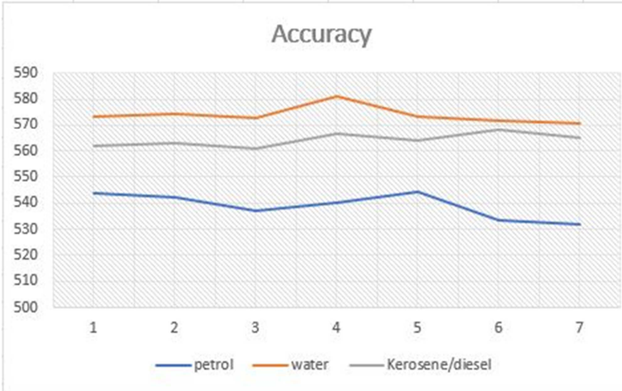

Figure 5: Accuracy graph of fuel and adulterants (water and diesel).

The graph in figure 5 shows the accuracy of the system in detecting fuel and adulterants (water and kerosene). The blue line indicates the result of unadulterated fuel, the purple line indicates the result of kerosene and diesel adulterants and while the orange line indicates the adulterant result of water.

Table 2: Response time

S/N	RESPONSE TIME (SEC)
1	1.3
2	1.2
3	1.7
4	1.5
5	1.2
6	1.1
7	1.4

The Table 2 shows the result of the response time taken for the density of fuel to be measured at every time of trials.

$$\tau = \frac{T_1 + T_2 + T_3 \cdots T_n}{N} \quad \text{(Lepton, 2013)}$$

Where,

τ = Average response time.
T_n = Time at each interval
N = Number of trials taken
So,

$$\tau = \frac{1.3+1.2+1.7+1.5+1.2+1.1+1.4}{7}$$

τ = 1.34seconds

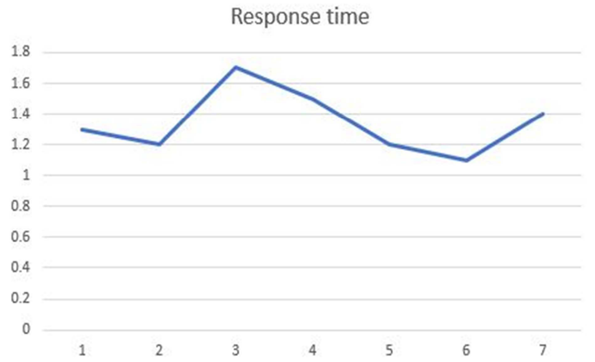

Figure 6: Graph of response time.

The graph in Figure 6 implies the time it takes to measure the weight of fuel to determine adulteration. This implies the system can be used in emergency situations. This means the system is efficient in time management.

Table 4: Bill of Engineering Measurement and Evaluation

S/N	Components	Cost (₦)
1	Pattress box	1,000
2	Arduino Uno	4,500
3	Hx711 + load cell	3,200
4	Wi-Fi module	2,000
5	LCD module	2,500
6	12v power supply	5,000
7	Connecting wires	1,000
8	Servo motor	2,000
9	Others	25,530
	Total	**46,730**

8. Conclusion

This research developed an IoT fuel adulteration detection system that detects the adulteration of fuel and as well increasing the safety of lives and properties. The system detects adulteration based on the density of the fuel and then signifies the automobile users. Thus, creating an immediate awareness of adulteration if detected. Fuel adulteration detection, IoT system and remote monitoring were achieved after the implementation of this project.

9. Recommendation

For future implementation, here is some recommendation to enhance the performance and usability of the IoT based fuel adulteration detection system;

- The subsequent system should improve on the speed and the hardware sensing unit using a powerful controller like the Raspberry Pi and Node MCU.
- Subsequent IoT based fuel adulteration detection system fabrication should be made in such a way that it detects adulteration even before entering the tank.

10. Acknowledgements

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References

[1] V. J. Felix, P. A. Udaykiran, and K. Ganesan, "Fuel Adulteration Detection System," vol. 8, no. January, pp. 90–95, 2015, doi: 10.17485/ijst/2015/v8iS2/59076.

[2] M. De, A. K. Pathak, and V. K. Singh, "Optik Single channel photonic crystal fi ber based high sensitive petrol adulteration detection sensor," *Opt. - Int. J. Light Electron Opt.*, vol. 183, no. November 2018, pp. 539–546, 2019, doi: 10.1016/j.ijleo.2019.03.001.

[3] R. K. Verma, P. Suwalka, and J. Yadav, "Optical Fiber Technology Detection of adulteration in diesel and petrol by kerosene using SPR based fi ber optic technique," *Opt. Fiber Technol.*, vol. 43, no. April, pp. 95–100, 2018, doi: 10.1016/j.yofte.2018.04.011.

[4] G. Joel and L. N. Okoro, "Recent Advances in the Use of Sensors and Markers for Fuel Adulteration Detection : A Review," *Ijrsi*, vol. VI, no. XI, 2019.

[5] I. Haloulos, D. Theodorou, Y. Zannikou, and F. Zannikos, "Monitoring fuel quality : a case study for quinizarin marker content of unleaded petrol marketed in Greece," *Accredit. Qual. Assur.*, vol. 21, no. 3, pp. 203–210, 2016, doi: 10.1007/s00769-016-1199-7.

[6] B. Kanyathare, K. Kuivalainen, J. Räty, P. Silfsten, and P. Bawuah, "A prototype of an optical sensor for the identification of diesel oil adulterated by kerosene," 2018, doi: 10.1186/s41476-018-0071-2.

[7] I. Ofondu, "Fuel Adulteration in Nigeria and its," no. August 2011, 2020.

[8] M. Patil, A. Madankar, and V. Chakole, "Portable Fuel Adulteration Detection System," vol. 4, no. 1, pp. 1–7, 2019.

[9] O. Access, "We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %."

[10] V. Kude and A. Patil, "Detection of Fuel Adulteration in Real Time Using Optical Fiber Sensor and Peripheral Interface Controller," *Int. J. Opt. Photonics*, vol. 11, no. 2, pp. 95–102, 2017, doi: 10.18869/acadpub.ijop.11.2.95.

[11] V. Rawat, V. Nadkarni, and S. N. Kale, "Highly Sensitive Electrical Metamaterial Sensor for Fuel Adulteration Detection," vol. 66, no. 4, pp. 421–424, 2016.

[12] V. P. Sankaran, S. Dubey, and A. Sharma, "Stereolithographic 3D Printed Microfluidic Viscometer for Rapid Detection of Stereolithographic 3D Printed Microfluidic Viscometer for Rapid Detection of Automobile Fuel Adulteration," no. October 2020, 2017, doi: 10.1166/sl.2017.3848.

[13] V. Kude, "Detection of Fuel Adulteration in Real Time Using Optical Fiber Sensor and Peripheral Interface Controller," no. April, 2018, doi: 10.18869/acadpub.ijop.11.2.95.

[14] S. Kulkarni and S. Patrikar, "Fiber optic detection of kerosene adulteration in petrol Fiber Optic Detection of Kerosene Adulteration in Petrol," vol. 050004, no. August, pp. 1–4, 2019.

[15] V. Bhardwaj, V. Bhardwaj, A. K. Pathak, and V. K. Singh, "No-core fiber-based highly sensitive optical fiber pH sensor," vol. 22, no. 5, 2021, doi: 10.1117/1.JBO.22.5.057001.

[16] X. Zhang, X. Qi, M. Zou, and J. Wu, "Rapid detection of gasoline by a portable Raman spectrometer and chemometrics," no. March, 2012, doi: 10.1002/jrs.4076.

[17] B. Kanyathare, "Hand-Held Refractometer-Based Measurement," no. May, 2018, doi: 10.3390/s18051551.

[18] R. Dey and A. Dwivedi, "Design and Simulation of Portable Fuel Adulteration Detection Kit," no. August, 2015.

[19] B. Lv and M. Himanth, "Review on the Detection of Fuel Adulteration through Sensor based Techniques," vol. 7, no. 9, pp. 447–451, 2017.

[20] V. B. U, M. Ramakrishna, M. Nagamani, and S. Kumar, "OpenCV libraries for Benzene Image Processing Applications using Python Programming," no. September, 2020, doi: 10.35940/ijrte.D7392.118419.

[21] R. Ganesan and K. Somasundaram, "PETROL QUALITY ANALYSIS FOR DIFFERENT LEVEL OF ADULTERATION USING THERMAL IMAGNING AND GLCM FEATURES," vol. 14, no. 5, pp. 1043–1050, 2019.

[22] T. Pongsuttiyakorn, P. Sooraksa, and P. Pornchalermpong, "Simple Effective and Robust Weight Sensor for Measuring Moisture Content in Food Drying Process," vol. 31, no. 7, pp. 2393–2404, 2019.