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Investigating Fuel Adulteration Using Arduino as an Engine Protection Device (EPD)

Oluwaseyi Omotayo Alabi[1], Sunday Adeola Ajagbe[2,3]*, Oyetunde A. Adeaga[4], Matthew O. Adigun[2]

[1] Department of Mechanical Engineering, University of Ibadan, Nigeria

[2] Department of Computer Science, University of Zululand, Kwadlangezwa, 3886, South Africa

[3] Department of Computer Engineering, First Technical University, Ibadan, 200255, Nigeria

[4] Department of Mechanical and Mechatronics Engineering, First Technical University, Ibadan, Nigeria

* Corresponding author: 230015266@stu.unizulu.ac.za

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Abstract: This study explores the potential application of an Arduino-based engine protection device (EPD) for detecting tainted gasoline and engine protection. Fuel that has been tampered with can seriously harm engines, raising maintenance costs and lowering fuel efficiency. To look for any irregularities that would indicate fuel adulteration, an Arduino-based EPD can be programed to monitor metrics, including fuel flow rate, temperature, pressure, and quality. However, the precision and sensitivity of the employed sensors, the dependability and toughness of the Arduino platform, and the caliber of the device's programing and calibration will all affect how well an Arduino-based EPD detects gasoline adulteration. In conclusion, with an average mean detection time of 35 s and the ability to find adulteration levels of adulterants in fuel in less than a minute, the use of an Arduino-based EPD to detect fuel adulteration shows promise as a potentially effective and cost-effective solution for protecting engines from damage caused by contaminated fuel. The efficacy of an Arduino-based EPD for detecting gasoline adulteration under various operating circumstances and with various types of fuel needs to be further investigated and tested.

Keywords: Arduino, fuel adulteration, engine protection device, sensor, fuel flow rate.

使用 Arduino 作为发动机保护设备(环保署)调查燃料掺假

摘要：本研究探讨了基于 Arduino 的发动机保护装置(环保署)在检测受污染汽油和发动机保护方面的潜在应用。被篡改的燃油会严重损害发动机，增加维护成本并降低燃油效率。为了查找任何表明燃料掺假的异常情况，可以对基于 Arduino 的环保署进行编程来监控指标，包括燃料流量、温度、压力和质量。然而，所采用传感器的精度和灵敏度、Arduino 平台的可靠性和耐用性以及设备编程和校准的水平都会影响基于 Arduino 的环保署检测汽油掺假的效果。总之，平均检测时间为 35 秒，并且能够在不到一分钟的时间内找到燃料中掺假物的掺假水平，使用基于 Arduino 的环保署来检测燃料掺假有望成为一种潜在有效且成本低廉的方法。保护发动机免受污染燃油损坏的有效解决方案。基于 Arduino 的环保署在各种操作环境和各种燃料类型下检测汽油掺假的功效需要进一步研究和测试。

关键词：Arduino、燃油掺假、发动机保护装置、传感器、燃油流量。

1. Introduction

The purposeful or accidental addition of additional compounds to a fuel, such as gasoline or diesel, can have a negative impact on the fuel's quality and performance. Fuel adulteration is referred to as this. Water, methanol, ethanol, kerosene, and even vegetable oil are some examples of common adulterants. Fuel adulteration is a significant issue that can harm people's health, automobiles, and the environment in several ways. It is crucial for gasoline users to be aware of the dangers and take precautions to safeguard themselves and their vehicles. Some of these precautions include only using reputable gas stations and keeping an eye out for symptoms of adulteration, such as a change in color or smell. Fuel adulteration, commonly known as the illegal mixing of low-quality cheap fuel with high-quality expensive fuel, is a widespread yet global problem in most developing nations [1, 2]. Fuel adulteration is mostly performed to increase profits [3, 4]. Kerosene is typically added to gasoline or diesel to accomplish this. Gasoline dealers may blend indistinguishably high-priced gasoline with comparably lower-priced fuel to boost their profit margin. Petrol and diesel of varying amounts and octane rating-inspired quality have varied prices. When using contaminated fuel, the performance quality of engines powered by gasoline and diesel may suffer. For instance, fuel adulteration can result in incomplete combustion, which raises the air's tailpipe emissions of hydrocarbons [5, 6], carbon monoxide (CO), nitrogen monoxide (NO), and particulate matter (PM) [7, 8]. The price difference between kerosene, petrol, and diesel influences dishonest merchants to mix kerosene with petrol and diesel to achieve a high profit margin. This type of kerosene mixing with petrol and diesel is more severe in rural areas. Kerosene is tough to burn. Therefore, kerosene-mixed petrol and diesel not only hamper the proper functioning of the engine but also lead to high emissions of carbon, carbon monoxide, and nitrogen monoxide, among others [9-11]. However, fuel adulteration that goes above a particular point is harmful to the environment and living things, according to a WHO assessment on urban air pollution [12, 13]. Furthermore, fire mishaps caused by contaminated fuel damage may occasionally result in serious injuries or even the loss of life and property [14]. However, because there are no globally controlled on-the-spot monitoring techniques, persistent fuel adulteration is still a possibility.

In the event of a breakdown or malfunction, an engine protection device (EPD) is a safety system intended to prevent harm to the engine or other connected components. The EPD monitors several variables, including temperature, pressure, speed, and fluid levels, and acts to stop additional damage if any of these variables exceed safe limits. For instance, the EPD may sound an alert or switch off the engine to prevent additional damage if the engine oil pressure falls below a specified threshold. Similar to this, the EPD may turn on a cooling fan or lower the engine's load to prevent overheating if the engine coolant temperature exceeds a safe limit. To prevent damage to costly and important equipment, EPDs are frequently used in industrial applications such as power generation, marine propulsion, and heavy machinery. To avoid catastrophic engine failure and ensure safe operation, they can also be used in cars and other vehicles. An EPD is critical to safe and reliable running of engines and related equipment; therefore, it is important to maintain and test these devices on a regular basis to ensure that they are working properly. Technology-based methods for detecting fuel adulteration have advanced. Checking qualities, including density, viscosity, color, odor, and specific gravity, are only a few of the procedures that are currently in use [15, 16]. Other tests include titration and ultrasonic techniques. However, the methods outlined above have significant measurement flaws that could impact their sensitivity and overall performance. Additionally, some of these methods require time-consuming and expensive laboratory procedures. Various research groups have previously reported on several optical fiber- and Bragg grating-based fuel adulteration sensors [17, 18]. Despite having a high sensitivity, these optical fiber sensors have weaknesses such as fragility, immobility, and cross-sensitivity [19].

Recent years have seen the development of photonic crystal fiber (PCF)-based sensors for the detection of liquids, such as simple alcohol, hydrocarbons, water, blood components, and chemical warfare nerve agents [20-22], particularly for use in the terahertz (THz) region of the electromagnetic spectrum, which is located between the infrared and microwave spectra. Advanced optical fibers, known as PCFs, are more adaptable in terms of design and application than standard optical fibers. A porous core PCF-based alcohol sensor was modeled by [23]. Concealment loss (CL) measured by the sensor was approximately 7.79. On the other hand, the model had a low sensitivity of only 68.87% and a high effective material loss (EML) of approximately 0.05 cm [24]. The sensor had a CL of 1.7, which was slightly higher. Using information regarding an unexpected drop in gasoline level, along with the date and location of the incident, [25, 26] proposed developing a system that can identify vehicle fuel theft and SMS the owner or person in charge (PIC) of the vehicle with the relevant information.

This paper describes the use of Arduino as a device for tracking products during transportation, adulteration detection, and engine protection. Engine protection devices can be created using Arduino, a well-liked open-source electronics platform that can be used for a variety of applications [27, 28]. The Arduino platform's adaptability and programmability make it a great option for creating unique EPD solutions that can satisfy certain needs and requirements. Among the applications of Arduino for engine safety gears are monitoring and regulating engine settings. Sensors can be installed on Arduino boards to track engine characteristics such as temperature, pressure, and speed. An Arduino microcontroller can be used to process the data gathered from these sensors in real time and manage the engine's performance. A strong and adaptable platform is provided by Arduino for creating unique engine protection systems that can deliver a high level of safety and dependability. Due to the flexibility of the Arduino platform, EPDs can be customized to match unique needs and specifications, which makes them a fantastic option for various applications.

2. Methodology

2.1. Materials and Methods

The gasoline-detecting system has a breadboard-friendly Arduino Nano based on the ATMega328, a liquid crystal display (LCD), and a mini-submersible pump employing a brushless DC motor. Fig. 2 and 3 show the Arduino Nano base and the mini-submersible pump, respectively. A GTS200 DS18B20 temperature sensor, which is part of a new generation of adaptive intelligent temperature sensors, is used in this diesel screening system. It can directly transform temperature information into serial digital signals for processing by computers. Measurement accuracy and long service life are improved using tight welding and assembly procedures.

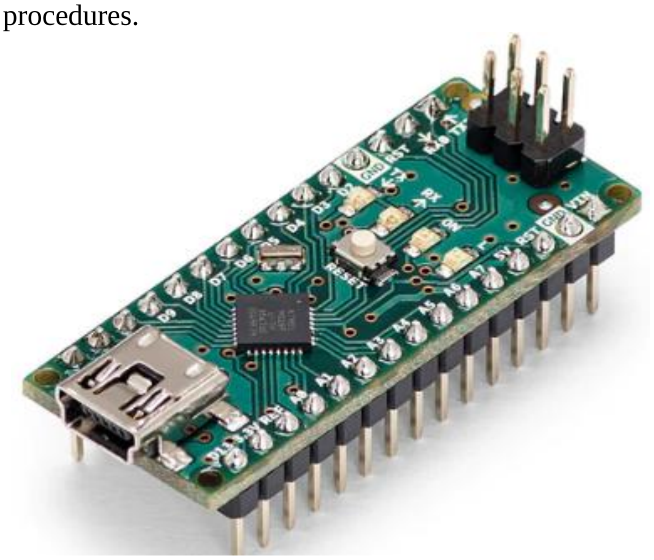

Fig. 1 Arduino Nano board

Fig. 2 Mini submersible pump

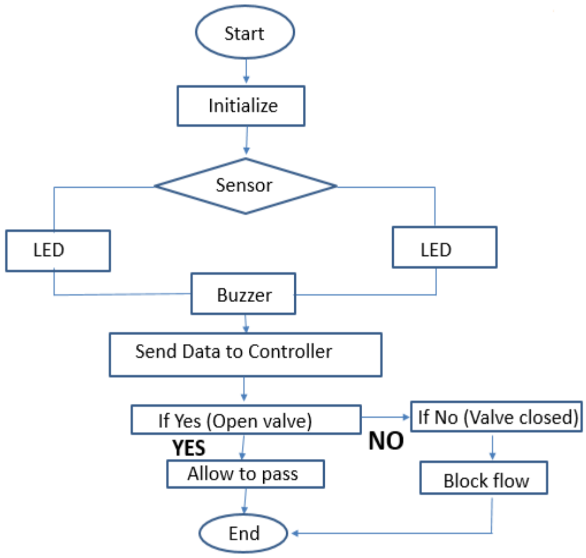

Fig. 3 The sensing system design flowchart and algorithm

To detect contaminated fuel, active and chronological algorithms will be used, as indicated in Figure 3. The active algorithm is a closed-loop blocking technique that uses feedback from obstructing the flow of adulterated fuel as a control basis. The system's microcontroller (ATMega328), which measures temperature, receives data from a temperature sensor. The microcontroller uses the gathered values to analyze and control the submersible pump that enables or prevents fuel flow. The system does a good job of measuring diesel temperature in an ambient environment, but performance may suffer from fuel variations. As depicted in the block diagram, the microcontroller panel shares a plate with LEDs and buzzers. The diesel temperature readings are not constant because of their innate attribute of humidity. Following startup, the microcontroller sends the appropriate signals to the sensor for detection after running the programs. The detection sensor senses the adulteration rate and regulates the gate of the pump or valve. Fig. 4 shows a block diagram of the fuel adulteration system. Fig. 5 shows the experimental setup. The valve stays closed if the fuel is tainted, but opens if the fuel is pure.

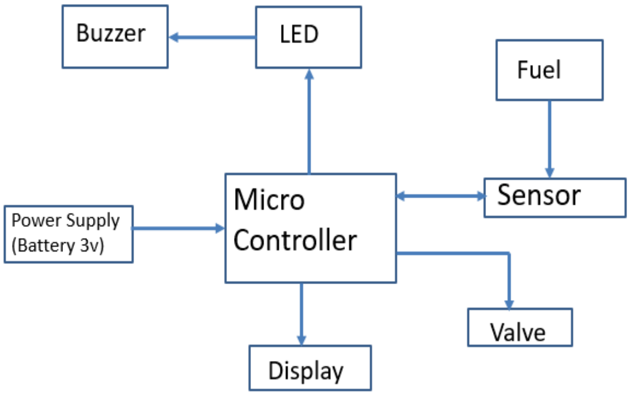

Fig. 4 Proposed block diagram of the design

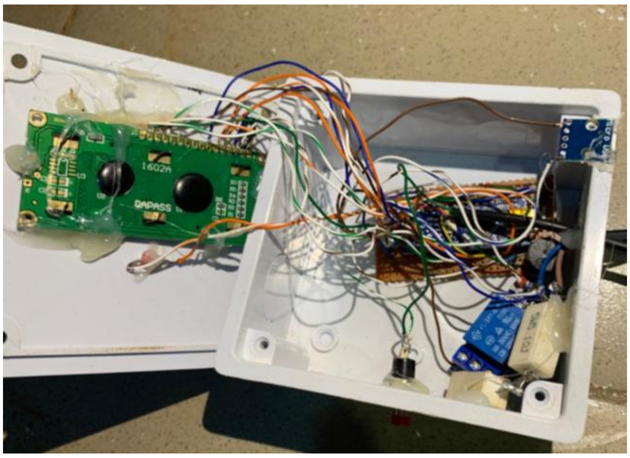

Fig. 5 Experimental setup

2.2. Material Selection

Table 1 shows the material selection for this study.

Table 1 Materials used

S/N	Component	Possible Materials	Selected Material
1	Arduino Board	Arduino Nano	Arduino Nano
2	Microcontroller Unit	ATMega328	ATMega328
3	Temperature Sensor	Thermistor, Semiconductor-based	Thermistor Probe (GTS200 DS18B20)
4	Pump/Valve	Dynamic Pump, Submersible pump	Mini-submersible pump
5	Power Supply		A 3v lithium battery
6	Flexible Wires	Breadboard wires Solid core wires (22 gages) Conductive thread	Breadboard wires
7	Relay Module	Electromagnetic relay Reed relay High-voltage Time delay relay	Time delay relay
8	Buzzer	Piezoelectric buzzer Magnetic buzzer Mechanical buzzer	Piezoelectric buzzer

2.3. Implementation of the Description Program

Connecting the device to a power source causes it to start. Various measurements at constant temperatures were made. With the help of the pinMode(pin, mode), the necessary analog pins are chosen as input. When the reset button (v0) on the ATMega328 is depressed, the analog values are read and converted into integer values between 28.5 and 29.50 C using four selected variables. The test can be repeated numerous times while the liquid crystal display (LCD) shows the percentage of adulteration if the recorded temperature is outside the calibrated range and the microcontroller controls the valve to block and activate the buzzer.

This investigation was programed using open-source software Arduino IDE. It makes it easier to write and upload code to the Arduino Nano microcontroller. Using this offline IDE, the installation file was downloaded from the company's official website, www.arduino.cc, onto a Microsoft Windows 10 Pro PC. The program was opened following installation, and coding to control the servo angle and orientation began after the installation of the "library." The Arduino software runs in the "void setup()" and "void loop()" default routines. The void setup() function is called once when the microcontroller is turned on, and the void loop() function is called continuously as long as the microcontroller is powered. Hardware components were quickly necessary to test the software code.

The adulteration detection system is made economically and sustainably using an Arduino Nano board with 20 pins, an LCD, resistors, a temperature sensor, a submersible pump, and a battery (to power the pump). The delivery of the hardware component was prompt. By testing the program on a breadboard, this idea was put into practice. The hardware components were connected in accordance with the circuit schematic provided for this report on a solderless board, often known as a breadboard, to ensure that the circuits worked before the components were soldered on a Vero board.

To determine various properties of diesel, several alternatives were considered in this study, including an artificially based model, NMR imaging, a titanium dioxide sensor, a microwave sensor, and a gas vapor emission approach. Microcontrollers and other communication systems have been intensively researched. The design's uniqueness lies in the incorporation of a very sensitive funnel that prevents contaminated fuel from passing through it. Because of its excellent reliability, an autonomous system like this one will increase workflow and decrease the need for human labor. On a breadboard, the project was successfully implemented, and each step was executed as planned and met the expected objectives.

3. Results and Discussion

3.1. Smart Home Monitoring System

The process of locating and quantifying the presence of foreign substances or contaminants in a product, such as food, medication, or fuel, that may jeopardize its quality or safety is known as adulteration detection. In the case of fuel adulteration detection, monitoring several metrics, such as fuel flow rate, temperature, pressure, and quality, entails looking for any irregularities that would suggest adulteration. The detection of adulterated fuel can be performed in several ways, including laboratory testing, chromatography, spectroscopy, and electronic sensors. To detect fuel adulteration, electronic sensors, such as those found in an Arduino-based EPD, can be a practical and reasonably priced option. Table 2 compares the percentage of adulteration and the time of detection. The graph shows that it takes a lot of time to detect fuel with a significant percentage of adulteration. The increase in the rate of adulteration is explained by the decrease in temperature. Fig. 6 displays the described extrapolated graph of Table 2.

Table 2 Adulteration detection

TEST	ADULTERANT (%)	TIME (s)
A	24	19.5
B	44	14.7
C	49	16
D	59	11.8
E	71	11
F	97	1.9

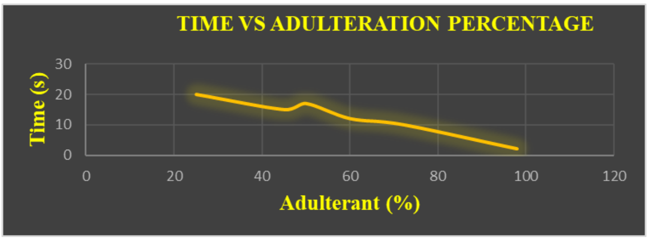

Fig. 6 Time vs. adulteration percentage

A mixture's purity can be determined by its temperature. Pure substances often have clearly defined melting and boiling temperatures, and their temperature does not fluctuate during phase changes. In contrast, contaminants can cause substances to have a wide range of melting or boiling points and cause temperature fluctuations during phase shifts. For instance, if a fuel is adulterated, the presence of pollutants may cause the fuel's boiling point to vary, changing the temperature at which the fuel boils. Consequently, keeping an eye on a fuel mixture's temperature might be a good approach to assess its purity and spot fuel adulteration. Temperature might not be sufficient to assess a mixture's purity on its own. The mixture's specific heat capacity, pressure, and volume, among other things, can also affect the temperature. To accurately determine the purity of a combination, temperature measurements should be used in conjunction with other analytical techniques such as spectroscopy or chromatography. The temperature of the percentage combination in relation to purity is shown in Table 3. The extrapolated graph of Table 3 is depicted in Fig. 7. This shows that lowering the temperature of the tested sample lowers the purity of the sample.

Table 3 Temperature of percentage purity and mixture

TEST	MIXTURE	PURITY (%)
A	18	25
B	20	50
C	23	58
D	27	84
E	29	99

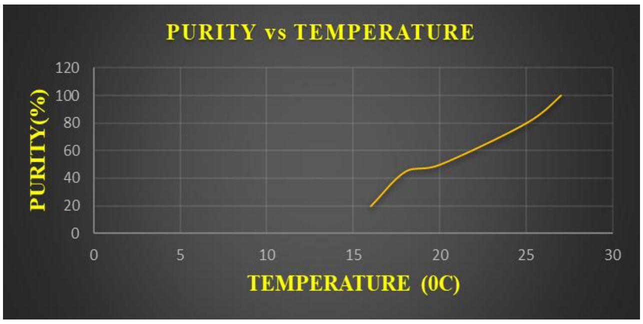

Fig. 7 Time versus adulteration

4. Conclusion

Practically speaking, an Arduino-based EPD's ability to detect fuel adulteration will be influenced by several variables, including the precision and sensitivity of the sensors used, the dependability and toughness of the Arduino platform, and the caliber of the device's programing and calibration. To assure the EPD's efficiency and dependability, it will also need to be tested and validated under a variety of operating circumstances and with a variety of fuels. With an average mean detection time of 35 s and the ability to identify adulteration levels of adulterants in fuel in less than a minute, the use of an Arduino-based EPD to detect fuel adulteration shows promise as a potentially efficient and cost-effective solution for safeguarding engines from damage caused by contaminated fuel. To validate this strategy and improve its performance for various applications and operating environments, further study and experimentation are necessary.

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