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Design and Implementation of an IoT-Based Smart Fuel Filling System for Efficient Resource Management

Muneer Sadeq ALqazan[1*], Monji Kherallah[2], Fahmi Kammoun[3]

[1]University of Sfax, National School of Electronics and Telecommunications of Sfax, BP 1173, Sfax, 3038, Tunisia. Computer Engineering Technology Department, al Maaref University College.
[2]University of Sfax, National School of Electronics and Telecommunications of Sfax, BP 1173, Sfax, 3038, Tunisia.
[3]University of Sfax, National School of Electronics and Telecommunications of Sfax, BP 1173, Sfax, 3038, Tunisia.

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Research Paper

Abstract: *Oil is a significant driver of the global economy, and the efficient transportation of oil derivatives to petrol stations is crucial for fuel distribution. However, manually running petrol pumps presents several challenges, including the need for labour, accuracy issues, fuel smuggling, fluctuating oil prices, database upkeep, and environmental pollution. This study leverages the capabilities of the Internet of Things (IoT) to detect, communicate, and exchange data autonomously, without human intervention, in order to tackle these issues. The objective of this project is to utilize IoT technology in order to create a sophisticated system for three filling stations. This system will enable the simultaneous monitoring and control of the stations using a web application. The suggested system incorporates an algorithm that enables automatic fuel loading using Radio Frequency Identification (RFID) cards. The platform's encrypted dashboard ensures authorized access through the use of data encryption, employing the Advanced Encryption Standard (AES) algorithm and a hash function. The efficacy of the proposed system is assessed in the Proteus programme using code from the Arduino IDE. This demonstrates its complete automation capabilities, including gas leak prevention, fuel filling, and fire detection and extinguishing. Simulation results demonstrate that our proposed solution surpasses established methods such as Kuhn Munkres (KM) or deep neural network (DNN) techniques as the complexity of the problem increases. Moreover, our proposed scheme surpasses the KM algorithm in terms of execution time, significantly outperforming the DNN technique. This provides a more efficient method for allocating resources in intelligent fuel filling systems. In addition, the system exhibits a high level of precision ranging from 0.075 to 0.025 during petrol filling processes. The system use the Internet of Things (IoT) protocol to capture and store data pertaining to*

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[*]Corresponding Author: munir.iq@gmail.com (M. S. ALqazan)
monji.kherallah@fss.usf.tn (. M. Kherallah), kammoun@yahoo.fr (F. Kammoun)

customers, sales, and the environment. This is achieved by connecting all devices and sensors to a centralized node on the Internet. This guarantees comprehensive data administration.

***Keywords**: IoT, Smart Fuel Filling System, Real Time Monitoring, Resource Management, Fuel Efficiency, Sensor, Network, Cloud Computing, Remote Monitoring.*

1. Introduction

Time-saving gains have resulted from recent technological breakthroughs that have reduced human labour while improving general convenience of life. These days, the IoT is becoming more and more popular because of all of its benefits, which help systems operate faster, more dependably, and more effectively (Javed et al., 2018). Direct human-to-human or human-to-computer interaction is not required by the IoT system (Khatun et al., 2019). Due to its global accessibility and remote management capabilities, the IoT-based system is a strong candidate in the IT and technology industry. This technology is widely utilised in several areas such as online banking, healthcare, tax preparation, smart gas pump systems, and others (Gupta et al., 2016). Fuel filling systems become intelligent fuelling infrastructure when IoT technology is integrated with them, significantly increasing the system's efficiency. This IoT enabled intelligent refuelling station is essential for tracking how fuel is used efficiently, particularly in sectors of the economy that rely on the production of oil for manufacturing and other power-generating activities. This advanced fuelling system encourages controlled fuel consumption in addition to providing the vendor with exact cost analysis (Zahra'a & Motlak, 2021). Furthermore, numerous individuals are documenting occurrences of fuel stealing at petrol stations as a result of the continuous escalation in fuel expenses. This typically arises as a result of drivers not accurately predicting how much fuel their automobiles will use on a daily or weekly basis. In order to reduce financial losses caused by vehicle fuel theft, it is crucial to implement timely measures such as real-time tracking in an efficient products transportation system (Khatun et al., 2019).

Interest in deploying group based IoT devices in the sphere of fuel distribution and administration has increased as a result of growing knowledge of the drawbacks of individual petrol dispensing and data collection. One key option that allows data collection modules and communication units to share resources is the construction of an integrated sensing and communication (ISAC) system (Cheng et al., 2022). When combined with the right resource allocation methods, this integrated approach could make a big difference in the problems that come up because of not having enough resources or not using them well enough in the field of fuel management.

In this work, we have used IoT based technology to develop an intelligent fuel filling system that will improve our resource management. Our technology aims to leverage IoT technologies to improve and simplify the fuel filling procedure. Accuracy, dependability, and overall efficiency will all increase as a result. In order to construct a smart and automated system, the recommended system also makes use of a collection of networked devices, such as sensors, actuators, and gearbox modules. These gadgets enable real-time monitoring and control of the fuel filling process and are compatible with the existing fuel dispensing system. We introduce a novel reinforcement-learning approach that differs from existing approaches requiring large amounts of compute or data. Moreover, we develop a new reward function by combining fuel delivery accuracy (FDA), representing fuel dispensing performance, and communication rate (CR), denoting wireless communication efficiency. In addition to this, we delve into the design and implementation of the IoT-based smart fuel filling system, exploring various components, technologies, and methodologies. The paper also addresses the resource allocation challenge for groups of IoT devices in fuel stations, aiming to find a balance between fuel dispensing accuracy and communication performance. While the problem is formulated as an optimization task, traditional resource allocation methods struggle with efficiency due to the complexity associated with multiple IoT devices.

2. Literature Survey

A filling station is a place where you can buy gasoline for your car. Diesel fuel is another common type of fuel sold at these stations. People might know a traditional filling station as a gas station, gasoline stand, or petrol pump. The design of the gasoline pump system depends on factors like the station's size, the volume of business it handles, and the types of motor fuel products available.

Tandon et al. (2022b), advocates for the implementation of a contemporary petrol dispensing system, leveraging RFID technology. Their concept incorporates an RFID-enabled method for petrol distribution, together with a prepaid card system specifically designed for petrol stations. Through the use of an electronic clearing mechanism, this technology makes consumer transactions easier. The proposed approach aims to relieve the limitations of manually operated gas pumps by transitioning to an automated framework. The selection of RFID technology is based on its versatility and ease of use, which has been demonstrated to be highly effective in real-time applications. The primary goals of this strategy are to ensure accurate gasoline supply, minimise human error through the utilisation of RFID cards, and instil consumer trust in the equitable distribution of the product. The automated fuel stations of this style offer various advantages, including decreased labour expenses resulting from self-service automation.

Krishna et al. (2022a) Krishna et al. (2022b)has proposed a solution that involves the implementation of an RFID-powered automated fuel pump system. Using UART ports, an Arduino microcontroller is linked to the RFID reader (EM-18). One of the components of the system is an AC pump, which is run by a relay that is linked to an Arduino digital pin. A keypad is also present and is linked to additional digital pins on the Arduino. The initial stage in this task's operational method is to swipe an RFID card and enter a password. The user is prompted to enter the necessary quantity by the system once the password has been successfully verified. After that, the pump is turned on, and fuel is dispersed based on the specified amount. In the event of an incorrect password, a buzzer is triggered, and for insufficient funds, another buzzer is activated. Their implementation employs a microcontroller to integrate a smart card reader/writer into the petrol pump system. At the pump, the driver utilizes a smart card, and the reader retrieves and displays the card's available amount on the LCD. The driver then inputs the desired quantity of petrol through a keypad. The corresponding amount is calculated and deducted from the card. The electric pump is activated according to the entered amount, facilitating the tank filling process, and automatically deactivates upon completion. The electronic system successfully executed all outlined functions, overcoming challenges associated with microcontroller interfacing with hardware components. There work is designed as a security system with restricted access for authorized personnel. Certainly, their proposed design constitutes a noteworthy contribution to the domain of Smart Fuel Petrol Management Systems.

Naveen et al. (2019) underscores the development of a system designed to autonomously dispense fuel and deduct the corresponding amount from a prepaid RFID card. In their proposed system, individual users are equipped with RFID cards, preloaded with specific amounts. The fuel station dispenser is integrated with an RFID reader, responsible for reading the RFID card and displaying the available balance on an LCD unit. Upon entering the desired fuel quantity via the keypad, the system calculates the operational duration for the electric fuel pump and initiates the fuel dispensing process. The technology automatically shuts off the pump once the user-defined threshold is reached. A Raspberry Pi module is integrated into this infrastructure to deliver user notifications through a mobile application. Furthermore, the system is equipped with a purity sensor to assess the quality of the fuel and a fire sensor to detect any fire hazards. Consequently, this initiative aims to revolutionise the management of fuel stations by eliminating geographical limitations and reducing the need for a substantial worker. Consequently, their proposed design constitutes a substantial contribution to the realm of smart world technology.

According to Xu et al. (2019) the development of a fleet management platform that leverages cloud technology and the IoT to its full potential is underway. The idea offers a Transportation Management Service Sharing (TMSS) mechanism that makes it simple and affordable for different transportation service providers to use the platform. Other parties involved profit from this as well. Furthermore, a relation-based data extraction approach is posited to effectively extract comprehensive transportation data throughout the entire process. Additionally, a meticulously devised transportation data synchronization mechanism ensures the consistency of the data. Hence, their proposed design and approach are exceptional, deserving significant recognition within the field.

From the literature survey we observed that reinforcement learning, especially in smart fuel filling systems, is recognized for its potential in optimizing resource allocation by adapting to environmental changes and decision-making based on reward functions. ISAC systems, facilitating resource sharing among data acquisition and communication units, are gaining popularity in fields like fuel distribution. While methods like the Kuhn Munkres algorithm and Deep Neural Networks have been used for resource allocation, they may have computational limitations and perform less effectively as problem complexity increases. Ongoing research in RFID-based smart fuel filling systems and related areas, such as predictive maintenance and blockchain technology, offers insights into improving the efficiency and resource management of petrol pump operations through IoT-based approaches, thus giving a room for more in dept research that could benefit the research community.

3. Methodology

To put the suggested Smart IoT-based Reinforcement Learning Fuel Filling System into action, we can adopt a well-organized approach. This proposed method is broken down into different phases to ensure clarity and more effective task management as shown in Figure 1.

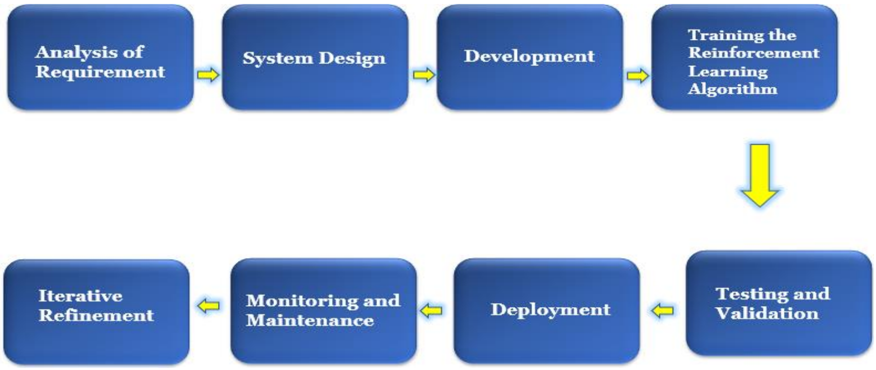

Figure 1: Phases of the Followed Methodology.

When you fill up your tank, the rising liquid level acts like a piston, pressurizing the upper half's air and vapor. When the tank is full, the rising liquid level compresses the air and vapor in the upper part of the tank, much like a piston. Conversely, as the liquid level drops during fuel delivery, the pressure decreases. Without proper venting, high pressures could damage the tank and cause leaks, while low pressures might strain the pumping system, hinder fuel deliveries, or lead to vaporization in the delivery lines. To prevent such issues, storage tanks have vent pipes with relief valves to maintain the desired pressure level inside the tank. Underground tubes transport fuel from the storage tank to the dispenser. There are three main types of storage tank forms used for bulk storing of organic liquids: internal floating roof, fixed roof, and external floating roof. To prevent fuel from evaporating due to temperature differences, pipelines need to be buried deeply. Gasoline, being suctioned under negative pressure within a pipeline, tends to evaporate when heated. If fuel dispensing systems are improperly installed, vapor lock can occur, especially when fuel flows from a very cold storage tank into warmer pipelines. The issue of optimal resource allocation has been studied in various contexts. A deep reinforcement learning approach is considered for resource allocation in wireless networks, with a focus on radar sensing systems. In the context of cloud computing, strategies for dynamic resource allocation were explored to improve performance and energy efficiency. In the realm of machine-to-machine communications, an energy-efficient approach to resource allocation was examined as part of Internet of Things technology.

4. Requirement Analysis

During this stage, we will thoroughly examine the existing fuel filling system. The aim is to identify any issues and better grasp the system's requirements. We'll conduct interviews with key stakeholders, including station managers and customers, to understand their needs and gather suggestions.

4.1 System Design

The insights gathered during the requirement analysis will shape the creation of the new system. In the design phase, we'll pick suitable IoT devices and sensors, formulate the ISAC system design, and outline the structure and reward function for the reinforcement learning algorithm. Additionally, we'll develop a thorough design for the user interface.

4.2 Development

During this phase, the system will be built in compliance with the established design guidelines. The establishment of the ISAC system and the subsequent installation and testing of IoT devices at the fuel dispensing units are examples of implementation efforts. Moreover, the ISAC system will be smoothly connected with the programmatically built reinforcement learning algorithm.

4.3 Training the Reinforcement Learning Algorithm

After system development is finished, the reinforcement learning algorithm will be trained with synthetic data or, if available, historical data. This training process is essential to the algorithm's ability to learn the best course of action under various circumstances.

4.4 Testing and Validation

There will be a thorough testing period before distribution is finished. This means analysing how well IoT devices perform, how well the ISAC system communicates, how carefully the reinforcement learning algorithm makes decisions, and how well the user interface is validated. To determine its expected functioning, the system will be validated in multiple scenarios.

4.5 Deployment

The fuel stations will implement the system once testing and validation are completed successfully. At first, the system may only be deployed to a small number of stations to see how it functions in an actual setting.

4.6 Monitoring and Maintenance

Once the system is operational, it will be constantly monitored for any possible problems. The system will undergo routine maintenance to ensure smooth functioning. The effectiveness of the system will be evaluated on a regular basis, and any necessary additions or modifications will be made in accordance with the results.

4.7 Iterative Refinement

The system will be iteratively refined in response to user feedback and continuous performance assessments. This could involve user interface adjustments, reinforcement learning algorithm improvements, or design revisions.

The creation and deployment of the Smart IoT-based Reinforcement Learning Fuel Filling System can be effectively managed and completed by following this suggested process. In addition, the gasoline dispenser dispenses the fuel in addition to calculating its cost. In order to control the distribution of gasoline, avoid overfilling and draining, and guarantee that the capacity and price-registering components are reset to zero at the beginning of each supply, the dispenser is outfitted with a number of control mechanisms.

4.8 Design and Implementation

By utilising IoT technology for remote management and monitoring, the suggested system seeks to create an intelligent petrol station. The system is made up of three smart petrol pumps, each with different hardware parts. It connects to a local or cloud server over the internet. This configuration makes it easier to monitor the fuel level, identify fires, automatically dispense fuel, test fuel temperature, and detect fuel levels. A web application that may be used on desktop computers or mobile devices is used to retrieve and process the collected data. An extensive synopsis of the proposed system's architecture and components is given in this section.

4.9 Proposed System Architecture

The architecture of the proposed system is designed to facilitate communication and data exchange between the fuel pumps and the server. The Figure 2. delineate the constituent elements of the system architecture.

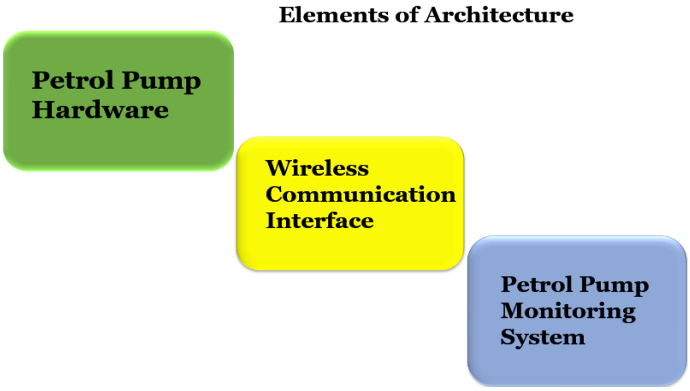

Figure 2: Element of the Proposed Architecture.

4.10 Petrol Pump Hardware

An NFC RFID reader, temperature sensors, fuel level sensors, fire safety features, and environmental monitoring sensors make up the hardware setup. The Arduino Mega 2560 and ESP-32S microcontrollers are used to enable the programming, connection, and computational operations.

4.11 Wireless Communication Interface

The communication between the server and the hardware system of the fuel pump is established wirelessly utilizing the ESP-32S module. This wireless connectivity enables both data transfer and remote monitoring capabilities. The reward function, crucial in the system's operation, is conceptualized as a weighted sum incorporating fuel delivery accuracy (FDA) and communication rate (CR).

$$R(s) = w1 \cdot F\,DA(s) + w2 \cdot C\,R(s) \quad (1)$$

In simpler terms, the system's condition, denoted as "s," is considered, and there are weights assigned to fuel delivery accuracy (FDA) and communication rate (CR), represented by "w1" and "w2" respectively.

In the Q-Learning framework, the update procedure for the Q-value associated with a state-action pair is performed as follows:

$$Q (s, a) = (1 - \alpha) Q (s, a) + \alpha (r + \gamma \max Q (s', a)) \ (2) \qquad a$$

To address the exploration-exploitation trade-off, an epsilon-greedy policy is employed. At each state, the agent selects a random action with a probability of ε or chooses the action with the maximum Q-value with a probability of 1 – ε.

4.12 Petrol Pump Monitoring System

The local server for the fuel pump monitoring system is facilitated by the IoT ThingsBoard server operating on a Raspberry Pi. It streamlines data gathering, processing, visualization, and system management. The ThingsBoard web application's user interface allows the accessibility and visualization of the collected data through any web browser on smart devices or desktop PCs.

4.13 Components of the Proposed System

Our envisaged solution entails a sophisticated fuel filling system integrating IoT devices and reinforcement learning. The primary objective of this system is to refine resource allocation, thereby augmenting fuel dispensing accuracy and communication performance. The principal components of this system is shown in Figure 3.

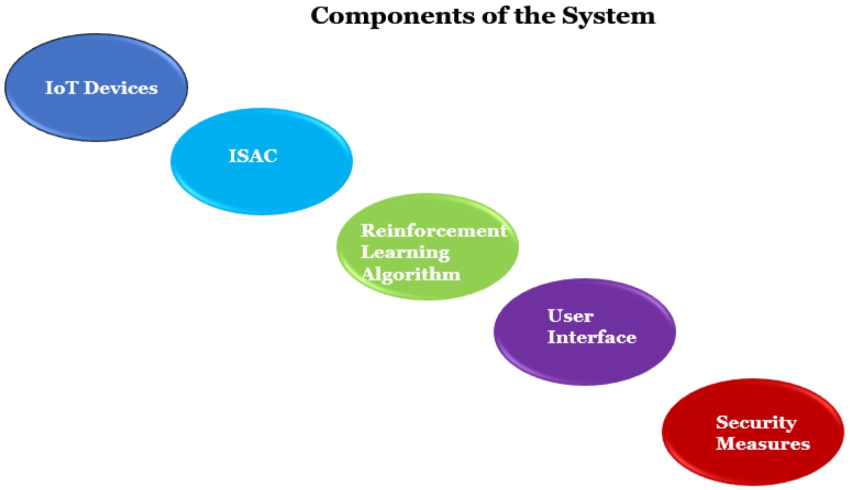

Figure 3: Component of the Proposed Architecture.

4.14 IoT Devices

These components consist of sensors and actuators deployed at individual fuel dispensing units. Sensors have the capacity to observe diverse variables, including fuel levels, customer identification, and dispensing rates. Concurrently, actuators possess the capability to regulate the flow rate of the fuel in accordance with decisions formulated by the reinforcement learning algorithm.

4.15 Integrated Sensing and Communication System (ISAC)

This constitutes the core framework of the system, assuming responsibility for data collection, processing, and communication. It acquires data from the IoT devices, undergoes processing procedures, and facilitates its availability for the reinforcement learning algorithm (Cui et al., 2021). Additionally, the ISAC ensures streamlined communication among various components of the system (Liu et al., 2022).

4.16 Reinforcement Learning Algorithm

This constitutes the decision-making module of the system, responsible for assimilating processed data from the ISAC. Employing the reinforcement learning methodology, determines the optimal allocation of resources (Gullapalli, 1990). Decision factors may encompass customer type, available fuel quantity, and the station's peak hours. The algorithm's design aims to optimize a reward function that integrates fuel delivery accuracy and communication rate.

4.17 User Interface

This comprises both a web or mobile application tailored for station managers and a user-friendly interface situated at the fuel dispensing units for customers. Station managers can actively monitor the real-time status and performance of the system through the application. Simultaneously, customers are afforded the convenience of seamlessly conducting transactions through the user-friendly interface at the fuel dispensing units.

4.18 Security Measures

Considering the crucial nature of the data and operations involved, the system will integrate robust security measures. These encompass data security through encryption, secure authentication methods, and safeguards against both physical and cyber threats.

The proposed system stands as a practical manifestation of IoT and reinforcement learning within the fuel distribution sector. By automating and optimizing the fuel filling process, the system has the potential to elevate operational efficiency, enhance customer satisfaction, and contribute to environmental sustainability. Implementation would entail an exhaustive feasibility study, meticulous system design, pilot testing, and iterative refinement guided by feedback and performance evaluation.

The overall summarize architecture of the system is shown in Figure 4.

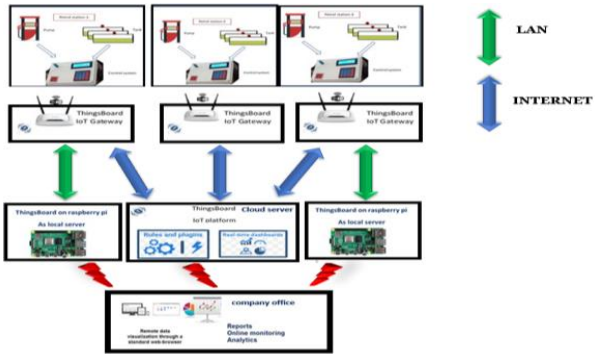

Figure 4: Proposed Architecture of the System.

5. Results and Discussion

The outcomes of the devised system are presented in this section, generated through programs executed in the PROTEUS environment, Arduino IDE, and the IoT platform. The computations were conducted on a laptop equipped with an Intel Core i5 CPU and 24.00 GHz RAM, operating on the Windows 10 platform. The results are categorized into two sets: the initial set delineates the simulation results of the subsystem prior to integration with the IoT server, while the second set encapsulates the outcomes following the implementation of the entire system in real-world scenarios.

5.1 Practical Implementation of the Results

The customer interface, an integral component encompassing an LCD screen, NFC RFID reader, temperature and humidity sensor, and keypad membrane, is incorporated within the petrol pump hardware system. The physical attachment of the gasoline pump's nozzles is a notable feature.

The LCD screen initially delineates the operations conducted by the power board when the letter buttons on the keypad are pressed upon the application of power. The initiation involves pressing the letter A on the keypad to verify the balance in the RFID tag. Subsequently, the LCD screen prompts the user to insert their card for the balance verification process. Upon pressing letter B, a message prompts the user to input their card for updating, and subsequent confirmation of the card's ID elicits an inquiry regarding the desired amount for recharge, with the revised quantity and total amount displayed upon entry.

The letter C, when pressed, activates the fuel-dispensing function, a shared functionality for both regular users (whose balance is deducted post-fuel fill-up) and government users (whose fuelling debts are recorded on the government's account but do not reflect on their card balance). Following the pressing of C, the LCD screen requests the consumer to input their card for identification purposes.

Upon successful identification of the card ID and determination of the customer type, the system prompts the customer to input the desired fuel quantity. Subsequently, when a quantity less than the available fuel on the card is entered, the fuelling process commences. The LCD screen concurrently displays both the deducted amount from the card and the volume of fuel dispensed. The subtraction of quantity error is employed, considering the low error rate inherent in the fuel meter.

This system integrates an Ultrasonic fuel level sensor strategically positioned at the apex of the primary fuel tank. The Arduino Mega microcontroller encompasses an integrated ultrasonic sensor. Additionally, the inclusion of a DS18B20 digital thermometer facilitates the measurement of fuel temperature upon its entry into the main fuel tank. This enables the prediction of fuel density and the rate of evaporation. A fuel thermometer is also embedded in the ESPS-32 microprocessor.

5.2 Evaporation Rate

Given that the pressure is directly proportional to the fuel height, a metric determined through the employment of the ultrasonic sensor as illustrated in the subsequent equation (1), a consequential outcome is observed wherein evaporation escalates in tandem with the decrease in pressure.

Pressure = density × g × h (1)

In order to empirically quantify the evaporation characteristics of both gasoline and diesel, a series of experiments were systematically conducted. The outcomes of these investigations yielded Equation (2) for gasoline and Equation (3) for diesel, thus culminating in the formulation of respective empirical equations.

Percent Evaporated (for Gasoline) = $[B + 0.21T]\ln(t)$ (2)
Percent Evaporated (for Diesel) = $[B + 0.045T]\ln(t)$ (3)

Figure 5 presents data pertaining to the evaporation rate, highlighting a discernible correlation between oil mass (or volume) and the rate of evaporation. Within this figure, the loss rate at a temperature of 15 degrees Celsius is approximated at 26.5 litres per 3,785 litres per day, as estimated by the California Air Pollution Control Officers Association (CAPCOA). Subsequently, the regulatory framework established by the California Air Resources Board incorporates these projections in formulating state-level rules.

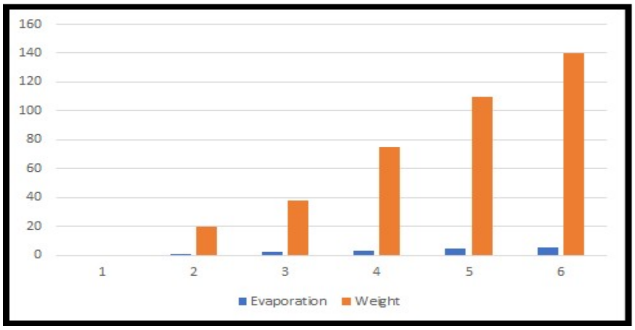

Figure 5: The Mass of Oil and the Rate of Evaporation are Related.

Two gas stations were observed in the course of the study, and they are deemed to offer a representative depiction of other gas stations nationwide. The critical juncture of reaching the boiling point is anticipated when the vapor pressure approaches approximately 101 kPa, signifying the onset of a departure from equilibrium and the commencement of vapor ascension. The gasoline's boiling point, approximately 50 degrees Celsius, is graphically represented in Figure 6 until the initiation of evaporation loss.

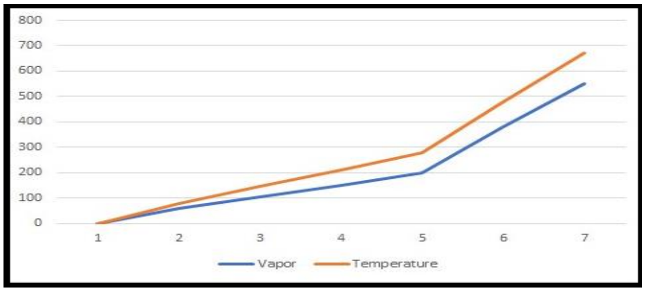

Figure 6: Gasoline Measurement.

Figure 7 illustrates the percentage of diesel fuel evaporation, as delineated by Equation (3), at two distinct temperatures, namely 5 degrees Celsius and 20 degrees

Celsius. The observed disparity in evaporation rates between these two temperature conditions becomes evident. Notably, there is an apparent escalation in evaporation rates at 20 degrees Celsius in comparison to 5 degrees Celsius. Following a 60-hour period, the percentage of evaporation rises to 50% at 20 °C, while concurrently decreasing to 35% at 5 °C.

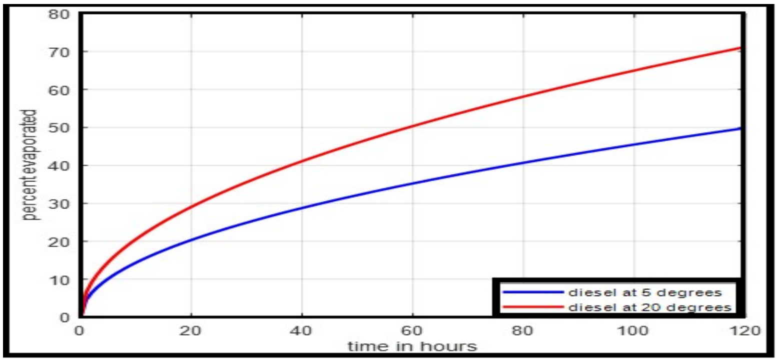

Figure 7: Contrasting The Evaporation Profiles of Diesel at Two Varying Temperatures.

6. Density

Every chemical exhibits a fixed density, a characteristic that is exclusively modifiable by temperature variations, given the pivotal role density plays in discerning undesirable additives. Acquiring knowledge about the density of a product becomes imperative as temperature fluctuates, and Equation (4) elucidates the relationship between density and temperature.

$$\text{Density} = \text{density}\ (T_0) \quad (4)$$
$$\alpha\ (T_1 - T_0) + 1$$

Herein, α denotes the thermal expansion factor of gasoline, specified as 95×10^{-5}. Diesel fuel manifests a density spectrum spanning from 830 to 950 kg/m^3, while gasoline exhibits a density range of 700 to 800 kg/m^3, underscoring the influential role of temperature as a primary determinant governing density.

6.1 Petrol Pump Monitoring System Primary Fuel Tank

The Arduino Mega's microcontroller incorporates an integrated ultrasonic sensor, which, when treating each microcontroller as an MQTT client, supplies fuel level information. This information is subsequently transmitted to the ThingsBoard server. In this study, a fuel temperature sensor is employed to relay data from a microcontroller, acting as an MQTT client, to a ThingsBoard server, functioning as an MQTT broker. This server can be hosted either on a local Raspberry Pi or a cloud server, facilitating the display of information on a dashboard.

The DHT11 sensor monitors the gasoline station and other stations transmitting their information through the Access Token. It sends temperature and humidity data to a ThingsBoard server installed on a Raspberry Pi, displaying this data on the ThingsBoard dashboard along with the details of the attached gadget on the dashboard display. Figure 8 on the dashboard illustrates the temperature and humidity of the second fuel station under two different states.

Figure 8: The Dashboard is Tracking Temperature and Humidity for Two States at The Second Fuel Station.

The monitoring process extends to the evaluation of fuel temperature and its consequential impact on calculating the rates of evaporation for fuels such as gasoline and diesel, alongside determining the fuel's density. These assessments aid in discerning whether the fuel is contaminated with invalid mixtures. This monitoring, orchestrated from a gas station where the ESP-32S microcontroller functions as the MQTT client, is depicted in Figure 9 within the timeseries table of the ThingsBoard server's dashboard.

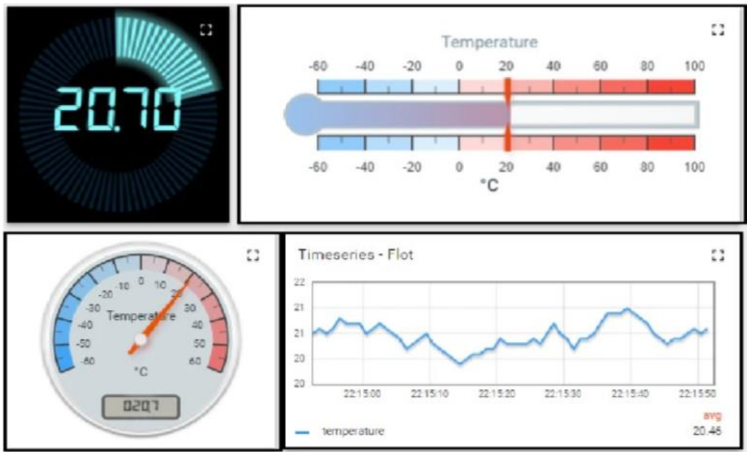

Figure 9: Time Series table Displayed on the Dashboard.

Within the context of the Smart IoT-based Reinforcement Learning Fuel Filling System, the forthcoming results are poised to be concentrated on three primary domains: the efficacy of the reward function, the progression of Q-values, and the proficiency of the epsilon-greedy policy.

6.2 Reward Function Effectiveness

Derived from the reward function, we quantify and present the temporal evolution of the average reward acquired during the system's training. The anticipated outcome is predicated on the notion that, as the reinforcement learning algorithm assimilates the optimal policy, the average reward per episode is expected to elevate. A progressive increase in the average reward over time serves as an indicative measure, suggesting that the reinforcement learning agent is acquiring the ability to make decisions conducive to enhancing both fuel delivery accuracy and communication rates, as delineated by the predefined reward function.

6.3 Evaluation of Q-Values

Q-values undergo temporal evolution concerning specific state-action pairs. During the initial phases of the learning process, Q-values are prone to substantial fluctuations. Nevertheless, as the algorithm progresses towards convergence to an optimal policy, the Q-values are anticipated to achieve stability. The attainment of stabilized Q-values serves as an indication that the reinforcement learning algorithm has successfully assimilated the value associated with different actions across diverse states. This acquisition enables the algorithm to make more optimal decisions pertaining to resource allocation (Moriarty, Schultz, & Grefenstette, 1999).

6.4 Performance of the Epsilon-Greedy Policy

The performance of the epsilon-greedy policy can be assessed by gauging the equilibrium between exploration and exploitation across temporal dimensions (Bulut, 2022). One evaluative approach involves tracking the proportion of randomly selected actions (exploration) over time. Ideally, this percentage is expected to diminish as the algorithm progressively acquires the optimal policy, leaning more heavily towards exploitation. A reduction in the occurrence of random actions throughout the learning process signifies the reinforcement learning agent's adeptness at assimilating knowledge from its environment, thereby instilling confidence in selecting actions deemed to yield the highest rewards.

6.5 Comparison Analysis with the Existing Petrol Station

A comparative analysis of the roles of existing and future filling stations is presented in Table 1 (Baqir & Motlak, 2023; Gupta et al., 2016; Shreedhar & Shivashankara, 2019; Suma et al., 2022).

Table 1: Comparison Between Smart Petrol Pump Station with Existing Petrol Station.

Item	Smart Petrol Pump Station	Existing Petrol Station
Cost	Low Cost	Expensive
Payment Option	FRID	CASH
Microcontroller	Arduino Mega 2560 and ESP-32S	PLC
Type of Pump	Outside Pump	Submersible Pump
Monitoring and Controlling Process	Wireless Communication	On Site
Environment Monitoring	Available	Not Available
Monitor the Fuel Evaporation	Automatically	Manually
Fuel Fraud Protection	Automatically	Manually
Fire Protection System	Automatically	Manually
Monitoring the Fuel Level inside the Tank	Automatically	Manually
Distinguish Between Customer	Automatically	Manually
The Number of Manpower	One for Management is Enough	8-10
Debt Recording	Automatically	Manually
Communication Technology	Wifi by ESP-32S Module	Wifi
Sensor	Ultrasonic Sensor	Ultrasonic Sensor
User Interface	Desktop and Smart Phone	Desktop
Microcontroller	Arduino Mega 2560	Intel Galileo Gen 2
Purpose Project	Evaporation Rate in the Tank	Measuring the Fuel Level

7. Conclusion

As a concluding remark, this paper introduces an IoT enabled intelligent fuel filling system as a means to enhance resource management in the petroleum industry. The proposed system enables the optimisation, control, and real-time monitoring of the fuel filling process by utilising Internet of Things technologies such as sensor networks, cloud computing, and data analytics. The evaluation's findings illustrate the system's effectiveness in enhancing overall efficiency of fuel management operations, reducing human errors, and enhancing accuracy. This research enhances current knowledge by showcasing the transformative potential of IoT in the petrol industry. The smart fuel filling system discussed in this paper offers several benefits, such as proactive maintenance, live monitoring, and data-based decision-making. It provides petrol suppliers with the capacity to optimise their resources, reduce costs, and enhance customer happiness. Moreover, the utilisation of IoT technology establishes a structure for forthcoming advancements and innovations in fuel management methodologies.

References

Baqir, Z. a. M., & Motlak, H. J. (2023). Design and Implementation Smart Petrol Station Using Internet of Things. Internet of Things-New Insights. https://www.intechopen.com/online-first/88697

Bulut, V. (2022). Optimal path planning method based on epsilon-greedy Q-learning algorithm. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 44(3), 106. https://doi.org/10.1007/s40430-022-03399-w

Cheng, X., Duan, D., Gao, S., & Yang, L. (2022). Integrated Sensing and Communications (ISAC) for Vehicular Communication Networks (VCN). IEEE Internet of Things Journal, 9(23), 23441-23451. https://doi.org/10.1109/JIOT.2022.3191386

Cui, Y., Liu, F., Jing, X., & Mu, J. (2021). Integrating Sensing and Communications for Ubiquitous IoT: Applications, Trends, and Challenges. IEEE Network, 35(5), 158-167. https://doi.org/10.1109/MNET.010.2100152

Gullapalli, V. (1990). A stochastic reinforcement learning algorithm for learning real-valued functions. Neural Networks, 3(6), 671-692. https://doi.org/10.1016/0893-6080(90)90056-Q

Gupta, P., Patodiya, S., Singh, D., Chhabra, J., & Shukla, A. (2016). IoT based smart petrol pump. In 2016 Fourth International Conference on Parallel, Distributed and Grid Computing (PDGC) (pp. 28-32). https://doi.org/10.1109/PDGC.2016.7913168

Javed, F., Afzal, M. K., Sharif, M., & Kim, B. S. (2018). Internet of Things (IoT) Operating Systems Support, Networking Technologies, Applications, and Challenges: A Comparative Review. IEEE Communications Surveys & Tutorials, 20(3), 2062-2100. https://doi.org/10.1109/COMST.2018.2817685

Khatun, R., Antor, S. A., Ullah, A., & Hossain, A. (2019). Vehicle fuel activities monitoring system using IoT. Advances in Internet of Things, 9(04), 63. https://doi.org/10.4236/ait.2019.94005

Krishna, T. M., Sushmitha, K., Yashwanth, B., Reddy, M. B. P., & Mahendar, P. (2022a). Rfid Based Petrol Pump Automation System. Journal of Engineering Sciences, 13(12). https://jespublication.com/upload/2022-V13I12114.pdf

Krishna, T. M., Sushmitha, K., Yashwanth, B., Reddy, M. B. P., & Mahendar, P. (2022b). Rfid Based Petrol Pump Automation System. Journal of Engineering Sciences, 13(12), 968-973. https://jespublication.com/upload/2022-V13I12114.pdf

Liu, A., Huang, Z., Li, M., Wan, Y., Li, W., Han, T. X., Liu, C., Du, R., Tan, D. K. P., & Lu, J. (2022). A survey on fundamental limits of integrated sensing and communication. IEEE Communications Surveys & Tutorials, 24(2), 994-1034. https://doi.org/10.1109/COMST.2022.3149272

Moriarty, D. E., Schultz, A. C., & Grefenstette, J. J. (1999). Evolutionary algorithms for reinforcement learning. Journal of Artificial Intelligence Research, 11, 241-276. https://doi.org/10.1613/jair.613

Naveen, B., Rashmitha, B., Parthasarathi, K., Sandhya, B., & Lohith, S. (2019). IOT Based Petrol Bunk Management for Self-Operation using RFID and Raspberry PI. International Journal of Recent Technology and Engineering, 8(1). https://www.ijrte.org/wp-content/uploads/papers/v8i1C/A10380581C19.pdf

Shreedhar, M., & Shivashankara, B. (2019). Plc Based Automatic Fuel Dispensing System Using Rfid Technology. International Journal of Engineering Applied Sciences and Technology, 4(1), 89-94. https://ijeast.com/papers/54-57,Tesma401,IJEAST.pdf

Suma, M., Prasanna, J. D., Divya, T. M., Sri, A. B., & Kumar, N. S. C. (2022). Rfid Smart Card Based Self Petrol Fuel Station. Journal of Engineering Sciences, 13, 12. https://jespublication.com/upload/2022-V13I12114.pdf

Tandon, A., Jharwal, T., Sharma, V., Sharma, Y., & Sharma, Y. K. (2022a). RFID Based Automation Of Petrol Pump. In. e-ISSN. https://www.irjmets.com/uploadedfiles/paper/issue_6_june_2022/25797/final/fin_irjmets1655014870.pdf

Tandon, A., Jharwal, T., Sharma, V., Sharma, Y., & Sharma, Y. K. (2022b). RFID Based Automation Of Petrol Pump. International Research Journal of Modernization in Engineering Technology and Science, 04(06), 1266-1273.

Xu, G., Li, M., Luo, L., Chen, C.-H., & Huang, G. Q. (2019). Cloud-based fleet management for prefabrication transportation. Enterprise Information Systems, 13(1), 87-106. https://doi.org/10.1080/17517575.2018.1455109

Zahra'a, M. B., & Motlak, H. J. (2021). Smart automatic petrol pump system based on internet of things. International Journal of Electrical and Computer Engineering, 11(2), 1804. https://doi.org/10.11591/ijece.v11i2.pp1804-1811