Smart Gas Geyser with Real-Time Data Collection

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This paper presents an IoT-based Smart Gas Geyser system designed to address energy inefficiency, safety risks, and user inconvenience in conventional water heaters. It proposes an IoT-based smart gas geyser system that enables remote monitoring and real-time data collection via a mobile application. This data-driven approach allows for automated adjustments and instant alerts, enhancing both safety and performance. The system integrates ESP32 with various sensors to monitor temperature, gas leakage, and flame presence. Data is transmitted to a Firebase real-time database, allowing users to make informed decisions via a mobile app. The user-friendly mobile app provides features such as temperature setting, real-time monitoring, and automatic shutoff, making geyser operation seamless and secure. The proposed system enhances energy efficiency, ensures safety, and provides cost-effective automation for domestic and industrial applications. It includes experimental results, comparative analysis with conventional geysers, and future recommendations.

Keywords: Gas Geyser; IOT; Real-Time monitoring; Smart Technology; Mobile Application; Safety; Energy Efficiency

Introduction:

Gas geysers are commonly used for water heating because they are cost-effective and efficient. However, traditional geysers lack automated control, leading to energy wastage and safety concerns. In Pakistan, increasing natural gas demand and supply shortages necessitate smarter, more efficient geyser systems. Additionally, inefficient geyser usage results in unnecessary gas consumption, increasing both economic costs and environmental impact.

This paper presents a smart gas geyser system utilizing the Internet of Things (IoT) to enhance energy efficiency, ensure user safety, and enable remote monitoring through a mobile application. By integrating an ESP32 micro-controller, temperature sensors, gas detectors, and flame sensors, this system provides real-time data collection and control, ensuring optimal performance.

Literature Review:

Recent advancements in IoT-based systems have inspired numerous innovations in energy management and safety for heating devices. However, most existing approaches address either energy optimization or safety, lacking a truly integrated and user-centric design.

Author[1] highlighted the role of energy-efficient gas geysers in reducing gas consumption but did not implement IoT-based real-time monitoring or safety automation, leaving room for operational inefficiencies and user inconvenience. Similarly, author[2] proposed an energy recovery system that enhanced cost savings in instant geysers, yet did not integrate real-time user control or safety features. In the realm of intelligent control, author[3] introduced machine learning techniques for temperature and power optimization in water heating systems. While this approach improved efficiency, it required a complex setup and lacked safety mechanisms for gas leakage or combustion failures.

Several studies focused primarily on gas leakage detection. author[4] developed an IoT-based real-time gas detection system with mobile alerts, but it did not interface with a heating system to actively control energy use or provide automated shutoff**.** Similarly, the GASDUINO project [5] focused on air quality monitoring, demonstrating gas sensing capabilities but without integration into domestic water heaters. Efforts like those of authors[6] in smart shower systems illustrated how IoT can enable adaptive temperature control, yet did not address gas safety or heating system automation. Other works; including Io T Starters [7], Robotique [8], and HashStudioz [9] showcased practical gas leakage detection using ESP32 and MQ sensors but were primarily safety systems without full user interactivity or energy optimization for geysers.

More advanced research by author[10] employed reinforcement learning to optimize water heater performance. While this demonstrated significant potential for efficiency, it involved high system complexity and lacked user-friendly implementation, making it less applicable to common gas geyser setups in markets like Pakistan.

Identified Gaps:

Across these studies, there remains a lack of fully integrated systems that combine:

- Real-time gas and flame monitoring
- Intelligent temperature and energy control
- Automated safety mechanisms
- User-friendly mobile interfaces for seamless interaction and control

Contribution of this paper:

This work addresses these limitations by presenting an IoT-enabled gas geyser system that combines real-time monitoring, automated safety controls, and energy-efficient scheduling, all accessible via an intuitive mobile app. The system integrates multiple sensors with ESP32 and a Firebase database to enable proactive management of both safety and energy consumption.

Objectives:

- Developing an IoT-enabled gas geyser system that provides real-time monitoring.
- Enhancing safety mechanisms through automated gas leakage detection and shutoff features.
- Improving energy efficiency through smart scheduling and adaptive control of temperature and heating duration based on sensor feedback

System Design and Methodology:

System Architecture:

The proposed system consists of an ESP32 micro-controller connected to various sensors, including:

- DS18B20 Temperature Sensor: Monitors real-time water temperature.
- MQ5 Gas Sensor: Detects gas leaks.
- W104 Flame Sensor: Ensures burner operation.
- Solenoid Valve: Controls gas flow.
- Mobile Application: Provides a user-friendly interface for monitoring and control.

The system is engineered for real-time operation, continuously tracking the geyser's status and transmitting data to Firebase real-time cloud database for analysis, remote monitoring, and alert generation. By using Firebase as the cloud platform, the system ensures low-latency data updates and seamless integration with the mobile application.

Mobile Application Features:

The mobile application was developed using the Flutter framework with the Dart programming language, targeting the Android platform to ensure wide compatibility and responsive performance. The mobile application provides an intuitive user interface that allows real-time monitoring and control of the smart gas geyser system. Real-time alerts are generated in case of gas leakage, ignition failure, or temperature threshold exceed, and are delivered to the user's mobile device via push notifications. The app also supports historical data visualization, enabling users to view trends in temperature, gas levels, and system status over time. Users can adjust settings such as desired water temperature and heating schedules through the app's control options. To ensure secure operation, the application incorporates user authentication via login credentials, and all data transmissions between the ESP32, Firebase database, and mobile app are protected using TLS/SSL encryption. This comprehensive feature set enhances both safety and user convenience, making the system practical for real-world domestic use. The ESP32 micro-controller communicates with the Firebase cloud database via Wi-Fi using standard HTTP requests.

Experimental Setup:

The system was implemented and tested under different conditions to evaluate its performance. A prototype model was developed, integrating sensors with the ESP32 micro-controller. The mobile application was designed to display real-time sensor data and provide control options. The experimental setup included:

- **Testing Environment:** A controlled indoor environment replicating typical household conditions. The system was tested across a water temperature range of 20°C to 75°C to simulate normal usage scenarios. For gas leak detection, controlled gas concentrations of 100 ppm to 600 ppm were introduced near the MQ5 sensor to verify detection accuracy and system response. The threshold for gas leak alert was set at 300 ppm. Flame sensor tests included multiple ignition cycles to assess reliability under varying ambient light conditions.
- **Reliability Testing:** For each key system function, a minimum of 20 repeated trials were performed to ensure consistent operation. Specifically, 20 temperature control cycles were conducted, 20 gas detection tests were performed using varying gas concentrations, and

20 flame ignition cycles were executed to evaluate system reliability and response under different conditions.

- Hardware Configuration: Connection of ESP32 with temperature, gas, and flame sensors.
- Data Transmission: Use of Firebase real-time database for logging sensor data.
- Performance Metrics: Accuracy of temperature control, gas detection speed, and system response time.

Workflow:

Figure 1 shows the flowchart of the working of the system. When the system is turned on, all readings are initialized.

- The gas sensor detects gas presence and ensures safe levels.
  - If the gas level is within a safe threshold, the solenoid valve opens, and the igniter turns on.
  - The flame sensor verifies combustion; otherwise, the igniter retries for 5 seconds. If no combustion is detected, the solenoid valve closes and alarm is sent to the user mobile phone.
  - The system monitors water temperature, turning off the geyser when the set temperature is reached.
  - If any fault is detected (e.g., gas leak or ignition failure), the system shuts down and alerts the user via the mobile application.

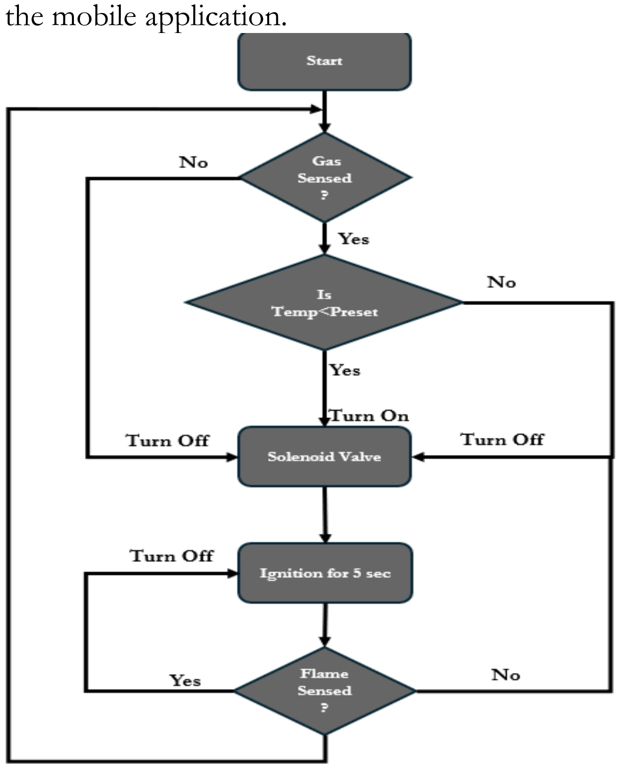

Figure 1. Work Flowchart.

Hardware Implementation:

Figure 2 shows the circuitry of sensors connected with ESP32 and placed on board. Figure 3 illustrates the gas sensor detecting leakage or emissions from the gas cylinder. The circuit is turned on after the gas concentration exceeds a fixed limit (300 ppm in this case). The temperature sensor then senses the temperature. If water temperature is below the threshold the gas solenoid valve is turned ON (simulated by an LED), as shown in figure 4 below.

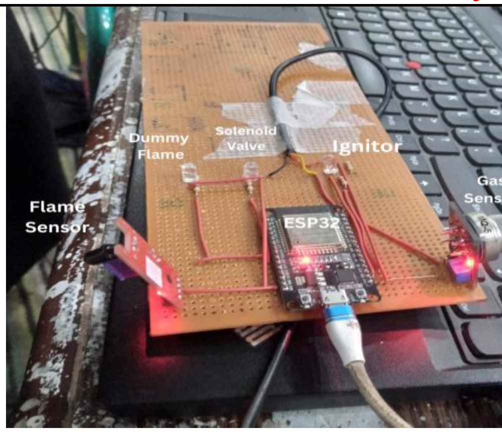

Figure 1. circuit of all components

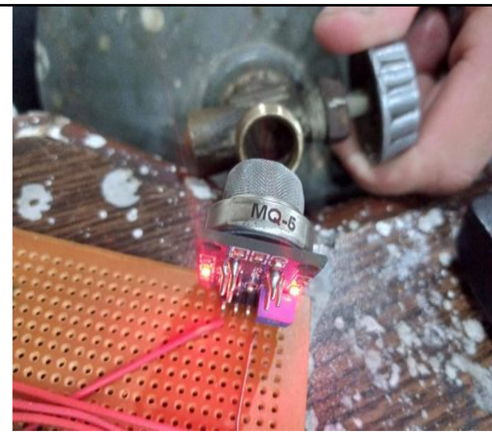

Figure 2. when the sensor detects gas

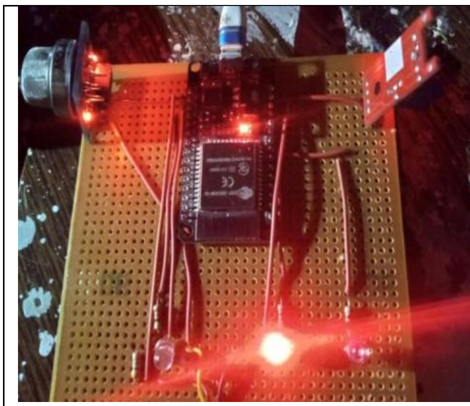

Figure 3. solenoid valve turns on after detection of gas

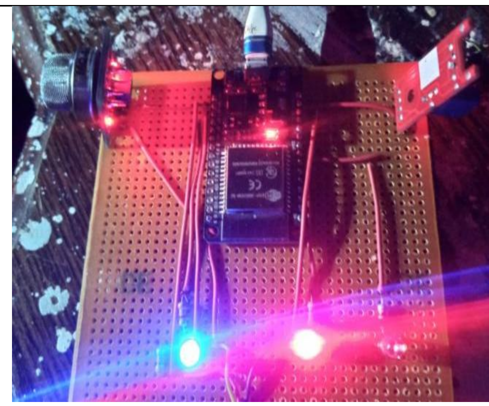

Figure 4. The igniter turns on after the gas flows

Figure 5 shows that the igniter (simulated by an LED) turns on after the gas is allowed to flow by the solenoid valve. If the burner flame persists, the igniter turns off after 5 seconds, and the solenoid remains open. If the flame does not light up successfully, the cycle repeats with gas detection, ignition, and flame detection.

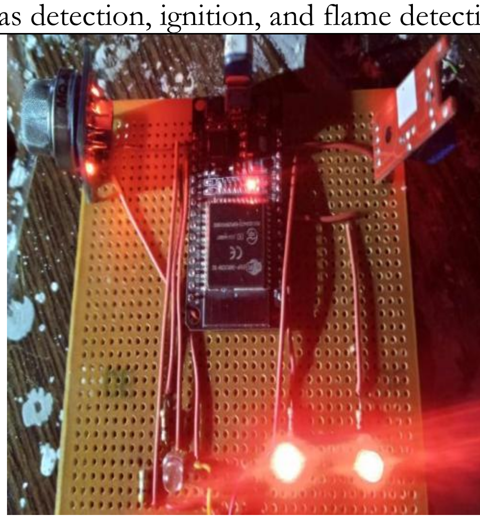

Figure 5. Dummy Flame turns on after ignition

Figure 6. system turns off after temperature exceeds threshold

When gas is detected, the solenoid valve opens and the igniter activates, producing a flame (simulated by an LED) as shown in Figure 6. The flame sensor then detects the flame and signals the system to turn on. Once the temperature surpasses the threshold, indicating that the water has reached the desired temperature, the system automatically shuts off to conserve energy. This is shown in Figure 7. Figure 8 shows the APP UI application dashboard.

Mobile Application Interface:

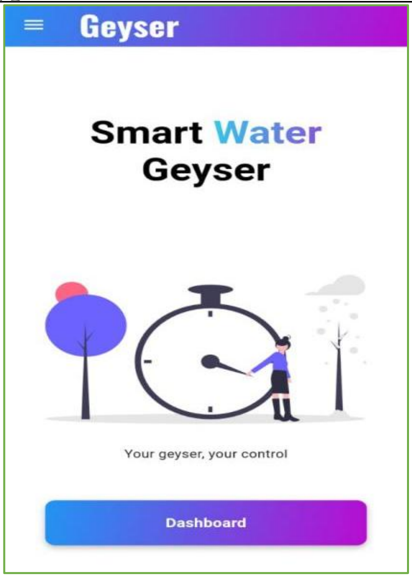

Figure 7. APP UI (dashboard)

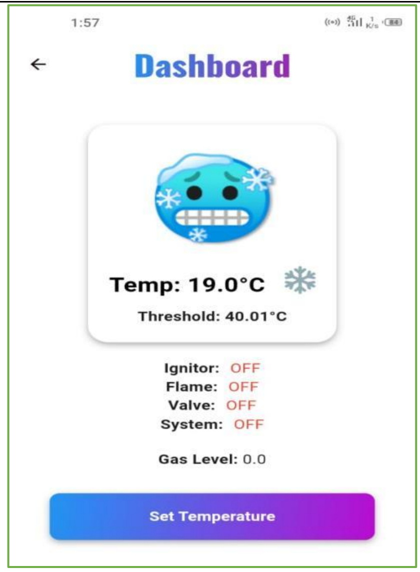

Figure 8. Main window showing all the components

Figure 9 shows the main window displaying the status of all the components. At this moment the system is off because of no gas.

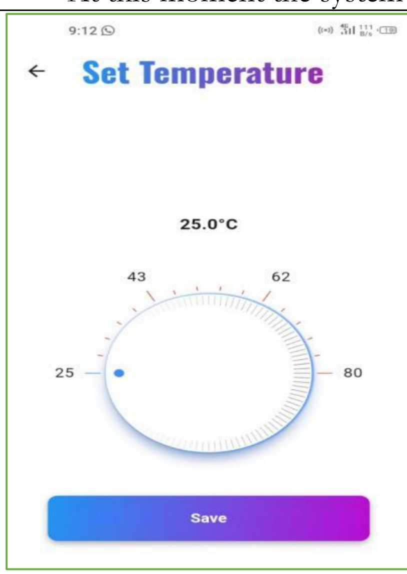

Figure 9. Window for temperature monitoring and controlling with ease

Figure 10. Gas level exceeds threshold and valve status is ON in APP UI

Figure 10. shows the window for temperature monitoring and control.

When the gas is detected by sensor and its level exceeds the threshold the valve turns on. The gas level and valve status are shown in figure 11. The igniter produces a spark or flame to light the fire. In this prototype, an LED blinks for five seconds to simulate the igniter being turned on. The status is shown in figure 12.

Figure 11. Ignitor status turns on showing in APP UI

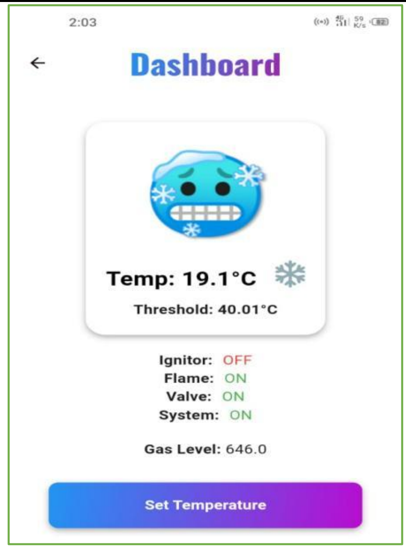

Figure 12. showing the system is ON

Figure 13 shows that the system is ON because the valve and flame are ON and the temperature is below the threshold. The system continuously monitors the temperature. If the temperature rises above the preset threshold, the entire system shuts down. If the temperature remains below the threshold, the system continues to operate until the limit is exceeded. The status is shown in Figure 14.

Figure 13. temperature cross the threshold, system turns off

Results and Discussion:

Performance evaluation:

The proposed smart gas geyser system was tested in a controlled indoor environment to assess its key functions. Each core module was evaluated over 20 repeated trials to ensure reliability and consistency.

- **Temperature Control Accuracy:**
  The system successfully maintained water temperature within ±0.5°C of the user-set threshold across all 20 trials. The DS18B20 sensor provided stable readings, and the solenoid valve reliably shut off once the target temperature was reached. This confirms the effectiveness of the temperature control logic and sensor integration.
- **Gas Leak Detection:**
  Using controlled gas concentrations (100–600 ppm), the MQ5 sensor consistently

detected leakage and triggered alerts once the threshold of 300 ppm was crossed. In all tests, the mobile application displayed real-time notifications, and the solenoid valve shut off as intended. The response time for leak detection was under 2 seconds, demonstrating prompt hazard response.

- **Flame Monitoring:**
  The flame sensor accurately confirmed ignition and detected failure cases. In cases of unsuccessful ignition (manually simulated), the system retried ignition up to three times before shutting down and alerting the user. This safety feature mimics real-world combustion control mechanisms and worked consistently across 20 tests.

Comparative Analysis with Traditional Geysers:

To understand the performance gain, the proposed system was compared against conventional gas geysers operated under similar heating demands. These improvements highlight the system's advantages in safety, convenience, and energy efficiency. Energy savings were primarily achieved by automated shutoff once the water reached the desired temperature and preventing unnecessary burner operation.

The proposed smart geyser offers several significant improvements over traditional geysers. Firstly, it reduces gas usage per session by approximately 20%, making it more energy-efficient and cost-effective. While traditional geysers require manual control, the smart geyser can be operated remotely through a mobile app, providing users with greater convenience and flexibility. Additionally, the smart geyser features real-time leak detection with instant alerts, a safety feature not available in traditional models. Shutoff logic is also automated in the smart geyser, eliminating the need for manual intervention and enhancing safety. Finally, the smart geyser responds to events almost immediately, within less than two seconds, whereas traditional geysers typically have delayed response times. Overall, these advancements make the smart geyser a safer, more efficient, and user-friendly option.

User Interaction and Experience:

The mobile app provided users with the ability to:

- Set temperature thresholds.
- Receive real-time alerts (e.g., gas leak, overheat, flame failure).
- View real-time sensor data and historical readings.

During field testing, the interface was found intuitive and stable across multiple Android devices. Notifications were received reliably via Firebase, and user feedback confirmed improved control and reduced manual involvement.

Discussion:

These findings align with the identified gaps in the literature, where many past systems focused only on isolated features (e.g., gas detection or temperature monitoring). Our system demonstrates an integrated solution combining safety, automation, and usability.

While results are promising, the study is limited by the absence of industrial-grade testing tools. Precision measurement of gas flow rates or energy use over long duration was not possible.

Conclusion and Future Work:

This research introduces an IoT-based smart gas geyser system that enhances safety, energy efficiency, and user convenience. By leveraging real-time monitoring and automated controls, the system significantly improves traditional geysers. Key benefits include reduced energy consumption, improved safety through automated shutdown features, and enhanced user control via mobile applications.

Future Work:

- Integration of machine learning algorithms to predict usage patterns and optimize energy consumption.
- Expansion of the system to support multiple geysers in a networked environment.

- Implementation of advanced security mechanisms to prevent unauthorized access.

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The manuscript has not been published or submitted to other journals previously.

Author's Contribution:

It is acknowledged that all authors have contributed significantly and that all authors agree with the content of the manuscript.

Conflict of interest.

There exists no conflict of interest for publishing this manuscript in IJIST.

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