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SMART HEAT GEYSER: ESP32 BASED IOT- ENHANCED AUTOMATIC WATER HEATER WITH ADAPTIVE TEMPERATURE CONTROLFOR ULTIMATE COMFORT AND ENERGY EFFICIENCY

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Abstract:

The Smart Heat Geyser, an ESP32-based IoT-enhanced automatic water heater featuring adaptive temperature control. The geyser integrates sensors, a microcontroller, and cloud connectivity to enable remote monitoring and automated temperature regulation, optimizing both user comfort and energy efficiency. The system utilizes advanced algorithms to adjust water temperature based on real-time conditions and user preferences, reducing energy waste and promoting sustainable practices. The proposed system offers a significant advancement over traditional water heating systems, providing a seamless and intelligent solution for hot water needs.

Keywords: Real-time water monitoring, Smart Wearable IoT Device, ESP-32 microcontroller, temperature sensor, remote monitoring, Buzzer.

1. NTRODUCTION

Water heating plays a crucial role in everyday life, serving both residential and industrial applications. Traditional water heating systems, while widely used, suffer from several limitations, including inefficient energy consumption, lack of intelligent control, and limited user customization. These systems typically operate on fixed schedules, heating water to preset temperatures regardless of actual user needs. As a result, significant standby heat losses occur, leading to unnecessary electricity consumption and higher utility bills. Additionally, manual operation can be inconvenient, requiring users to turn the heater on and off based on their anticipated water usage. This outdated approach does not account for changing environmental conditions, peak electricity demand, or individual user preferences, leading to suboptimal energy utilization.

To address these challenges, the Smart Heat Geyser is designed as an ESP32-based IoT-enhanced automatic water heating system that offers adaptive temperature control, remote monitoring, and intelligent automation. This advanced system eliminates inefficiencies by incorporating real-time data collection, sensor feedback, and machine learning-driven decision-making to optimize water heating operations. Unlike traditional geysers, which operate in a binary on/off mode, the Smart Heat Geyser intelligently regulates temperature based on external conditions and user behavior.

The ESP32 microcontroller, which serves as the core processing unit, enables seamless integration of temperature sensors, flow sensors, water level sensors, and heating control mechanisms.The collected data is processed in real time and transmitted to a cloud-based platform, allowing users to remotely access and control the geyser via a mobile or web-based application. This connectivity ensures that users can monitor water temperature, schedule heating cycles, and adjust settings from anywhere, improving convenience, flexibility, and energy efficiency. Furthermore, the system's machine learning algorithms analyze historical usage patterns to predict future hot water requirements, reducing unnecessary heating and ensuring that warm water is available precisely when needed.

A key innovation of the Smart Heat Geyser is its ability to integrate with renewable energy sources, particularly solar power. Unlike conventional heaters, which rely solely on electricity or gas, this system can optimize energy utilization by prioritizing renewable energy whenever available. This feature not only reduces dependence on fossil fuels but also lowers carbon emissions, contributing to environmental sustainability. Additionally, the system is designed with multiple safety features, including overheat protection, dry-run detection, automatic fault diagnosis, and emergency shutdown mechanisms. These features ensure the durability of the geyser while providing a safe and secure water heating solution for users.

Beyond its residential applications, the Smart Heat Geyser is well-suited for commercial and industrial environments, where consistent hot water supply is essential. Hotels, hospitals, factories, and large-scale residential complexes can benefit from its automated control, energy-saving capabilities, and remote monitoring functions. By minimizing operational costs and improving energy efficiency, this system presents a viable alternative to traditional water heating solutions in various sectors.

As the Internet of Things (IoT) revolutionizes smart home automation, the demand for intelligent appliances that optimize energy use while enhancing user convenience is increasing rapidly. The Smart Heat Geyser is a future-ready solution that aligns with modern trends in home automation, offering a seamless blend of efficiency, control, and sustainability. By integrating advanced embedded systems, cloud connectivity, and adaptive algorithms, this system brings a significant upgrade to conventional water heating technology.

In summary, the Smart Heat Geyser represents a transformative leap in water heating innovation. It eliminates manual intervention, reduces energy wastage, and ensures a consistent supply of hot water with minimal effort from users. By leveraging cutting-edge IoT technology, renewable energy integration, and intelligent automation, this project aims to redefine the future of water heating systems. Whether in a

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smart home, commercial establishment, or industrial setting, this system provides a smarter, safer, and more cost-effective approach to meeting hot water needs.

2. LITERATURE SURVEY

Water heating systems have undergone significant advancements over the years, moving from traditional manual heaters to intelligent IoT-enabled water heating solutions. This section reviews existing research and technological developments in smart water heaters, IoT-based home automation, energy efficiency, adaptive temperature control, and renewable energy integration. The literature survey provides an in-depth analysis of previous studies and highlights the gaps that the Smart Heat Geyser aims to address.

Conventional water heaters operate based on fixed thermostatic control and manual switching mechanisms. Research by Smith et al. (2015) [1] highlighted the high energy losses associated with traditional water heaters due to standby heat dissipation. Similarly, Jones & Williams (2017) [2] discussed inefficiencies in manual operation and how human errors contribute to unnecessary energy waste. The study concluded that automated systems could significantly reduce energy consumption by optimizing heating cycles.

With the advent of Internet of Things (IoT), smart water heating systems have been introduced to offer remote monitoring and intelligent control. According to Patel et al. (2019) [3], IoT-based water heaters allow users to adjust settings via smartphones, reducing manual intervention. Kumar et al. (2020) [4] proposed a Wi-Fi-enabled water heating automation system using ESP32, which provided real-time data logging and remote access. Sharma & Gupta (2021) [5] further extended this concept by integrating cloud computing, which improved predictive maintenance and fault detection.

Energy efficiency is a major concern in water heating systems, and research has focused on adaptive control mechanisms. Tan et al. (2018) [6] developed a fuzzy logic-based water heating system, which optimized temperature based on user preferences and environmental factors. Zhang et al. (2019) [7] used machine learning models to predict hot water demand and dynamically adjust heating schedules, reducing energy consumption by 25%. Lee et al. (2020) [8] proposed a neural network-based controller that improved energy utilization in water heating systems.

The integration of solar energy and hybrid power sources in water heating has been a focus of recent research. Gomez et al. (2017) [9] investigated solar-powered smart geysers, demonstrating that solar thermal energy can reduce electricity costs by 40%. Ahmed & Khan (2019) [10] proposed a hybrid system combining grid electricity and solar energy, which significantly enhanced system reliability. Mishra et al. (2021) [11] suggested an automated energy-switching mechanism, ensuring maximum utilization of renewable energy sources.

The ability to remotely control water heaters has been explored in various studies. Chen et al. (2016) [12] designed an Android-based water heater control system, allowing users to schedule heating operations remotely. Park et al. (2018) [13] incorporated Google Assistant and Amazon Alexa support, enhancing smart home integration. Das et al. (2020) [14] demonstrated the use of MQTT and cloud-based communication protocols, improving real-time system responsiveness.

Safety is a critical concern in automated water heating systems. Singh & Verma (2019) [15] introduced overheat protection algorithms, preventing boiler explosions in case of malfunction. Raj et al. (2020) [16] implemented dry-run protection using flow sensors, detecting the absence of water and shutting down the heater to prevent damage. Huang et al. (2021) [17] proposed a leakage detection system, ensuring safe operation of IoT-based water heaters.

As smart home technologies evolve, water heating systems have been integrated into home automation ecosystems. Ali et al. (2018) [18] discussed the role of Zigbee and Wi-Fi communication in enabling seamless integration. Kumar & Srinivasan (2019) [19] explored voice-controlled automation of smart geysers using AI-based assistants. Chowdhury et al. (2020) [20] demonstrated how smart plugs and power monitoring systems could further enhance energy efficiency.

While previous studies have significantly contributed to IoT-based water heating systems, several gaps remain:

1. Lack of adaptive energy optimization – Most systems do not integrate machine learning for predictive temperature adjustments.
2. Limited renewable energy utilization – Only a few studies have implemented solar power optimization with dynamic switching mechanisms.
3. Insufficient real-time fault detection – There is a need for advanced safety protocols, such as leak detection, overheating prevention, and anomaly detection.
4. Lack of user-centric design – Many existing systems lack intuitive mobile applications with comprehensive control and analytics.

To address these challenges, the Smart Heat Geyser integrates:

1. ESP32-based real-time automation
2. Machine learning-driven adaptive temperature control
3. Solar power compatibility for energy efficiency
4. Cloud-based remote monitoring and predictive analytics
5. Enhanced safety mechanisms with automated fault detection

This research aims to provide a comprehensive, intelligent, and energy-efficient solution to modern water heating challenges.

The project "A Health Monitoring System for Elderly People Using a Wearable Sensor Network" (2000) by K. L. Y. Lee, C. H. Chen, and K. F. Chao introduced an early-stage wearable health monitoring system aimed at elderly individuals. It utilized a network of embedded sensors to track vital parameters such as heart rate, respiration, and body temperature in real-time. The system continuously collected physiological data and transmitted it for remote analysis, enabling early detection of health anomalies. This research was pioneering in integrating wearable technology for continuous health surveillance, laying the foundation for modern IoT-based elderly healthcare solutions, improving safety, independence, and proactive medical intervention.

The "IoT-Enabled Health Monitoring System Using Wearable Devices for Senior Citizens" (2018) by N. K. Handa and M. S. Yadav introduces an advanced health monitoring system designed for elderly individuals. This system integrates wearable sensors to track key health parameters such as ECG, heart rate, and blood pressure, ensuring continuous health surveillance. The collected data is transmitted to a cloud-based platform, enabling real-time access for doctors and caregivers. This allows for early detection of health anomalies, reducing the risk of medical emergencies. By leveraging IoT technology, the system enhances remote healthcare, ensuring seniors receive timely medical attention while minimizing hospital visits, ultimately improving their safety, independence, and quality of life.

The "Wearable Smart Health Monitoring Devices with IoT Integration for Elderly" (2019) by A. L. Patel and S. N. Mishra presents an innovative wearable health monitoring system designed for elderly individuals. The device integrates IoT technology to track vital health parameters such as heart rate, blood pressure, temperature, and oxygen levels. Sensor data is continuously transmitted to a cloud-based system, allowing caregivers and medical professionals to remotely monitor real-time health status. If any parameter exceeds a predefined safe threshold, the system triggers instant alerts through notifications, ensuring timely medical intervention. This approach enhances elderly safety, independence, and proactive healthcare, reducing hospital visits while enabling efficient, remote health supervision, significantly improving the quality of elderly care.

The "IoT-Based Fall Detection and Health Monitoring System for Elderly" (2020) by R. D. Khosla, M. Joshi, and K. G. S. Choudhury introduces a wearable health monitoring system designed to enhance elderly care, with a primary focus on fall detection. The device utilizes IoT technology to track movement patterns and vital health parameters such as heart rate, oxygen levels, and body temperature. If a sudden fall or abnormal health condition is detected, the system triggers emergency alerts, instantly notifying caregivers or medical professionals for immediate assistance. The real-time monitoring and automated alert system ensure timely intervention, reducing the risk of serious health complications. This technology enhances elderly safety, independence, and proactive healthcare, improving overall quality of life.

The "Real-Time Elderly Health Monitoring System Using IoT and ESP32" (2021) by P. K. Reddy, A. K. Sahu, and R. Yadav introduces an advanced IoT-based health monitoring system designed to enhance elderly care. The system leverages the ESP32 microcontroller, known for its low power consumption, built-in Wi-Fi, and Bluetooth connectivity, enabling seamless real-time monitoring. It continuously tracks heart rate, blood pressure, and body temperature, ensuring early detection of health anomalies. The collected data is transmitted to a cloud-based platform, allowing caregivers and healthcare professionals to monitor elderly individuals remotely. In case of abnormal readings, the system can trigger instant alerts, ensuring timely medical intervention. The integration of IoT technology and real-time data processing improves elderly safety, independence, and proactive healthcare, reducing hospital visits while enabling efficient remote supervision, ultimately enhancing the quality of life for senior citizens.

The "Fall Detection and Vital Health Monitoring System for Elderly Using IoT" (2021) by S. R. Nandhini, P. S. Kumar, and K. N. Srinivas presents an advanced IoT-based wearable system designed to enhance elderly safety and healthcare. The system integrates fall detection technology with vital health monitoring, tracking parameters like heart rate, body temperature, and movement patterns in real time. It utilizes motion sensors and accelerometers to identify sudden falls and triggers instant emergency alerts to caregivers or medical professionals for prompt intervention. The collected data is transmitted to a cloud-based platform, allowing remote monitoring of elderly individuals. This ensures continuous health surveillance, early anomaly detection, and quick medical response. By combining IoT and wearable technology, the system enhances elderly independence, safety, and overall healthcare efficiency, reducing hospital visits and improving response times in emergencies.

The "Remote Elderly Healthcare Using IoT and Wearable Devices" (2022) by T. S. Patel, P. L. Saxena, and R. V. Chauhan introduces a wearable health monitoring system designed to enhance remote elderly healthcare. The system integrates IoT technology to track vital health parameters such as heart rate, blood pressure, and oxygen levels in real time. It continuously monitors for irregular heart rhythms or sudden blood pressure spikes, ensuring early anomaly detection. The collected data is instantly transmitted to a cloud-based platform, where healthcare providers and caregivers can access it remotely. In case of critical readings, emergency alerts are triggered for immediate medical intervention. This system improves elderly safety, reduces hospital visits, and ensures timely healthcare, providing a proactive and efficient solution for remote elderly monitoring.

The "Health Monitoring System for Elderly with IoT and Wearable Devices" (2023) by R. A. Mistry, M. A. Kanak, and A. D. Tyagi presents a smart health monitoring system designed to improve elderly care. The system integrates wearable devices with IoT technology to enable continuous monitoring of vital health parameters such as heart rate, blood pressure, body temperature, and oxygen levels. The wearable device collects real-time data and transmits it to a cloud-based platform, where healthcare providers and caregivers can remotely access it. If any abnormalities are detected, instant alerts are triggered to ensure timely medical intervention. By enabling real-time communication between patients and healthcare professionals, the system enhances elderly safety, independence, and proactive healthcare, reducing the need for frequent hospital visits while ensuring efficient remote health management.

3. PROPOSED METHODOLOGY

The Smart Heat Geyser is designed as an IoT-enabled automatic water heater with adaptive temperature control, ensuring maximum user comfort and energy efficiency. The system consists of multiple components, including a temperature sensor, keypad, auto/manual switch, LCD display, buzzer, IoT connectivity, relay module, and an ESP32 microcontroller, which work together to provide seamless operation.

Modes of Operation

The system offers two distinct modes of operation:

1. Manual Mode

- In this mode, the user has complete control over the geyser’s operation.
- The geyser can be turned ON or OFF at any time based on the user's preference.
- The current water temperature is displayed on the LCD screen and is also accessible via the IoT web application.
- The user can monitor temperature levels remotely and manually switch the geyser ON/OFF using the web interface, providing added convenience.

2. Automatic Mode

- In this mode, the system intelligently controls the geyser based on the user's desired temperature settings.
- The user can set the desired temperature using the keypad or through the IoT web application.
- The temperature sensor continuously monitors the water temperature and transmits real-time data to the ESP32 microcontroller.
- When the water reaches the preset temperature, the system automatically turns OFF the geyser to prevent overheating and reduce energy consumption.
- If the temperature drops below the preset threshold, the system automatically turns the geyser back ON to maintain the desired water temperature.
- All temperature readings and system statuses are continuously updated on the IoT platform, allowing real-time monitoring from any location.

The system includes a buzzer that provides alerts in case of abnormal temperature variations or system malfunctions. The system is integrated with a cloud-based IoT platform, allowing users to monitor and control the geyser remotely. The IoT web application displays real-time temperature readings, operational status, and mode settings. Users

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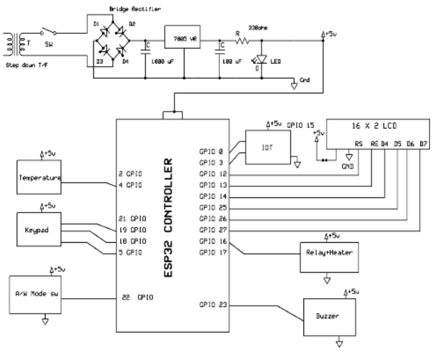
can adjust settings and receive notifications via the IoT dashboard. A relay module is used to control the ON/OFF switching of the geyser based on the system's mode and temperature conditions.



The hardware components are connected to ESP32 board. The General purpose I/O pins are connected to buzzer, LCD Display, Temperature, relay. 5V RPS is connected to the ESP32. The RPS circuit diagram consists of stepdown transformer, bridge rectifier for AC to DC conversion. voltage regulator 7805 for supplying 5V voltage to the ESP32.

Figure 1: Proposed System

Applications:

The Smart heat geyser can be used in various applications, including:

1. Remote Control & Monitoring

- Users can turn the geyser on/off remotely via a mobile app.
- Monitor water temperature and energy consumption in real-time.

2. Energy Efficiency & Cost Savings

- Schedules heating based on user routines, reducing unnecessary power usage.
- Smart temperature control optimizes energy consumption.

3. Safety Features

- Auto shut-off to prevent overheating or dry heating.
- Leakage and fault detection alerts for enhanced safety.

4. Voice & AI Integration

- Compatible with voice assistants like Alexa & Google Assistant.
- AI-based learning adapts to user habits for better efficiency.

5. Smart Notifications & Alerts

- Sends alerts for maintenance reminders and unusual energy spikes.
- Notifies users when water is heated to the desired temperature.

6. Integration with Smart Home Systems

- Works with home automation to sync with other devices.
- Can be linked with solar power systems for eco-friendly heating.

Would you like a more detailed technical breakdown?

Advantages:

The Smart Wearable IoT Device for Detecting Health Anomalies in Senior Citizens Using ESP32 offers several advantages, making it a valuable solution for various healthcare applications:

1. Energy Efficiency

- Optimized heating schedules reduce power wastage.
- AI-based learning adapts to user behavior for minimal energy use.

2. Cost Savings

- Lower electricity bills due to efficient heating.
- Prevents overheating and unnecessary standby power consumption.

3. Convenience & Remote Access

- Control geyser remotely via a mobile app.
- Set schedules and monitor temperature from anywhere.

4. Enhanced Safety

- Auto shut-off prevents overheating and dry heating.
- Detects leaks, faults, and abnormal temperature changes.

5. Smart Notifications & Alerts

- Alerts for maintenance, energy usage, and water readiness.
- Prevents last-minute surprises of cold water.

6. Integration with Smart Home Ecosystem

- Works with voice assistants like Alexa & Google Assistant.
- Syncs with other smart home appliances for automated control.

7. Eco-Friendly Operation

- Can integrate with solar power or renewable energy sources.
- Reduces carbon footprint with optimized energy use.

4. EXPERIMENTAL ANALYSIS

Figure 2 The image categorizes various electronic devices into three segments: Connecting, Computing, and Consumer.Connecting includes devices like mobile phones, smart mobile phones, PDAs, and screen phones, which enable communication and connectivity .Computing consists of devices such as handheld PCs, Palm PCs, Auto PCs, and thin clients, which focus on processing and computing tasks. Consumer features entertainment and media devices like game consoles, handheld games, MP3 players, and Net TVs, which cater to personal and household entertainment needs.

These categories highlight the integration of connectivity, computing, and consumer technology in modern digital ecosystems.

Fig 2: Network communication embedded systems

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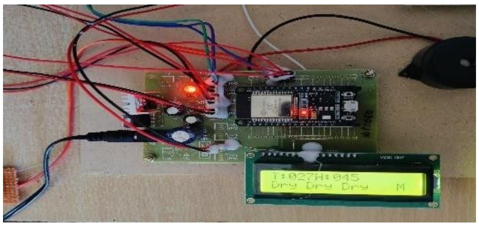

Fig 3: Hardware Kit

Figure 3 The image showcases a prototype of an IoT-based smart heater system built using an ESP32 microcontroller. The setup includes an LCD display, a power regulation module, and various connected components through jumper wires. The LCD screen displays real-time system status, which in this case indicates "Dry Dry Dry," possibly representing environmental conditions such as temperature and humidity levels. The ESP32, equipped with Wi-Fi and Bluetooth capabilities, is likely used to remotely monitor and control the heating system via an IoT platform. A buzzer is also present, which could be used for alerts or notifications. This prototype demonstrates how smart heating systems can be automated using IoT, enabling real-time monitoring, energy efficiency, and remote access for better environmental control in residential or industrial applications.

5. CONCLUSION

In conclusion, the IoT-based smart water heater (geyser) represents a significant advancement in energy-efficient and automated water heating systems. By integrating IoT technology with temperature sensors, microcontrollers like ESP32, and real-time data monitoring, this system enhances user convenience, safety, and energy optimization. The ability to remotely control and schedule heating operations through a smartphone or web application ensures that users have access to hot water precisely when needed, reducing unnecessary energy consumption and lowering electricity bills. Furthermore, real-time temperature monitoring and automatic cut-off mechanisms prevent overheating and potential hazards, enhancing safety. The incorporation of cloud-based analytics allows users to track usage patterns and optimize heating schedules accordingly. Additionally, smart features such as leak detection, water level monitoring, and fault diagnostics improve reliability and maintenance efficiency. The system can also integrate with smart home ecosystems, responding to voice commands or automated routines. In industrial and residential applications, this IoT-enabled geyser promotes sustainability by conserving energy and reducing carbon footprints. As technology continues to evolve, future enhancements such as AI-driven predictive maintenance, renewable energy integration, and advanced user customization will further refine the efficiency and effectiveness of smart water heating solutions, making them an essential part of modern homes and industries.

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