

REMOTE 3D PRINTER OPERATION AND MONITORING

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ABSTRACT

This project presents an integrated solution for monitoring and controlling key parameters of a 3D printer using an ESP32 microcontroller, with the data visualized and managed via the Blynk mobile application. The system provides real-time monitoring of critical parameters, including the bed temperature, nozzle temperature, fire detection, and filament level, ensuring improved safety and efficiency during 3D printing operations. The ESP32's Wi-Fi capabilities enable seamless communication with the Blynk app, allowing users to remotely track and adjust the printer's performance.

The bed and nozzle temperature sensors ensure that the printing process remains within optimal thermal ranges, while a fire detection module adds an extra layer of safety by immediately alerting users to potential hazards. Additionally, a filament level sensor keeps track of material usage, providing notifications when the filament is running low. This comprehensive system offers enhanced control, real-time feedback, and remote management, ultimately increasing the reliability and convenience of 3D printing operations.

Keywords: ESP32 microcontroller, Remote monitoring, 3D printer, Sensor integration, Real-time data visualization, Wireless communication, Automation.

I. INTRODUCTION

3D printing has become a revolutionary technology in various fields, but ensuring the smooth and safe operation of a 3D printer is crucial. One of the key challenges in 3D printing is real-time monitoring of critical parameters such as bed temperature, nozzle temperature, filament levels, and fire detection. Traditional 3D printers often lack integrated systems for remote monitoring and safety, which can lead to inefficient operations and potential hazards.

This project aims to address these issues by utilizing an ESP32 microcontroller to create a comprehensive monitoring system for 3D printers. The system tracks the bed and nozzle temperatures, detects fire hazards, and monitors filament levels, all of which are displayed and controlled via the Blynk mobile application. The ESP32's Wi-Fi capability allows users to monitor and adjust these parameters remotely, providing both convenience and enhanced safety. By integrating these features, the system ensures that 3D printing processes are efficient, safe, and user-friendly.

II. RELATED WORK

In the realm of remote 3D printer monitoring and control, various approaches have been explored to enhance the efficiency, safety, and user convenience of additive manufacturing processes. The integration of Internet of Things (IoT) technologies, particularly utilizing microcontrollers like the ESP32, has been central to these developments.

Complementing this, the Blynk mobile application has been employed to create user-friendly interfaces for monitoring and controlling 3D printers. Through Blynk, users can visualize real-time data, receive alerts, and even adjust printer settings remotely. Such integrations have been demonstrated in projects where environmental parameters within 3D printer enclosures are monitored, ensuring optimal printing conditions and reducing the risk of print defects. These collective efforts underscore a growing trend towards accessible, efficient, and user-centric remote monitoring systems in 3D printing. By building upon these foundational works, the current project aims to further enhance safety features—such as fire detection and filament level monitoring—while maintaining real-time control and feedback mechanisms through the integration of ESP32 microcontrollers and the Blynk application.

III. METHODOLOGY

The methodology for this project involves the development of an integrated system that combines hardware components for monitoring key parameters of the 3D printer with software for remote control and alert notifications.

3.1 Hardware Selection and System Design

To monitor critical thermal conditions, the system incorporates thermocouple sensors, such as the MAX6675, for precise nozzle temperature measurements, and NTC thermistors for bed temperature monitoring. These sensors provide accurate readings essential for maintaining optimal printing conditions.

Filament consumption is tracked using a filament level sensor, which can be based on resistive or capacitive sensing methods. This sensor detects the presence and quantity of filament in the extruder, allowing for timely alerts when filament levels are low, thus preventing print failures.

For enhanced safety, a fire detection module, such as the MQ-2 sensor, is integrated to detect smoke or flame near the printer. Upon detection of potential fire hazards, the system can trigger immediate alerts to the user via the Blynk app, enabling prompt intervention.

The entire system is powered through a carefully designed power supply and wiring configuration, ensuring stable and safe operation of all components. Proper power management is crucial to maintain the reliability and longevity of the monitoring system.

3.2 Sensor Integration and Data Acquisition

The bed and nozzle temperatures are monitored using thermocouple sensors, such as the MAX6675 for the nozzle, and NTC thermistors for the bed. These sensors are interfaced with the ESP32 microcontroller, which reads their outputs through appropriate analog or digital communication protocols. The ESP32 processes these readings to provide accurate temperature data, enabling the system to maintain optimal printing conditions and prevent thermal anomalies.

To monitor filament levels, a sensor—either resistive or capacitive—is strategically positioned to detect the presence of filament in the extruder or spool. When the filament reaches a predefined low threshold, the sensor sends a signal to the ESP32, which then triggers a notification to alert the user. This proactive measure helps in preventing print failures due to filament depletion.

For fire detection, a flame sensor, such as the KY-026, is integrated into the system to continuously monitor the environment around the 3D printer. The sensor outputs a digital signal to the ESP32 when it detects infrared light indicative of a flame. Upon receiving this signal, the ESP32 can initiate safety protocols, such as sending alerts to the user via the Blynk application or activating an alarm system. This integration enhances the safety of the printing process by enabling prompt responses to potential fire hazards.

3.3 Software Development and Programming

The ESP32 will be programmed using Arduino IDE or Platform IO. Code will be developed to manage sensor data collection, processing, and communication with the Blynk app. The program will read the temperature values from the sensors and compare them to predefined thresholds. If the temperature goes out of range, it will trigger an alert. The fire detection module will be continuously monitored for any signs of smoke or fire. If the sensor detects an abnormal level, the system will issue an emergency alert. The ESP32 will periodically check the filament level sensor, and when the filament is running low, it will send a notification to the Blynk app.

3.4 System Integration and Testing

All the components (sensors, ESP32, and the Blynk app) will be integrated into a complete system. The sensors will send real-time data to the ESP32, which processes the data and communicates with the Blynk app. Test each sensor individually to ensure proper functioning (temperature, fire, and filament sensors). Conduct integration testing to ensure the ESP32 correctly processes data and communicates with the Blynk app. Test the system under various operating conditions to validate real-time data monitoring, alerting, and remote-control functionality.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

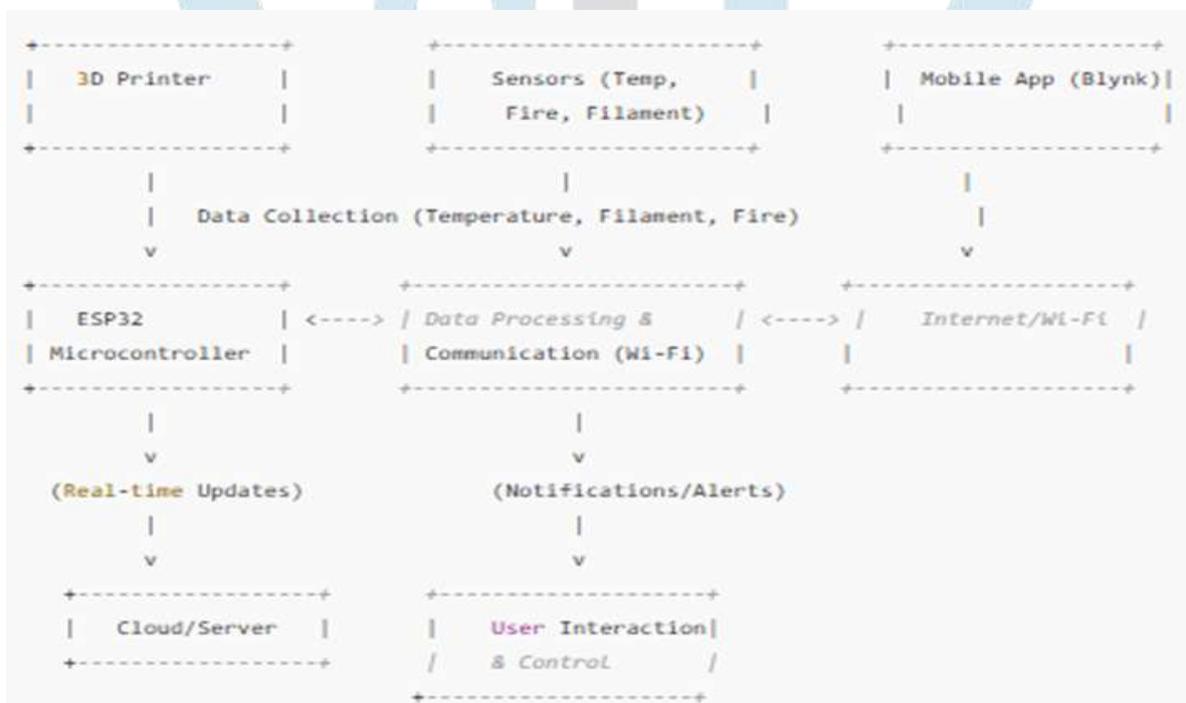
The result of this project is the successful development and implementation of an IoT-based monitoring and control system for 3D printers. The system was designed to provide real-time monitoring of key printer parameters, including bed and nozzle temperature, filament levels, and fire detection. It enables remote control and notification capabilities via the Blynk mobile application.

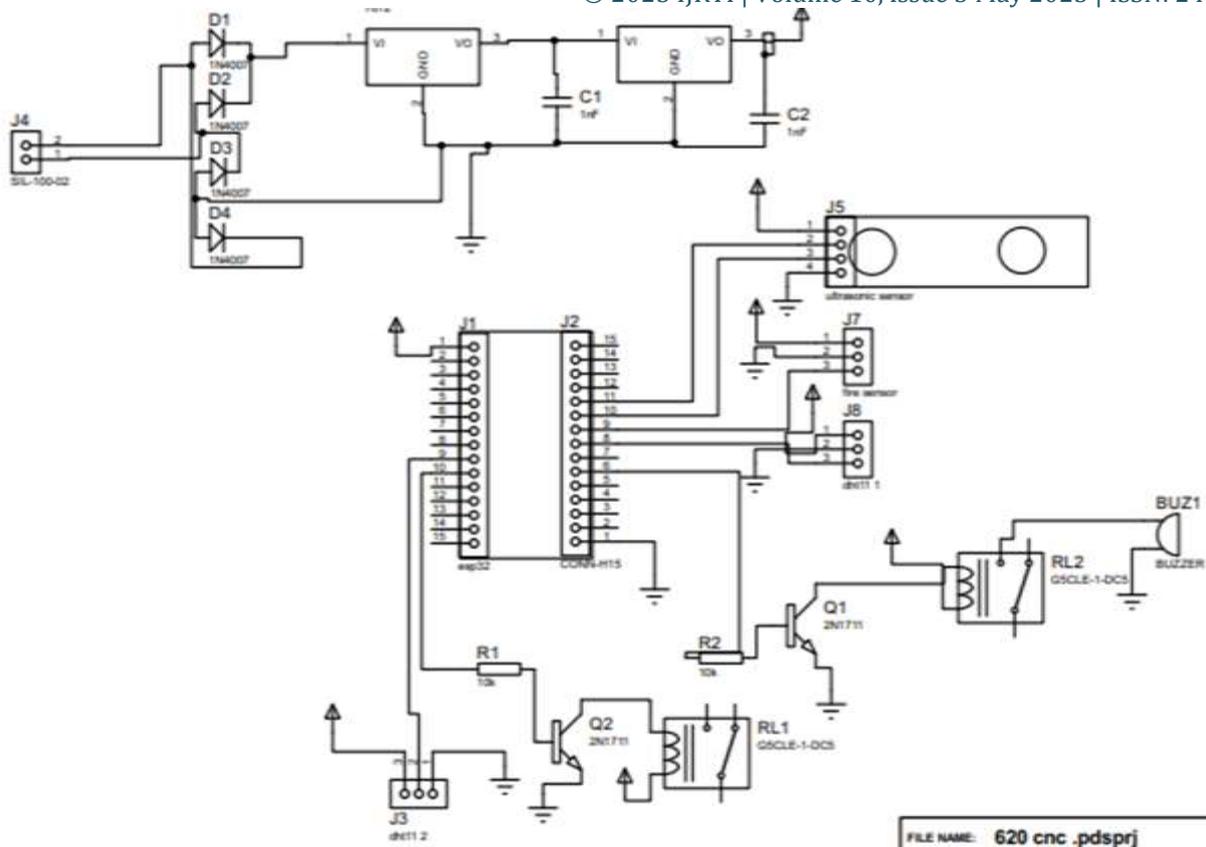
4.1 Performance

- **Temperature Monitoring:** Present the data collected from the bed and nozzle temperature sensors. Include graphs or tables showing temperature stability over time during printing operations. Discuss any observed fluctuations and their potential impact on print quality.
- **Filament Level Detection:** Detail the responsiveness and accuracy of the filament level sensor. Provide instances where the system successfully detected low filament levels and the corresponding alerts generated.
- **Fire Detection Capability:** Report on the sensitivity and reliability of the fire detection module. Include any test scenarios where the sensor identified potential fire hazards, and describe the system's response.

4.2 System Architecture Overview

The system architecture for the 3D printer monitoring and control system integrates various hardware and software components to monitor and control key printer parameters such as bed and nozzle temperature, filament level, and fire detection. It uses the ESP32 microcontroller as the central processing unit to interact with sensors and communicate with a mobile app (Blynk) via Wi-Fi.





4.3 Observations

During the implementation and testing of the proposed system, several key observations were recorded:

- The **ESP32 microcontroller** successfully established and maintained a stable Wi-Fi connection with the Blynk app throughout extended 3D printing sessions, enabling reliable real-time data transmission.
- The **temperature sensors** (thermocouple for the nozzle and thermistor for the bed) provided accurate and consistent readings, with minimal latency. The system was able to detect abnormal temperature spikes and notify the user promptly via the mobile application.
- The **filament level sensor** was effective in detecting low filament conditions. The alert mechanism triggered at the appropriate threshold, allowing the user to intervene before a print failure occurred.
- The **fire detection sensor** demonstrated good sensitivity during simulated fire/smoke conditions. In each test case, the sensor triggered an alert immediately, proving to be a reliable safety feature.
- The **Blynk mobile application** provided an intuitive and interactive interface for monitoring and controlling the printer. All sensor data were displayed in real-time, and the system was responsive to user input from the app.
- No significant **data lag** or disconnection was observed during normal printing operations, confirming the system's robustness in handling continuous data flow.
- The overall system was able to operate efficiently with **low power consumption**, making it suitable for continuous monitoring without significant energy cost.

V. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

In conclusion, the 3D Printer Monitoring and Control System developed using IoT technologies, sensors, and the Blynk mobile application successfully addresses key challenges in 3D printing, including safety, efficiency, and remote monitoring. The integration of temperature sensors, fire detection systems, and filament level monitoring enables real-time tracking of critical printer parameters, providing users with the ability to oversee and intervene in the printing process remotely.

The system's key features include:

- **Real-Time Monitoring:** Continuous tracking of bed and nozzle temperatures, filament levels, and fire risks, with data sent directly to the Blynk app.
- **Alerts and Notifications:** Immediate notifications are sent to users when abnormal conditions arise, such as overheating, filament depletion, or potential fire hazards, ensuring prompt corrective actions.
- **Remote Control:** Users can adjust settings (like temperature) or pause/resume prints directly from the mobile app, allowing for greater convenience and flexibility.
- **Enhanced Safety:** Fire detection mechanisms ensure that any potential fire risks are quickly identified, preventing damage or accidents.
- **Efficiency and Cost-Effectiveness:** By preventing print failures, material wastage, and downtime, the system enhances the overall efficiency of the 3D printing process.

5.2 Future Scope

The current system for remote monitoring and control of 3D printers offers a reliable and efficient solution. However, several avenues for improvement and future development can be explored:

1. **Machine Learning Integration:** Future work could involve incorporating machine learning algorithms to analyse sensor data for early detection of hardware failures or print anomalies, such as nozzle clogging or material inconsistencies. These models could provide predictive maintenance alerts.
2. **Camera Module Integration:** By adding an ESP32-CAM module, the system could include real-time video surveillance, enabling users to visually monitor the 3D print process remotely. This addition would provide a more comprehensive overview of the printing conditions.
3. **Automatic Safety Controls:** Future iterations could include relay modules and automated shutdown procedures triggered by fire or overheating sensors, enhancing the system's ability to respond to safety threats without requiring user intervention.
4. **Web Dashboard Development:** To complement the mobile interface, a web-based dashboard could be developed, enabling cross-platform access and control. This would be particularly useful in industrial or educational settings where multiple printers need to be managed simultaneously.
5. **Cloud Data Logging and Analytics:** Integration with cloud platforms like Firebase or AWS IoT could enable data logging and remote storage, allowing users to track historical trends, monitor printer health over time, and schedule maintenance based on usage patterns.
6. **Enhanced User Controls:** The future system could allow users to remotely start or stop printing jobs, adjust printer settings, and receive notifications about print progress or issues, improving user control and interaction.
7. **Improved Security Measures:** The addition of user authentication mechanisms would enhance the security of remote access, ensuring that only authorized users can interact with the printer system.

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