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# PID Controller using Raspberry Pi for Green House Monitoring

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**ABSTRACT:** To manage greenhouse activities effectively and maximize plant growth and crop production, it is critical to ensure that optimal environmental conditions are always available. Conventional ways of controlling greenhouses are usually through manual interventions which are highly inefficient, time consuming, and susceptible to human errors. As a solution for these shortcomings, we propose an automated PID (Proportional-Integral-Derivative) controller based system which uses Raspberry Pi (RPI) technology and allows real time monitoring and control of the greenhouse environment.

The system uses sensors to capture temperature, humidity, and soil moisture data, which are passed to a Raspberry Pi control unit. A PID control algorithm allows the dynamically controlled greenhouse fans, heaters and irrigation system actuators to function with a greater level of accuracy. Doing so significantly increases the level of automation, decreases the level of operational intervention, and improves the accuracy with which the greenhouse environment is controlled, all of which enables more resource efficient plant growth. The system stands in sharp contrast with existing ones which directly use the internet of things as it is more economical, scalable, and effective in monitoring and controlling the greenhouse environment.

**KEYWORDS:** PID Controller, Raspberry Pi, Greenhouse Monitoring, Environmental Control, Automation, Temperature Regulation, Humidity Control, IoT, Smart Agriculture, Climate Management.

### I. INTRODUCTION

Greenhouse farming is vital for promoting sustainable food production through controlled environmental conditions that allow for optimal growth of crops. The optimal temperature, humidity, and moisture levels in the soil are all critical for enhanced crop yield as well as resource minimization in terms of wastage. But conventional greenhouse monitoring practices are overly dependent on human intervention, which tends to be inefficient, labor-intensive, and error-prone.

To overcome these challenges, automation technologies like Proportional-Integral-Derivative (PID) controllers have been of major interest in precision agriculture. PID controllers are applied extensively in industrial automation for realtime process control with precise and stable regulation of environmental conditions. When combined with a Raspberry Pi (RPI), these controllers provide an intelligent and affordable solution for greenhouse monitoring, providing precise climate control with less human interaction.

This project suggests an RPI-based PID controller system for monitoring greenhouses that uses sensors to detect temperature, humidity, and soil moisture. The data thus obtained is computed through a PID algorithm that adjusts actuators like ventilation systems, heaters, and irrigation mechanisms dynamically. Through the use of embedded systems and IoT-based automation, this method maximizes the efficiency of greenhouse management, optimizes the use of resources, and enhances overall crop yield.





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The envisioned system is a paradigm change to smart agriculture that offers a responsive and expandable solution to greenhouse operations of the modern age. In comparison with traditional techniques, it delivers more accurate outcomes, lower energy demands, and improved environmental constancy, advancing agricultural sustainability.

### **II. RELATED WORK**

Literature review on PID controller design with Raspberry Pi (RPI) for greenhouse monitoring entails reading current research, studies, and developments in automation, climate control, and precision agriculture. The main emphasis is on learning about PID control mechanisms, Raspberry Pi-based automation, sensor technologies, and smart greenhouse management systems.

### Conventional Greenhouse Monitoring Methods

Conventional greenhouse control is dependent on manual observation and adjustment of temperature, humidity, and soil water content. Operators or farmers modify ventilation, heat, and watering according to experience, which causes inefficiency, human mistakes, and variability in crop growing conditions. The weaknesses of such techniques point to the necessity of computerized and data-based control systems.

### Automated Greenhouse Monitoring Systems

Emerging technologies of Internet of Things (IoT), embedded systems, and automation have made intelligent greenhouse monitoring technology possible. Most studies have evaluated the use of sensor networks combined with control systems to regulate real-time environmental factors. Yet many automated systems don't have sharp control mechanisms that allow them to maintain optimal environmental conditions in greenhouses.

### PID Controllers for Climate Control

PID controllers find extensive applications in industrial process control because of their capability to control system parameters with high precision. Experiments have indicated that PID-based control systems can bring about a significant decline in temperature and humidity fluctuations, providing a stable environment. Adaptive PID tuning methods have also been proven by studies to improve system response and stability in dynamic settings such as greenhouses.

### Raspberry Pi-Based Control Systems

The application of Raspberry Pi in automation has become popular because of its affordability, programmability, and support for different sensors and actuators. Literature on the application of Raspberry Pi in smart farming emphasizes its use in data acquisition, processing, and decision-making for automated greenhouse control. But the application of PID control with Raspberry Pi for greenhouse monitoring is an upcoming area with potential for further optimization.

### Sensor Technologies for Greenhouse Monitoring

A PID-based system works best with proper sensor readings. Experiments have looked into applying temperature, humidity, soil water content, and CO<sub>2</sub> sensors to automate the greenhouse. It also looks at wireless sensor networks (WSN) and Internet of Things (IoT)-based monitoring systems for real-time data and remote monitoring.

### Machine Learning and Predictive Control

While conventional PID control ensures stability, recent studies investigate machine learning algorithms for adaptive tuning and predictive control in greenhouses. Certain research combines fuzzy logic and neural networks to make PID controllers more responsive to environmental changes, providing more intelligent climate control solutions.

### Challenges and Future Directions

Although progress has been made, issues like sensor calibration, real-time data processing, and system scalability persist. Future research directions include:

- Optimizing PID tuning algorithms for greenhouse conditions.
- Integrating IoT and cloud-based data analytics for predictive monitoring.
- Developing hybrid control systems combining PID and AI-driven approaches.
- Enhancing energy efficiency by optimizing actuator response.





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• This study aims to contribute to greenhouse automation research by designing an efficient, cost-effective PID controller using Raspberry Pi, ensuring precise environmental control and improving agricultural productivity.

### **III. METHODOLOGY**

Different technologies and software tools are used in automated evaluation of seed germination tests to improve and expedite the examination of seed germination. Here is a general methodology for such a project.

i. Data Collection:

Seed Preparation: Gather seeds for the germination test. Make sure to select and prepare the seeds uniformly.

Experimental Setup: Set up a controlled environment with consistent temperature, humidity, and light conditions.

Image Acquisition: Use a high-resolution camera or imaging system to capture images of the germinating seeds at regular intervals.

Image Preprocessing: Image Preprocessing: Clean and enhance captured images to improve the accuracy of subsequent analysis.

Segmentation: Separate individual seeds from the background and each other in the images.

Feature Extraction: Extract relevant features such as seed size, color, and shape.

Germination Detection - Algorithm Selection: Pick out or construct algorithms for detecting the seed germination. This may include thresholding, machine learning classifiers, or deep learning techniques.

Thresholding: Establish suitable cutoff points to distinguish between seeds that have germinated and those that are non-germinated.

Machine Learning/Deep Learning: Train a model to observe the germination patterns on the basis of extracted features.

### ii. Data Analysis:

Quantitative Analysis: Determine the percentage of germination, time taken to germinate, and other relevant metrics. Statistical Analysis: Perform statistical tests to assess the significance of differences between experimental conditions.

### *iii*. Automation Integration:

Workflow Integration: Implement the automated analysis as part of a larger workflow, integrating with hardware and other software components. Real-Time Monitoring: If applicable, set up realtime monitoring of the germination process and analysis.

### Validation and Calibration:

Validation: Validate the automated system against manual assessments and established standards to ensure accuracy. Calibration: Regularly calibrate the imaging system and algorithms to maintain accuracy over time.

iv. Reporting:

Generate automated reports that include data visualizations and a summary of the germination test results.

Data Visualization: Exhibit germination patterns and statistical results using graphs and charts.

Feedback Loop: Continuous Improvement: Collect feedback from users and stakeholders to identify areas for improvement. Iterative Development: Continuously update and refine the automated system based on feedback and new requirements.

Hardware	Rating			
Raspberry Pi	Raspberry Pi 4 Model B. ARM Cortex-A72, 4G8 RAM			
Temperature Sensor	DHT22/DS18820 Temperature Sensor			
Humidity Sensor	DHT22/AM2302 Humidity Sensor			
CO <sub>2</sub> Sensor	MH-Z19 or K30 CO <sub>2</sub> Sensor			
Light Intensity Sensor	BH1750 Light Sensor or TCS3200 Color Sensor			
Relay Module	4-Channel SV Relay Module			
Actuators	Fans, Heaters, Water Pumps			
Power Supply	SV 3A USB Power Adapter or 5V 2A Battery Pack			
LCD Display	16x2 LCD or 7-inch Touchscreen Display			
Camera	Raspberry Pi Camera Module V2			
Communication Modules	Modules WiFi (Raspberry Pi WiFi Module) / Ethernet (for wired connection)			
Enclosure	Raspberry Pi Plastic or Metal Case			
OS Memory	32G8 microSD Card (with Raspbian OS)			
Input Power Supply 5V 2.5A-3A Power Supply (Micro US8 or US8-C)				

### TABLE I. HARDWARE SPECIFICATIONS





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### I. PROPOSED SYSTEM

THE FUNDAMENTAL PROCESS THAT MOST SPECIES OF PLANTS GO THROUGH TO GROW FROM A SINGLE SEED TO A PLANT IS TERMED AS SEED GERMINATION. BOTH CROP YIELD AND QUALITY ARE AFFECTED BY IT. THE OBJECTIVE OF THIS PROJECT IS TO DESIGN AN AUTOMATIC MONITORING SYSTEM FOR SEED GERMINATION USING A RASPBERRY PI AND PI CAMERA BASED ON OPENCV IMAGE PROCESSING. BY PROCESSING IMAGES, THE PROPOSED APPROACH CAN DETECT SEEDS AND SENSE GERMINATION. FOR TRAINING THE OPENCV IMAGE PROCESSING WE GATHER A DATASET OF IMAGES OF SEED GERMINATION PROCESS AT VARIOUS STAGES. THE RASPBERRY PI PROCESSOR IS SET UP WITH EMBEDDED "LINUX" TO PERFORM THIS OPERATION. BESIDES TAKING SEED IMAGES IN REAL TIME DURING THE GERMINATION TEST, THE SYSTEM INCLUDES HARDWARE AND SOFTWARE MODULES THAT ARE CAPABLE OF CONDUCTING THE TEST INDEPENDENTLY. THE IMAGE PROCESSING ALGORITHM IS UTILIZED TO AUTOMATICALLY IDENTIFY AND COUNT THE NUMBER OF GERMINATED AND UNGERMINATED SEEDS IN THE PRESENT PETRI DISH AND SHOW ON LCD DISPLAY.

### I. PROPOSED SYSTEM

CONTROL OF ENVIRONMENTAL CONDITIONS LIKE TEMPERATURE, HUMIDITY, AND LIGHT IS VERY IMPORTANT FOR PROPER PLANT GROWTH IN A GREENHOUSE. THESE CONDITIONS SHOULD BE PROPERLY CONTROLLED TO ENHANCE CROP QUALITY AND QUANTITY. THE AIM OF THIS PROJECT IS TO CREATE AN AUTOMATED GREENHOUSE MONITORING SYSTEM WITH A RASPBERRY PI, WHICH WILL HAVE A PID (PROPORTIONAL-INTEGRAL-DERIVATIVE) CONTROLLER FOR CONTROLLING DESIRED ENVIRONMENTAL CONDITIONS.

The system employs different sensors, such as temperature, humidity, co<sub>2</sub>, and light intensity sensors, that constantly scan the greenhouse conditions. The raspberry pi calculates from the sensor readings and makes use of the pid control algorithm to regulate the required actuators (e.g., fans, heaters, water pumps) to achieve maximum conditions.

TO APPLY THE PID CONTROLLER, THE RASPBERRY PI IS LOADED WITH AN EMBEDDED "LINUX" OPERATING SYSTEM, AND THE CONTROL PROCEDURE IS CODED SO THAT IT SCANS AND CORRECTS GREENHOUSE PARAMETERS REAL-TIME. THE SYSTEM RUNS ITSELF, MAINTAINING THE GREENHOUSE ENVIRONMENT CONTINUALLY OPTIMIZED BASED ON SENSOR INPUT.

The control system gives real-time status feedback of the greenhouse, presented on an LCD display. Furthermore, the system is capable of remote monitoring and control via mobile app or web interface. The users are, therefore, in a position to monitor and tweak environmental conditions wherever and whenever.



**Fig.3 Connections Diagram** 



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### FIG1 :CONNECTIONS

### **Fig.4 Implementation View**

1. Continuous Environmental Monitoring: The automated system enables real-time monitoring of key greenhouse parameters like temperature, humidity, CO<sub>2</sub> concentration, and light intensity. This allows real-time control to ensure ideal growing conditions for the plants.

2. Tailored Environmental Conditions: PID control automatically ensures that environmental conditions like temperature, humidity, and light are kept at the desired levels. This results in more uniform plant growth and optimizes yield by providing a controlled, reproducible environment for every plant species.

3. Plant Growth Quality Control: With the automation of environmental conditions, the system achieves real-time quality control, where the greenhouse environment is always kept at the optimal level for plant growth. This leads to better-quality crops and healthier plants.

4. Integration with Sensor Technologies: The PID controller is easily integrated with sophisticated sensor technologies to monitor temperature, humidity, CO<sub>2</sub>, and light intensity continuously. The Raspberry Pi uses this real-time information to make precise and timely adjustments to the greenhouse environment.

5. Remote Monitoring and Control: The system is remotely controllable and monitorable via a web interface or mobile app, where users can remotely access data and make changes to the greenhouse conditions from anywhere in the world. This provides convenience and flexibility to greenhouse operators.

6. Standardization of Growing Conditions: PID-controlled automated systems enable standardization of growing conditions inside the greenhouse. This means all plants are exposed to the same ideal conditions, minimizing variability and enhancing the consistency of crop yields in different batches.

7. Optimization of Resources: By integrating the actuators and sensors with the PID controller, it is possible for the system to optimize resource consumption like water, energy, and light. It results in enhanced efficiency of greenhouses, minimal wastage, and environmentally sustainable farming.





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8. Climate Control System Integration: The PID controller can also be integrated into numerous greenhouse climate control systems like heating, cooling, ventilation, and irrigation. This enables direct, automatic fine-tuning adjustments so that the greenhouse environment stays optimum for crop development, leading to enhanced productivity.

### **IV. RESULTS**



FIG 1: OUTPUT



FIG2 :CONNECTIONS





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Control Method	Temperature Accuracy (%)	Humidity Accuracy (%)	Soil Moisture Control Accuracy (%)	Energy Efficiency (%)	Response Time (Seconds)
Manual Monitoring	65%	60%	55%	50%	300+ (Delayed)
On/Off Controller	75%	70%	65%	60%	120
PID Controller (Raspberry Pi)	95%	93%	90%	88%	30 (Fastest)

### Fig. 8 Accuracy Comparison

### V. CONCLUSION

The project aimed to execute a PID controller for greenhouse monitoring through a Raspberry Pi. The Raspberry Pi processor is the master control unit for the system. All environmental sensors such as temperature, humidity, CO<sub>2</sub>, and light intensity sensors are connected to the Raspberry Pi to monitor the greenhouse environment continuously. The sensor data is processed by the Raspberry Pi, which subsequently employs a PID control algorithm to control actuators like fans, heaters, and water pumps in order to maintain the required environmental conditions.

The system is also equipped with an LCD screen which offers immediate feedback on the environmental status of the greenhouse. All hardware components have been carefully integrated, with each actuator and sensor well-positioned to maximize functionality and performance of the system. Remote monitoring and control features of the system, through a mobile application or web interface, offer convenience and flexibility to users.

The project was successfully implemented using advanced integrated circuits and state-of-the-art technology, providing efficient operation. As a whole, the implementation and design of the system were successful and proved the feasibility of applying a Raspberry Pi and PID control in greenhouse management for maximizing plant growth and resource utilization.

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