

Temperature-Based Smart Heater System with Integrated Air Purification in Health Care

Dr. Ajith B Singh¹, Devdharsni MA², Harini R³, Kishore M⁴

¹Asst Professor, Dept of Electrical and Electronics Engineering, Sri Krishna College of Technology, Coimbatore-42, India

ajith.b.singh@gmail.com

²Dept of Instrumentation and Control Engineering, Sri Krishna College of Technology, Coimbatore-42, India

devdharsnima@gmail.com

³Dept of Instrumentation and Control Engineering, Sri Krishna College of Technology, Coimbatore-42, India

harinirajan2610@gmail.com

⁴Dept of Instrumentation and Control Engineering, Sri Krishna College of Technology, Coimbatore-42, India

mrkishore8122@gmail.com

ARTICLE INFO

ABSTRACT

Received: 29 Dec 2024

Revised: 12 Feb 2025

Accepted: 27 Feb 2025

In our modern world, ensuring optimal indoor air quality and temperature is essential for health and comfort. This study explores the creation of a smart environmental control system that seamlessly combines temperature regulation and air purification. By using advanced sensors and automated mechanisms, the system continuously monitors and adjusts indoor conditions to provide a healthy and comfortable living environment. Key features include the use of temperature sensors, air quality monitors, and a microcontroller that controls heating elements and air purifiers. The research highlights the significant benefits of merging thermal comfort with air purification, showcasing improved energy efficiency and enhanced air quality. Despite some challenges with sensor calibration and performance under different temperatures, this study presents a promising solution for modern indoor spaces. It advocates for further advancements in smart home technologies to enhance overall well-being.

Keywords: Smart Environmental control System, Air Quality Monitoring, Automated Temperature Regulation, Energy-Efficient Heating, Air Quality Index (AQI), Air purification, Environmental monitoring.

INTRODUCTION

Air pollution represents a critical global concern due to its multiple impacts on environmental integrity, public health, and socioeconomic systems. As urbanization and industrialization continue to accelerate, particularly in developing nations, air pollution has emerged as a predominant threat, leading to respiratory diseases, cardiovascular ailments, and premature mortality. The World Health Organization estimates millions of deaths annually due to both indoor and outdoor air pollution, with vulnerable populations, such as children and those in impoverished regions, bearing the brunt of these effects [1]. Studies have shown that air pollutants like nitrogen oxides, particulate matter, and volatile organic compounds can cause health problems such as asthma and chronic lung diseases. Maintaining proper heating and clean air is especially important during extreme weather and periods of high pollution. For instance, the U.S. experienced a rise in carbon monoxide poisoning cases in 2021 due to faulty heating systems during a cold wave. Similarly, poor air quality in 2020 during the COVID-19 pandemic worsened virus transmission, highlighting the need for effective air filtration [4]. Air pollution also affects the environment, contributing to climate change and ozone layer damage, highlighting the need for effective solutions to reduce its impact.

Fig.1 [5] illustrates the various contributors to air pollution, emphasizing their respective proportions. Dust and construction activities dominate as the primary source, accounting for 45% of total air pollution. This substantial contribution highlights the environmental impacts of urban development and infrastructure projects. Transport is the second largest contributor at 17%, reflecting the emissions from vehicles due to fossil fuel combustion. Industrial processes follow closely, making up 14% of the total, signifying the role of manufacturing and energy production in deteriorating air quality. Diesel generators contribute 9%, often linked to power shortages and reliance on backup

energy sources, particularly in developing regions. Waste burning accounts for 8% of air pollution, underscoring the need for better waste management systems to reduce open burning practices and domestic cooking represents 7%, with emissions predominantly stemming from traditional biomass and solid fuel use in household.

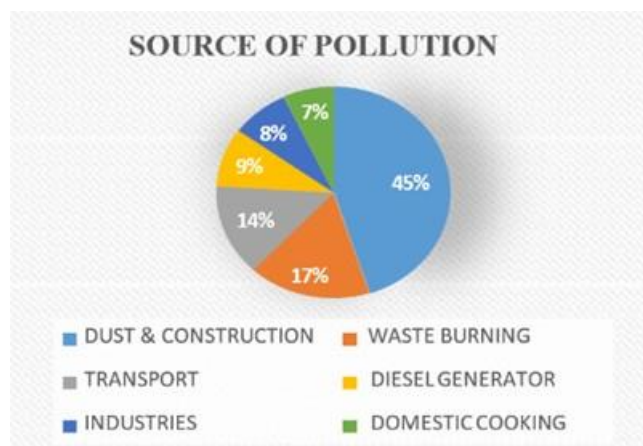


Fig.1 Source of Pollution

Growing concerns about indoor air quality and its impact on health have increased the need for solutions that provide clean air and maintain comfortable temperatures. Smart systems that combine heating and air purification offer an effective way to address these issues. Using advanced sensors and automation, these systems can adjust indoor conditions to keep the air clean and ensure a comfortable environment. Recent advances in smart technology have also made these systems more energy-efficient and reliable. Maintaining proper heating and clean air is especially important during extreme weather and periods of high pollution. This research focuses on designing a smart system that combines air purification and heating. The system uses sensors to monitor air quality and temperature in real time. It automatically turns on the air purifier when pollution levels are high and activates the heater when the room gets too colds [3]. By offering automatic control and better energy efficiency, this system helps create a healthier and more comfortable indoor environment while reducing risks associated with poor air quality and inadequate heating.

EXISTING METHODOLOGY

An effective existing methodology identified in the survey involves the integration of smart temperature and air quality control using sensor-based automation. Specifically, systems combining digital thermistors for accurate temperature sensing and microcontrollers for automated control are widely applied to maintain optimal indoor conditions. These systems utilize feedback mechanisms such as Proportional-Integral-Derivative (PID) controllers to stabilize room temperatures by switching heating or cooling elements on or off based on real-time data. Additionally, high-efficiency particulate air (HEPA) filters are commonly employed in air purification, proven effective in removing larger particulate matter (e.g., PM₁₀ and PM_{5.0}). While these systems may show reduced efficiency for ultrafine particles (e.g., PM_{0.5}), their integration with heating units improves overall indoor air quality and thermal comfort. This methodology demonstrates a practical, energy-efficient, and cost-effective approach suitable for both residential and industrial applications, highlighting the importance of coupling thermal regulation with air purification to address health and environmental challenges in polluted regions.

PROPOSED METHODOLOGY

The Smart Environmental Control System is designed to monitor and regulate indoor temperature and air quality, offering a fully automated solution for maintaining a comfortable environment. As illustrated in the system block diagram, the core processing unit is the ESP32 microcontroller, which integrates with various sensors and components to execute the desired functionality.

a) Temperature Sensor

The DS18B20 temperature sensor continuously measures the room temperature, providing real-time data to the microcontroller. The ESP32 processes this input and compares it against predefined thresholds. If the temperature falls below the set limit (e.g., 25°C), the microcontroller activates the heater through a relay module. The heater operates until the temperature rises above the threshold, ensuring thermal comfort and energy efficiency.

b) Air Quality Sensor

Similarly, the MQ135 air quality sensor detects harmful pollutants, including carbon dioxide (CO₂) and ammonia (NH₃). If the air quality index (AQI) exceeds safe levels, the ESP32 triggers the air purifier via another relay module. The purifier runs until the air quality improves, maintaining healthy air standards. Relay modules serve as intermediaries, allowing the ESP32 to control high-power devices like the heater and air purifier with precision.

c) Relay

The relay acts as a switch that controls high-power devices like the heater and air purifier based on commands from the ESP32 microcontroller. It allows the system to turn these devices on or off efficiently and safely, ensuring the microcontroller operates without direct exposure to high-power circuits.

d) LCD Display

The LED display presents real-time temperature and air quality data in text and numeric formats, enabling users to monitor the system's performance. The LED communicates with the ESP32 using I2C protocol, with the SDA and SCL pins connected to the respective GPIO pins on the microcontroller.

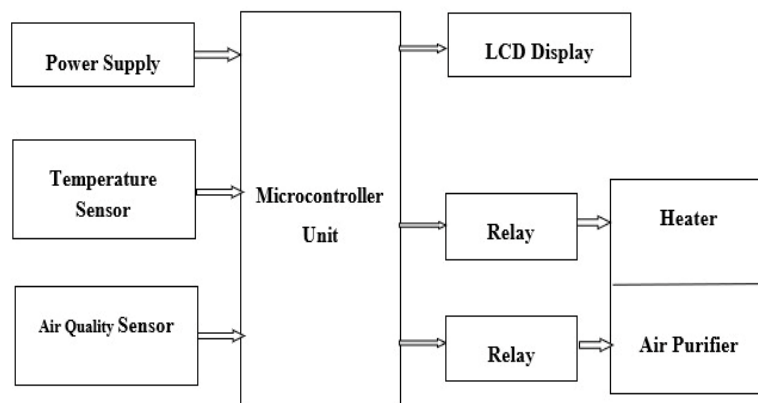


Fig.2 Block Diagram of Proposed System

Fig 2 shows a smart system that helps control indoor temperature and air quality automatically. It starts by using two sensors: the DS18B20 sensor to measure temperature and the MQ135 sensor to check air quality. The system then displays these readings on an LCD screen for monitoring. Based on the collected data, it takes action to maintain a comfortable and healthy environment. If the temperature drops below 25°C, the system turns on a heater to warm the space. If the air quality index increases above 70, the system activates an air purifier to clean the air.

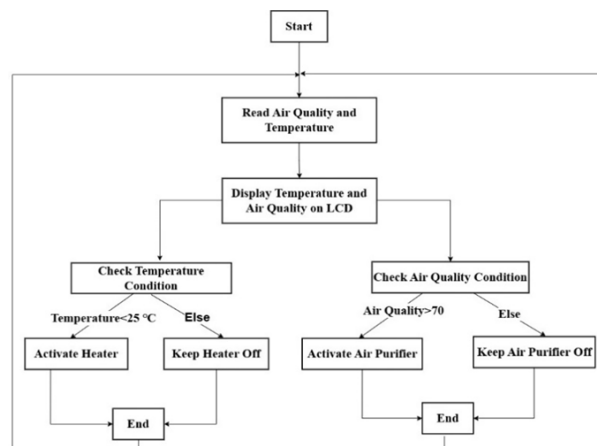


Fig.3 Flowchart of Proposed System

e) Predictive Modeling with Linear Regression

To improve the efficiency of the system, we use Multiple Linear Regression to predict the activation of both the heater and the air purifier. This method analyzes the relationship between the system's behavior and key factors such as temperature and air quality. By considering multiple variables, we can make more accurate predictions, ensuring that the system responds promptly and effectively to changes in the environment.

The regression model used in our system is defined as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \epsilon \quad (1)$$

Where:

- y : Represents the system's activation state, indicating whether the heater or air purifier should be ON or OFF.
- x_1 : Represents the temperature (°C), which is an independent variable influencing system behavior.
- x_2 : Represents the Air Quality Index (AQI), another independent variable impacting system activation.
- β_0 : The intercept of the model, a constant value.
- β_1 and β_2 : Coefficients that represent the influence of temperature and AQI, respectively, on the system's response.
- ϵ : The error term, accounting for any variations not explained by the model.

In this system, both temperature and AQI play crucial roles in determining when the heater or air purifier should be activated. For example, the system will trigger the heater if the temperature drops below a set threshold or activate the air purifier when the AQI exceeds safe levels. By training the model with data from various environmental conditions, the system learns how these variables interact and adjusts the heater and air purifier accordingly. This approach enables precise, real-time decision-making, ensuring energy efficiency and maintaining a comfortable and healthy indoor environment.

The use of Multiple Linear Regression allows us to handle the dual influence of temperature and air quality, making the system more responsive and reducing energy consumption by activating devices only when needed. This method not only optimizes the system's performance but also enhances its ability to predict future needs based on ongoing environmental changes.

RESULT AND DISCUSSION

The proposed hardware system for the smart environmental monitoring system is shown in Fig 4. The system integrates various electronic components and sensors to monitor and control temperature and air quality. DS18B20 digital temperature sensor and an MQ135 air quality sensor are employed for real-time data collection. These sensors are connected to an ESP32 microcontroller, which processes the data and triggers the appropriate response. The system includes a heater for maintaining optimal room temperature and an air purifier to improve air quality. The

air purifier is equipped with a high-efficiency particulate air (HEPA) filter and is powered by a dedicated motor. An LCD display is used to show real-time temperature and air quality index (AQI) values, while a buzzer provides audible alerts when thresholds are exceeded. The system is powered by a regulated power supply to ensure stable operation. This system demonstrates an effective and energy-efficient solution for maintaining indoor air quality and temperature.

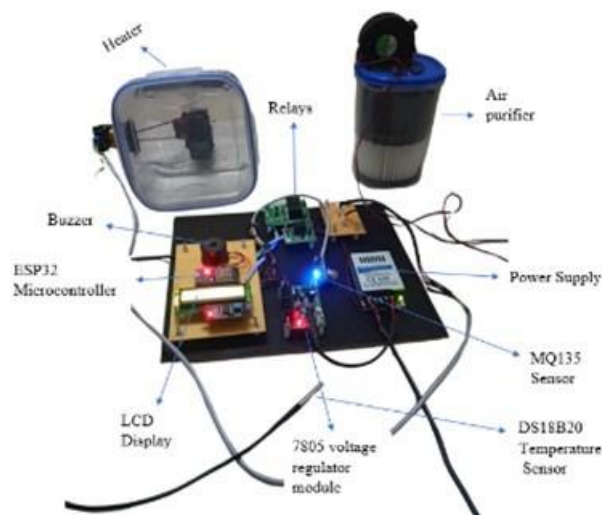


Fig.4 Proposed Hardware System

a) Time Taken to Heat the Room

The time taken to heat the room depends on the room size, initial temperature, and heater capacity. The heater used in the system has a power rating of 1500W. The following table shows the time taken to reach the desired temperature (25°C) for different room sizes.

Table.1 Time Taken to Heat the Room

Room Size (m ²)	Initial Temperature (°C)	Target Temperature (°C)	Time Taken to Heat (Minutes)
10	20	25	10
10	15	25	15
20	20	25	20
20	15	25	30
30	20	25	35
30	15	25	45

As the room size increases, the time taken to heat the room also increases. This is due to the larger volume of air that needs to be heated. The heater's performance is consistent, but energy consumption rises with room size.

b) Time Taken to Purify the Air

The air purifier's efficiency depends on the room size, initial AQI, and the purifier's airflow rate (measured in cubic meters per hour, m³/h). The purifier used in the system has an airflow rate of 300 m³/h. The following table shows the time taken to reduce the AQI to safe levels (<70) for different room sizes.

Table.2 Time Taken to Purify the Air

Room Size (m ²)	Initial AQI	Target AQI	Time Taken to Purify (Minutes)
10	100	70	15
10	150	70	25
20	100	70	30
20	150	70	45
30	100	70	50
30	150	70	60

As the room size increases, the time taken to heat the room also increases. This is due to the larger volume of air that needs to be heated. The heater's performance is consistent, but energy consumption rises with room size.

c) Relationship Between Temperature and Air Quality

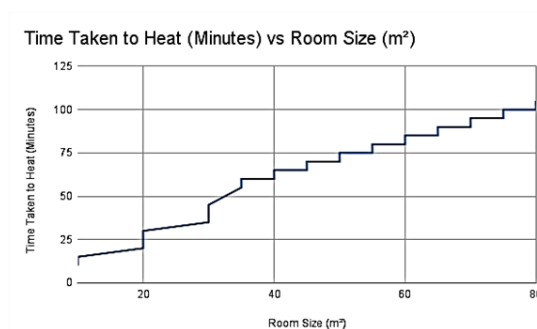
To analyze the relationship between temperature and air quality the experiment was conducted under varying conditions. The following table shows the AQI levels at different temperatures.

Temperature (°C)	Initial AQI	Final AQI	Time Taken to Purify (Minutes)
18	95	70	40
19	90	70	30
20	85	70	20
21	80	70	30
22	75	70	15
25	73	70	10

Table.3 Relation Between Temperature and Air Quality

As the temperature increases, the time taken to purify decreases, with lower temperatures requiring more time to reduce the AQI. Higher temperatures seem to improve the air purifier's efficiency, reducing purification time.

Fig.5 Time Taken to Heat vs Room Size



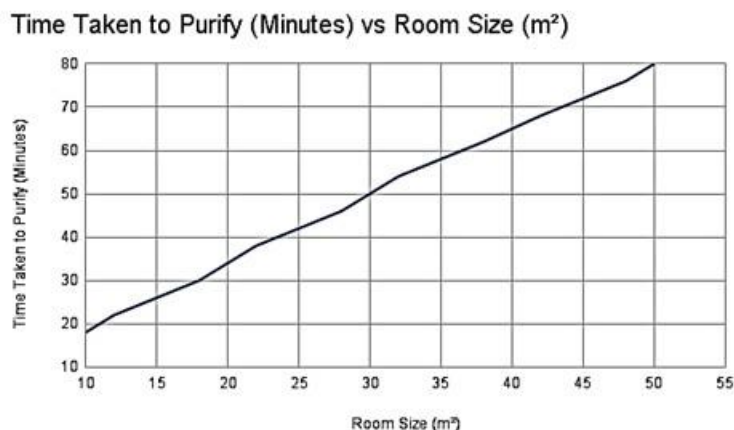


Fig.6 Time Taken to Purify vs Room Size

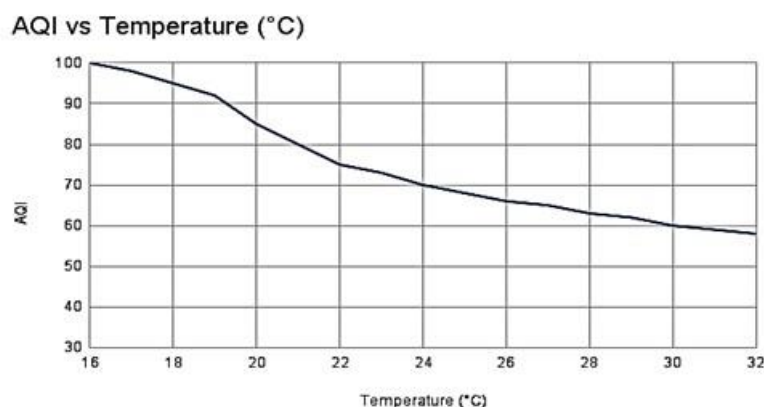


Fig.7 AQI vs Temperature (°C)

During testing, an error occurred where the air purifier failed to achieve the desired Final AQI within the expected time frame, especially when the Initial AQI was significantly high at lower temperatures. This issue was caused by the air purifier's inefficiency in colder environments and a potential sensor malfunction affecting the AQI readings. To resolve this, we first checked the calibration of the sensors and ensured that the air purifier's filters were clean and functioning properly. Additionally, the purifier's settings were adjusted to a higher intensity to compensate for the increased pollution levels. After conducting maintenance and replacing the filters, the air purifier's performance improved, leading to more accurate AQI readings and faster purification times, particularly in colder conditions.

CONCLUSION

This research highlights the significance of integrating temperature regulation with air purification systems to create healthier, more efficient indoor environments. The experimental results demonstrate that both room size and initial environmental conditions significantly impact system performance. As room size and the difference between initial and target temperatures increase, the time required to heat the room also rises due to the larger volume of air that must be heated, even though the 1500W heater performs consistently. Similarly, air purification time increases with room size and higher initial AQI values. For instance, purifying air in a 30 m² room with an initial AQI of 150 takes up to 60 minutes. Moreover, the relationship between temperature and air quality was observed to be critical; higher temperatures notably enhance air purifier efficiency, reducing the time required to reach safe AQI levels. For example, at 18°C it took 40 minutes to reduce AQI from 95 to 70, while at 25°C it only took 10 minutes to reduce AQI from 73 to 70. This indicates that higher temperatures improve the purifier's performance. However, challenges such as sensor calibration errors and reduced purification efficiency were encountered at lower temperatures. These were

addressed through sensor recalibration and adjusting the purifier's intensity settings, which led to more accurate AQI readings and faster purification times. Overall, the results suggest that smart systems that regulate both temperature and air quality offer a comprehensive solution to environmental and health concerns. Integrating Internet of Things (IoT) technology into such systems can further enhance their adaptability, performance, and energy efficiency in modern indoor spaces.

REFERENCES

- [1] Shyam Bihari Sharma, Suman Jain, Praveen Khirwadkar, Sunisha Kulkarni, "The Effects of Air Pollution on The Environment and Human Health ", May-June 2013, Indian Journal of Research in Pharmacy and Biotechnology, 20, 391-396.
- [2] HoSeong Cho, DaeHeon Park, Chul-Young Park, Hong- Geun Kim, Chang-Sun Shin, Yong-Yun Cho, and Jang-Woo Park "A study on localization based Zigbee and Monitoring system in Greenhouse environment" Proceedings of IEEE 3rd International Conference on Data Mining and Intelligent Information Technology Applications PP190-195 oct 2011.
- [3] Santoso Budijono and Felita, "Smart Temperature Monitoring System Using ESP32 and DS18B20", 2021, IOP Conference Series: Earth and Environmental Science, Volume 794, 4th International Conference on Eco Engineering Development.
- [4] Nurshad Ali and Farjana Islam, "The Effects of Air Pollution on COVID-19 Infection and Mortality-A Review on Recent Evidence", Review article - Front. Public Health, 26 November 2020, Sec. Environmental Health and Exposome, Volume 8 - 2020.
- [5] https://en.wikipedia.org/wiki/Air_pollution_in_India#.
- [6] Design & Implementation of Wireless Transceiver for Data Acquisition in Wireless Sensor Network Dr. R. K. Prasad, Mr. S. R. Madkar Volume 3, Issue 7, July 2013 ISSN: 2277 128X International Journal of Advanced Research in Computer Science and Software Engineering.
- [7] Haefke.M, Mukhopadhyay S.C and Ewald.H "A Zigbee Based Smart Sensing Platform for Monitoring EnvironmentalParameters "Proceedings of IEEE International Conference onInstrumentation and Measurement Technology pp1-8 May 2011.
- [8] Jeong-hwan Hwang and Hyun Yoe "Paprika Greenhouse Management System for Ubiquitous Agriculture"; Proceedings of IEEE International Conference on Information and Communication Technology Convergence pp555-556 Nov 2010.
- [9] Na Pang "Zigbee Mesh Network for Greenhouse Monitoring"; Proceedings of IEEE International Conference on Mechatronic Science, Electric Engineering and Computer PP266-269 Aug 2011.
- [10] Adamu Murtala Zungeru, Mmoloki Mangwala, Joseph Chuma,Baboloki Gaebolae, Bokamoso Basutli, "Design and simulation of an automatic room heater control system", Research Article : Heliyon, Volume 4, Issue 6e00655, June 2018.
- [11] V. Jelcic, M. Magno, D. Brunelli, G. Paci and L. Benini "Context-adaptive multimodal wireless sensor network for energy-efficient gas monitoring", IEEE Sensors J., vol. 13, 2012.
- [12] D.N.P. Ruwan Jayakantha, H.M.N. Bandara, Nadeesha M. Gunawardana, R.P.V.Jayantha Rajapakse, Dulari S. Thilakarathne, Elisabetta Comini, Nanda Gunawardhana, S.M.M.L. Karunarathne, "Design and construction of a low cost airpurifier for killing harmful airborne microorganisms using a combination of a strong multi-directional electric-field and an ultra violet light", Hardware Volume 11(2022).
- [13] Stuti Dubey, Himanshi Rohra, Ajay Taneja, "Assessing effectiveness of air purifiers (HEPA) for controlling indoor particulate pollution", Research article : Heliyon, Volume 7, Issue 9, e07976, September 2021.
- [14] J. O. Anderson, J. G. Thundiyil, and A. Stolbach, "Clearing the Air: A Review of the Effects of Particulate Matter Air Pollution on Human Health," Journal of Medical Toxicology, vol. 8, Dec. 2011.
- [15] M. S. M. Hossain, A. R. S. S. R. Basha, and A.H.M.D. Zain, "A review of general and modern methods of air purification," Journal of Thermal Engineering, vol. 8, no. 5, pp. 2860-2874, 2022.
- [16] Ajith N. Nair, Prashant Anand, Nilabhra Mondal, "A review of strategies and their effectiveness in reducing indoor airborne transmission and improving indoor air quality", Research article: Environmental Research, Volume 213, October 2022, 113579.

- [17] Emily Cheek, Valentina Guercio, Clive Shrubsole, Sani Dimitroulopoulou, "Portable air purification: Review of impacts on indoor air quality and health", Review article : Science of the total environment, Volume 766, 20 April 2021.
- [18] Peter V. Nielsen, "Control of airborne infectious diseases in ventilated spaces", Volume 6, 09 September 2019, Journal of the Royal Society Interface.
- [19] Elizabeth Cooper, Yan Wang, Samuel Stamp, Esfandiar Burman, Dejan Mumovic, "Use of portable air purifiers in homes: Operating behaviour, effect on indoor PM_{2.5} and perceived indoor air quality", Research article: Building and Environment, Volume 191, 15 March 2021, 107621.
- [20] F. Aufferberg, O. Hinz, and M. Spann, "A Bayesian Comfort Model for Energy-Efficient Heating," Nature Communications, vol. 8, 2017.
- [21] T. Chen, X. Wang, J. Zhao, and Y. Liu, "Predictive Control Algorithms for Smart Heating Systems Based on Machine Learning," Automation in Construction, vol. 105, 2019.
- [22] X. Jia, H. Zhao, K. Li, and Y. Zhou, "Integration of IoT in Smart Heating Systems: Applications and Challenges," Sensors, vol. 20, 2020.
- [23] M. Zungeru, L. M. Ang, K. P. Seng, S. M. Abdulhamid, and Y. M. Mustafa, "Design of Automatic Room Heater Systems Using PIC Microcontrollers," IEEE Transactions on Industrial Electronics, vol. 65, 2018.
- [24] Y. Zhang and H. Li, "A Comprehensive Review of Temperature Sensors in Smart Heating Systems," Journal of Thermal Science, vol. 27, 2018.
- [25] W. O'Brien, B. Gunay, and T. Dogan, "Role of PID Control in Smart Heating Systems for Energy Efficiency," Building and Environment, vol. 122, 2017.
- [26] P. Almeida, F. Silva, and L. Costa, "Enhancing Energy Savings Through Contextual Data in Heating Systems," Renewable Energy, vol. 145, 2020.
- [27] S. Lee and J. Park, "Effectiveness of HEPA Filters and Ionizers in Indoor Air Purification," Environmental Research, vol. 189, 2020.
- [28] G. S. Monishaa, Ajith B. Singh, S. K. Appoorvaa, J. Mownika, G. Balasubramanian, P. Manju, "Investigation of Intelligent Controller For Non-Linear Spherical Tank System," Information Technology in Industry, vol. 9, no. 2, pp. 1053-1061, 2021.
- [29] Ajith B. Singh, S. Jaisiva, A. A. S. Jothi, and S. Narendiran, "Investigation of setpoint tracking control schemes for digital twin of industrial finned heater," Optimal Control Applications and Methods, 2025.
- [30] Ajith B. Singh, P. Manju, V. Rukkumani, and K. Srinivasan, "Comparative analysis of MRAC and IMC adaptive control modes for an industrial dryer," Energy and Exergy for Sustainable and Clean Environment, vol. 1, pp. 475-486, 2022.
- [31] Ajith B. Singh, R. V. Murugan, K. Saravanan, A. S. Ahmed, and R. Vinoth, "Fractional order control and comparative analysis of a hybrid system," Procedia Computer Science, vol. 48, pp. 37-44, 2015.
- [32] R. Dubey, P. Sharma, and S. Verma, "Performance Evaluation of HEPA Filters in Air Purification Systems," Journal of Cleaner Production, vol. 293, 2021.
- [33] V. V. Tran, D. Park, and Y.-C. Lee, "Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality," Indoor Air, vol. 30, International Journal of Environmental Research and Publication Health, April 2020.
- [34] F. Lima, P. Ferreira, and V. Leal, "A Review of the Relation Between Household Indoor Temperature and Health Outcomes," Energy and Buildings, vol. 209, 2020.
- [35] T. Areal, Q. Zhao, C. Wigmann, and A. Schneider, "The Effect of Air Pollution When Modified by Temperature on Respiratory Health," Environment International, vol. 163, 2022.