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WindowSense: A Smart Convenience Window

Muhammad Hamizan Yusof[1], Muhamad Izamuddin Mohd Nasir[1], Syarifuddin Sujuanda[1], Shelena Soosay Nathan[1, 2, *]

[1] *Department of Information Technology, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA*

[2] *ICT for Technology Humanization, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600 Pagoh, Johor, MALAYSIA*

*Corresponding Author: shelena@uthm.edu.my
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Abstract

Smart windows have garnered significant interest as IoT technology advances, enabling the development of more sophisticated and effective solutions. While traditional windows face challenges related to adverse weather, air quality, and user convenience, this study aims to address these issues by identifying user requirements, developing a smart window prototype, and evaluating its effectiveness in residential areas. To ensure efficient problem-solving, an agile methodology is employed throughout the study. The prototype incorporates three key sensors: a gas sensor, raindrop sensor, and humidity sensor. These sensors enable the smart window to detect and respond to changes in the environment accordingly. The developed smart window demonstrates enhanced convenience and efficiency, leading to high levels of user satisfaction. Looking ahead, the integration of the WindowSense project with other smart home devices and systems holds the potential for further improvements in user efficiency and convenience. This aligns with the study's objectives, and the results obtained provide a strong foundation for future enhancements and integration efforts.

1. Introduction

Internet of Things (IoT) is a new trend of innovation which is the integration of software and hardware in the world of Internet [1]. IoT is defined as any smart devices and appliance that are connected through the internet with the assistance of computing system. Implementation of IoT in our daily life helps to ease and optimize activities. The Internet of Things is an omnipresent topic as it is already applied in the concept of "Smart Home". In which smart home devices can be controlled and monitored through the internet. Hence, devices and users can communicate with each other with the help of computing systems. The WindowSense project aims to address various common issues with traditional windows, including rain damage, air quality, and user convenience. It incorporates rain sensors that automatically close the window when it detects rain, preventing water from entering the house. There are many other existing smart home and smart window projects that serve different purposes compared with this project as shown in Table 1.

Table 1 *Differences between the existing projects*

Project	Features	Advantages	Disadvantages
WindowSense	Have user-friendly application that display real time sensors data and can control the smart window.	Improves indoor air quality, comfort, and protection against adverse weather conditions	Lacks emphasis on energy efficiency and privacy management
Google Nest Hub [2]	Smart home integration, centralized control hub, voice commands, temperature control, lighting controls, security cameras	Comprehensive smart home experience	Does not specifically address window-related challenges like rain damage or gas detection
View Dynamic Glass [3]	Automatic tint adjustment based on external conditions, glare reduction, maximizing natural light	Energy efficiency, comfortable lighting	Does not incorporate features like gas sensors or motorized blinds, limiting air quality control and precise airflow adjustments

This project focuses on several key objectives, including comprehensive user requirement identification, app design, and prototype development for the WindowSense system. Its primary goal is to provide an automated window control solution that adjusts the opening and closing of windows based on environmental factors like temperature, humidity, and air quality. This innovative system grants residents enhanced convenience and control over their windows through seamless adjustments made via a discreet mobile app interface. Rigorous evaluation processes are conducted to ensure the prototype's imperceptible integration, optimal functionality, and user-friendly experience.

2. Materials and Methods

The WindowSense is equipped with various sensors and utilizes an ESP32 module to establish a connection with the user's smartphone, enabling monitoring and control functionalities. The concept of IoT devices is introduced, highlighting their usefulness in modern times. The WindowSense, similar to other IoT devices like smart refrigerators, enhances convenience for users by providing remote access through smartphones. Additionally, the WindowSense contributes to home security. Overall, this section emphasizes the advantages of the WindowSense, including convenience and enhanced security.

2.1 Sensors

Sensors are devices used in various fields to detect and measure environmental changes by converting them into electrical signals. In robotics, sensors act as the "senses" of the system, providing crucial information to the controller or brain [4]. They detect factors like heat, pressure, humidity, and movement, playing a vital role in measurement systems by serving as the initial point of contact with the environment and providing output for processing. To ensure accurate readings, good sensors possess key characteristics such as high sensitivity for precise measurements, minimal noise and interference to avoid false readings, and low power consumption to prevent heat generation. Sensors can be classified based on the quantities they measure, including temperature, pressure, force, speed, and light. Additionally, they can be categorized as either active or passive, with active sensors functioning without external power while passive sensors require external power sources [5]. This project specifically incorporates three sensors: the raindrop sensor, gas sensor, and humidity sensor. These sensors enable the system to detect and respond to changes in rain, gas levels, and humidity, respectively. By leveraging these sensors, the project aims to enhance monitoring and control capabilities in relevant applications.

2.2 Methodology

The agile methodology is utilized in the WindowSense project to address dynamic project requirements and facilitate efficient development. Agile methodologies as in Fig. 1 offer flexibility, collaboration, and iterative development, making them suitable for projects involving evolving technologies and complex environments [6]. In this project, the agile approach allows quick responses to changes, promotes collaboration among stakeholders, and integrates emerging technologies seamlessly. The iterative nature of agile methodology enables regular feedback loops, ensuring that the final product exceeds user expectations. By dividing the development process into sprints, the project team can showcase incremental progress and continuously improve the solution [7].

Overall, implementing agile methodology in the WindowSense project ensures adaptability, collaboration, and the delivery of a high-quality, user-centric solution.

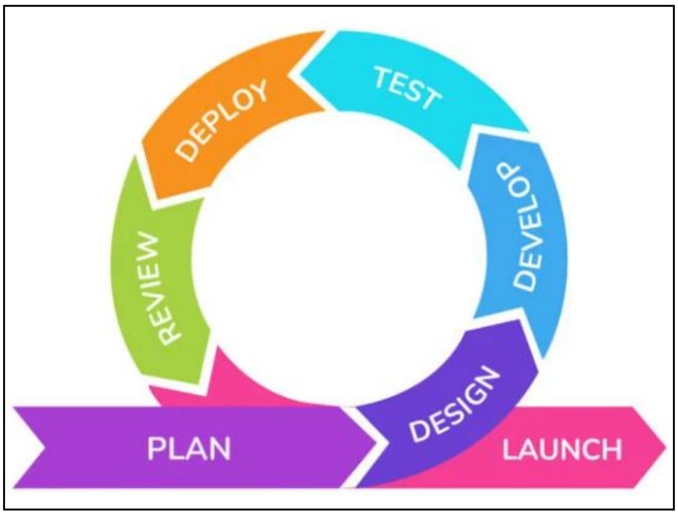


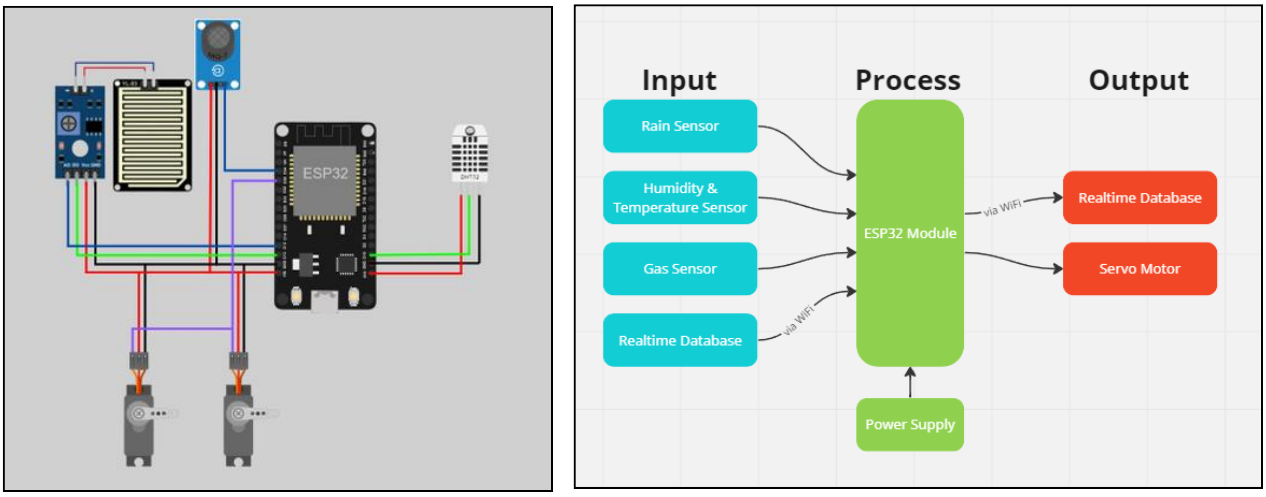
Fig. 1 *Agile methodology*

2.2.1 Planning Phase

During the planning phase, the project team conducts a feasibility study for hardware and software components, evaluating cost, availability, compatibility, and specifications. Research explores options for mobile applications, considering frameworks and technologies. User behaviours are analysed to optimize user experience (UX), and criteria for hardware components are defined. A detailed plan is created with task allocation, timelines, and resource management. Project requirements and scope are identified, and risks are assessed and addressed.

2.2.2 Designing Phase

In the design phase, the project team performs an analysis of the required hardware components for the WindowSense. Circuit and block diagrams in Fig. 2 and Fig. 3 are designed to develop a functional hardware prototype. Simultaneously, the team focuses on designing the UX and user interface (UI) for the mobile application. This involves creating prototypes and visually appealing designs that enhance usability and aesthetic appeal.



(a) **(b)**

Fig. 2 *Example of the project diagrams (a) Project's circuit diagram; (b) Project's block diagram*

2.2.3 Development Phase

During the development phase, the project team writes code, implements algorithms, and integrates software with the hardware prototype. This includes developing the mobile application with the required features and ensuring proper connectivity with the WindowSense hardware.

2.2.4 Testing Phase

The testing phase involves evaluating the functionality, performance, and reliability of the WindowSense system. Thorough testing is conducted on the mobile application to ensure smooth operation, checking for hidden errors or issues across various hardware and operating systems. The overall performance, usability, and user satisfaction of the mobile application are assessed.

2.2.5 Deployment Phase

In the deployment phase, the project team physically sets up and connects the IoT hardware components for the WindowSense. Regular updates are released to address reported issues or bugs and maintain the functionality and security of the mobile application.

2.2.6 Review Phase

The project team conducts an evaluation of the WindowSense system, identifying any deficiencies or shortcomings. Feedback is collected from users or testers to gather insights and identify areas for improvement.

2.2.7 Launch Phase

The final phase of the project involves the official launch of the WindowSense system and mobile application, making them available to users.

3. Result and Discussion

In WindowSense project, the author aimed to develop a window system that improves indoor air quality, comfort, and protection against adverse weather conditions. The key sensors used in this project include a gas sensor, humidity sensor, and raindrop sensor as shown in Fig. 3.

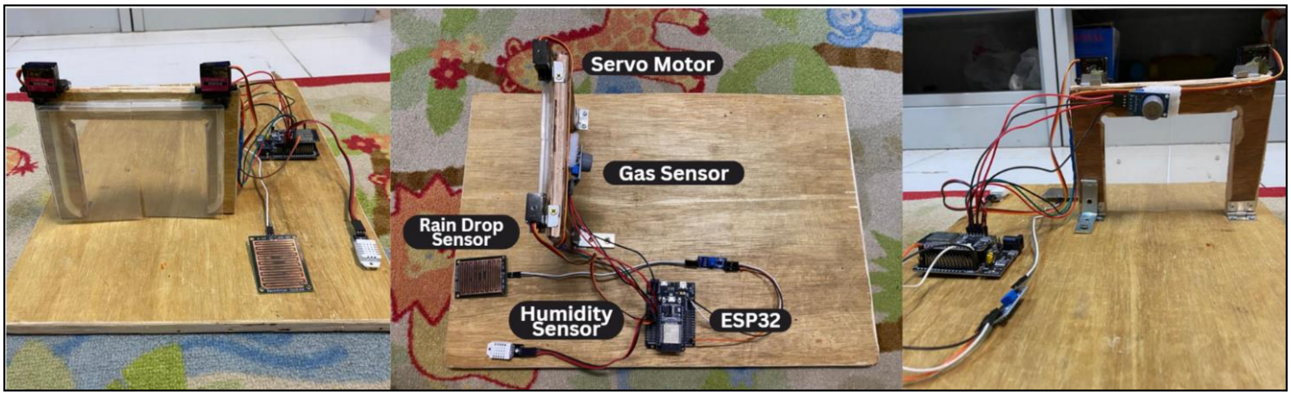


Fig. 3 *Prototype model*

3.1 Gas Sensor Measurement

This study successfully integrated a gas sensor into the WindowSense system to monitor air quality within the room. The sensor will consistently collect the data on change in carbon monoxide (CO) level in the room. By analysing the sensor data, it will able to identify periods of poor air quality and trigger appropriate actions to improve indoor air quality. The accuracy and sensitivity of the gas sensor were confirmed by comparing the measurements with standard reference values, showing reliable performance.

3.2 Humidity Sensor Reading

The humidity sensor integrated into the WindowSense system effectively captured environmental moisture levels. It will observe consistent and accurate measurements of relative humidity from outside the room. The sensor data provided valuable insights into the fluctuations of humidity, enabling the system to make informed decisions regarding window operations.

3.3 Rain Drop Sensor Functionality

The raindrop sensor proved to be highly responsive in detecting rain or water droplets from outside the window. It reliably triggered the appropriate actions to close the window and prevent water leaked into the room. Through extensive testing, as shown in Fig. 4 it will confirm the sensor's accuracy in identifying precipitation events, ensuring the rainwater from entering the room.

Fig. 4 *Sensors reading in application*

3.4 User Interface and Integration

The user interface of the WindowSense application software included with a control panel that displayed real-time sensor data, providing users with insights into air quality, humidity levels, and rain detection status. The intuitive interface allowed users to monitor the system's performance and make informed decisions regarding window operations. Additionally, the system generated alerts or notifications to inform users of any significant changes in environmental conditions. Fig. 5 shows the wireframe for the user experience that will be implemented in the application software for the project.

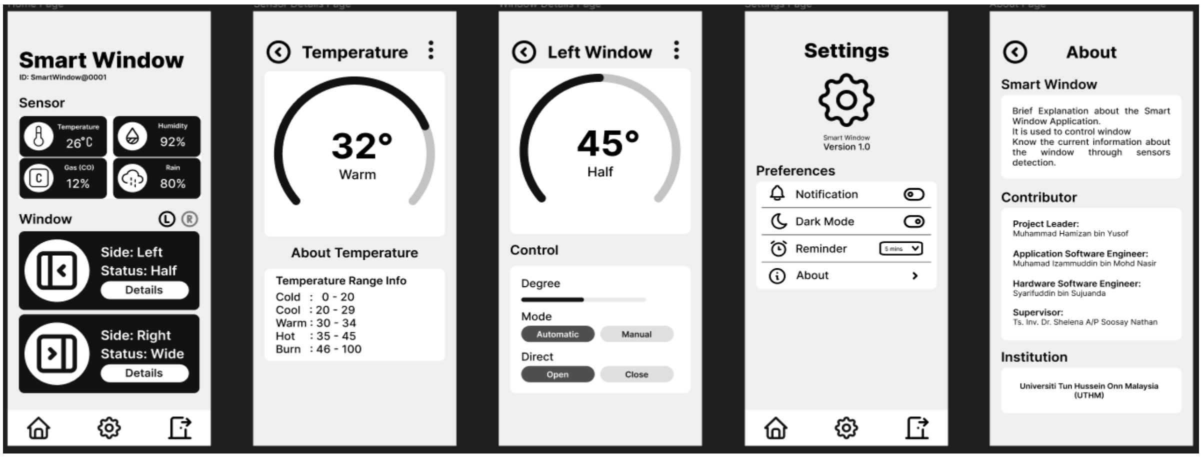


Fig. 4 *Wireframe for WindowSense user experience (UX)*

3.5 Limitation and Future Improvements

While the WindowSense Project demonstrated promising results, there are a few limitations and areas for improvement to consider in future iterations. Firstly, the system could benefit from additional gas sensors to detect and monitor many kinds of pollutants for more detailed air quality analysis. Secondly, incorporating predictive algorithms based on historical data and external factors could further enhance the system's ability to proactively respond to changing environmental conditions. Finally, expanding the capabilities to include weather forecast data could enable the system to anticipate and adapt to upcoming weather events more effectively.

4. Result and Discussion

In summary, WindowSense system, which incorporates gas sensors, humidity sensors, and a raindrop sensor, effectively improves indoor air quality, comfort, and protection against harsh weather conditions. These sensors reliably gather real-time data, allowing informed decisions and appropriate responses. The adaptive ventilation system ensures optimal air quality and humidity levels, while the rain protection feature prevents water from entering the building. With a user-friendly interface and seamless integration with smart home systems, the system offers enhanced convenience and automation. Looking ahead, potential enhancements include expanding pollutant detection capabilities, predictive algorithms, and integrating weather forecasts. The project demonstrates the potential of IoT solutions in creating sustainable and pleasant living environments.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design, data collection, draft manuscript:*** *Muhammad Hamizan Yusof, Muhamad Izamuddin Mohd Nasir;* ***draft manuscript preparation:*** *Muhammad Hamizan Yusof, Muhamad Izamuddin Mohd Nasir, Syarifuddin Sujuanda, Shelena Soosay Nathan. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Radouan Ait Mouha, R.A. (2021) 'Internet of things (IOT)', *Journal of Data Analysis and Information Processing*, 09(02), pp. 77–101. doi:10.4236/jdaip.2021.92006.

[2] Kim, S. *et al.* (2020) 'Smart Home Forensics—Data Analysis of IOT devices', *Electronics*, 9(8), p. 1215. doi:10.3390/electronics9081215.

[3] Pilechiha, P. *et al.* (2020) 'Multi-objective optimisation framework for designing office windows: Quality of view, daylight and energy efficiency', *Applied Energy*, 261, p. 114356. doi:10.1016/j.apenergy.2019.114356.

[4] Budi, K.S. and Pramudya, Y. (2017) 'Pengembangan Sistem Akuisisi Data Kelembaban dan Suhu Dengan Menggunakan Sensor DHT11 dan Arduino Berbasis IoT', *Prosiding Seminar Nasional Fisika (E-Journal) SNF2017 UNJ* [Preprint]. doi:10.21009/03.snf2017.02.cip. 07.

[5] Rayes, A. and Salam, S. (2022) 'The things in IOT: Sensors and actuators', *Internet of Things from Hype to Reality*, pp. 63–82. doi:10.1007/978-3-030-90158-5_3.

[6] Srivastava, A., Bhardwaj, S. and Saraswat, S. (2017) 'Scrum model for Agile methodology', *2017 International Conference on Computing, Communication and Automation (ICCCA)* [Preprint]. doi:10.1109/ccaa.2017.8229928.

[7] Hayat, F. *et al.* (2019) 'The influence of Agile Methodology (scrum) on Software Project Management', *2019 20th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD)* [Preprint]. doi:10.1109/snpd.2019.8935813.