Design and Development of IoT-Smart Mirror Information Display System for Organizational Efficiency

Daimler Benz Alebaba[1], *Suaini* Sura[1*], *Nooralisa* Mohd Tuah[1], and *Seungwon* Lee[2]

[1]Faculty of Computing and Informatics, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Malaysia
[2]Bundang Convergence Technology, Campus of Korea Polytechnic University, 13590 Gyeonggi-do, Rep. of Korea

Abstract. In the realm of the Internet of Things (IoT), a smart mirror is akin to a regular mirror possessed with intelligence, incorporating technology to provide useful information. The need for an integrated multi-functional information display, efficiently consolidating global information, optimizing electricity consumption, and monitoring fire hazards, has become crucial for increasing awareness among organizational staff and visitors. However, many organizations still rely on traditional information displays, leaving them vulnerable to issues such as electricity wastage and hazard oversight. To tackle these issues, we developed a smart mirror enhanced with voice recognition to quickly retrieve global information, simultaneously reducing electricity costs and enabling early detection of fire hazards. This paper details the design and development of smart mirror, following a systematic approach based on the System Development Life Cycle (SDLC) methodology. As a result, evaluations of user acceptance measured through the System Usability Scale (SUS) tool, confirms the operational efficiency and positive reception of the system. This paper significantly contributes to advancing smart mirror research, providing a valuable resource for developers, researchers, and practitioners constructing their iterations and offering inspiration for future enhancements.

1 Introduction

The Internet has a big impact on different organizations, especially in the field of Information and Communication Technology (ICT). It makes information easily accessible. This widespread access to global information allows us to combine it with everyday objects like a regular mirror, turning it into a smart mirror. This transformation allows the smart mirror to show information on its surface, using the technology of the Internet of Things (IoT) [1], [2]. In this large IoT system, the smart mirror stands out. It includes network infrastructure, hardware, and software all connected through the internet, making it easy to exchange data seamlessly. Instead of just being a mirror for reflection, the smart mirror becomes a sophisticated system that displays global information like news on its mirror surface [3].

* Corresponding author: su_sura@ums.edu.my

In the organizational context, there is a common reliance on traditional information displays that keep operating 24/7, mainly showing ads. This constant operation leads to two main issues: first, a lack of important real-time and global information when needed, and second, the wasteful use of electricity as the display runs continuously, even when no one is around. This situation calls for the development of a multi-functional information display system. Such a system plays a crucial role by actively monitoring fire risks to create early awareness, and controlling electricity use to be more cost-effective.

Ensuring that the developed system is accepted by users is crucial. To achieve this, we conducted a user acceptance test using the System Usability Scale (SUS) tool. The SUS tool offered a measurable gauge of the system's user-friendliness, efficiency, and overall usability as perceived by its intended end users [4]. Through these thorough testing procedures, this paper guarantees not only the system's technical proficiency but also its alignment with users, confirming its capability to be an effective and user-friendly multi-functional information display solution.

This paper is organized into distinct sections to enhance a systematic understanding. Section 2 elaborates on the materials and methods employed in the development process. Section 3 undertakes a comprehensive analysis and discussion of the results obtained. Section 4 provides a brief yet insightful summary.

2 Materials and methods

2.1 The methodology

The System Development Life Cycle (SDLC) serves as a methodology, offering a structured approach to the development of smart systems. The choice of SDLC is rooted in its capacity to clearly define inputs and outputs, especially within ICT projects, facilitating the organized allocation of tasks in each phase before proceeding to the subsequent phase [5], [6]. The selected methodology enhances transparency throughout the development process, including the incorporation of usability testing in the final phase [7]. SDLC typically comprises five phases: planning, analysis, design, implementation, and testing. Each phase generates results that undergo evaluation by developers.

2.2 System planning, analysis, and design

In the system planning phase, a user perspective survey is distributed among focus groups to determine the justification for developing the smart mirror system and whether it would genuinely enhance user convenience. This phase helps evaluate the actual need for the system. Additionally, the system's scope is defined, involving a detailed examination of budget allocation, necessary equipment, and the required hardware and software components.

The analysis phase involves a comprehensive assessment of different hardware and software components that are appropriate for integration, resulting in the creation of a smart mirror system. This assessment takes into account the user perspective, encompassing aspects like user experience and the functionality provided by the system. Our analysis reveals robust support from the target users.

In the design phase, the components such as the Raspberry Pi, Arduino UNO, LCD monitor, microphone, LED lights, buzzer, sensors, and others were installed. The required software components, which include Arduino IDE, Raspbian OS, MagicMirror2 modular, and third-party modules such as Google Assistant and Remote-Control, were installed to ensure seamless functionality. The overall design architecture framework illustrated in Fig. 1. The system is connected to the internet network to achieve five key functions: 1) retrieving web services to provide real-time global information displayed on the mirror's surface, 2) utilizing a microphone to capture user voice commands, enabling Google Assistant for voice recognition, 3) incorporating a Remote-Control module, allowing users to control the mirror, receive alerts, and manage appointments, 4) installing a motion sensor to detect human presence, triggering the activation of LED lights for optimizing electricity, and 5) equipping an Arduino Uno with a smoke sensor to detect any fire, gas, or smoke hazards for the activation of an alarm.

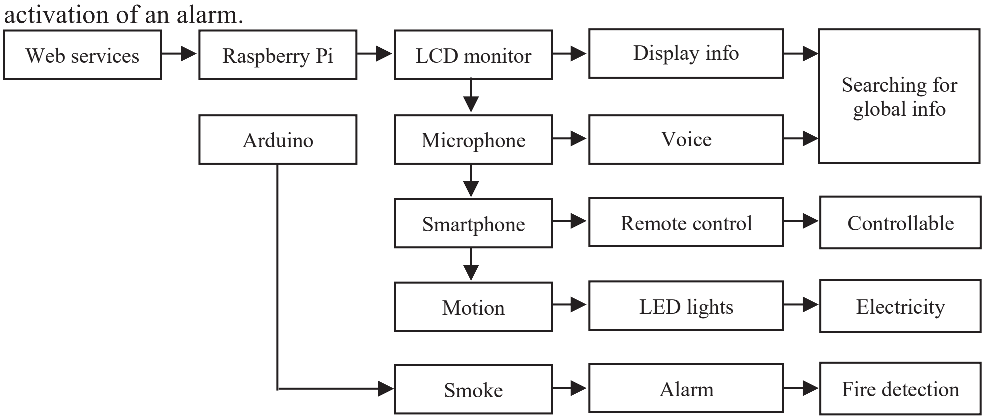

Fig. 1. System architecture framework.

2.3 Implementation and testing material

The Implementation phase involved two main tasks: hardware installation and software installation. For hardware, the mirror was cut to match the monitor screen's dimensions, attached to a pallet wood frame for stability, and connected to the Raspberry Pi. Software installation included loading Raspbian OS onto a microSD card, installing MagicMirror2 before Google Assistant and Remote-Control modules to prevent errors, and configuring the smoke sensor and motion sensor with appropriate connections and programming (C++ for alarm and Python for LED lights). The overall implementation process successfully resulted in a fully functional system, as shown in Fig. 2.

Fig. 2. Multi-functional information display system.

Additionally, to ensure the proper functionality and user acceptance of the fully developed system, we conducted user acceptance testing utilizing the SUS tool [8]. According to the study by [9], SUS helps minimize the likelihood of non-response or scoring errors, particularly in surveys or usability studies conducted without direct supervision. In this phase, participants were presented with the developed system and provided with a manual system as a reference guide. After that, participants were given questionnaires to assess their experiences, where they rated their responses using a five-point Likert scale.

3 Results and discussion

The user interface seamlessly presented real-time global information on the mirror surface, integrating with third-party modules without encountering problems. This customizable information included date, time, holiday dates, to-do lists, current and forecasted weather, complimentary messages, announcements, and news. Furthermore, the Google Assistant voice recognition performs well, accurately capturing user commands from a distance of 3 meters. However, to ensure voice recognition accuracy, it's crucial to use a high-quality microphone which capable of capturing voices effectively from distances of up to 3 meters. On the other hand, the system can be efficiently controlled using smartphones. Authentication is established through the system's IP address, allowing simultaneous access by up to five different smartphones. Regarding the detection sensor, the system effectively detects human heat and movement within a five-meter range, activating LED lights for electricity cost-effectiveness. The motion sensor transmits movement data to the Raspberry Pi within two seconds, initiating the lights and automatically turning them off after five minutes. The smoke sensor reliably detects smoke, fire, and various gases such as ammonia, sulfide, and benzene vapor. It promptly sends data within two seconds to activate the buzzer alarm. Overall, no system errors were encountered, reflecting the system's robust performance and reliability.

A total of 25 participants were invited with diverse backgrounds, to represent a broad range of perceptions. Their backgrounds encompassed various experiences with smart devices, reflecting a mix of individuals who have interacted with and utilized technology in different capacities. This diversity in participant backgrounds aimed to provide a comprehensive evaluation of the system's usability and functionality, taking into account the perceptions of individuals with varied levels of familiarity and expertise in the realm of smart devices. Participants were not physically guided during this process; instead, they relied on the system manual as a self-guideline. After completing the tasks, participants were asked to fill out the SUS questionnaire, comprised of 10 items, constructed following the standard SUS format [10]. The frequency and percentage of the obtained SUS questionnaire results are summarized in Table 1. The abbreviations used in the table are as follows: SD (Strongly Disagree), D (Disagree), N (Neutral), A (Agree), and SA (Strongly Agree).

Table 1. System Usability Scale frequency and percentage.

No.	Item	SD	D	N	A	SA
1.	I think that I would like to use this system frequently.	0	0	3 (12%)	9 (36%)	13 (52%)
2.	I found this system unnecessarily complex.	15 (60%)	9 (36%)	1 (4%)	0	0
3.	I thought this system was easy to use.	0	0	2 (8%)	6 (24%)	17 (68%)
4.	I think that I would need assistance to be able to use this system.	13 (52%)	10 (40%)	2 (8%)	0	0
5.	I found the various functions in this system were well integrated.	0	0	1 (4%)	9 (36%)	15 (60%)
6.	I thought there was too much inconsistency in this system.	12 (48%)	10 (40%)	3 (12%)	0	0

7.	I would imagine that most people would learn to use this system very quickly.	0	0	2 (8%)	5 (20%)	18 (72%)
8.	I found this system very cumbersome to use.	6 (24%)	17 (68%)	2 (8%)	0	0
9.	I felt very confident using this system.	0	1 (4%)	3 (12%)	6 (24%)	15 (60%)
10.	I needed to learn a lot of things before I could get going with this system.	13 (52%)	9 (36%)	3 (12%)	0	0

The convenience of use (as reflected in the odd-numbered questions) received the majority more positive percentages towards SA and A rates, with none indicating SD responses. Conversely, the complexity of use (as reflected in the even-numbered questions) garnered the majority more responses towards SD and D, with none indicating A and SA responses. The mean (average) SUS score obtained is 86.3%, which corresponds to an adjective rating of 'Excellent'. The mean SUS score is determined by following the workflow illustrated in Fig. 3. Additionally, we observed that the system, featuring upgraded components like superior microphones, adeptly captures user voices even from significant distances. Respondents value the developed system's user-friendly design and perceive it as easily adaptable for daily use within the organization. Overall, the obtained results show that this system is well-suited for use within organizations and is generally accepted by end users. This is derived from the interpretation of the mean SUS score, wherein a score above 68% is considered a positive adjectival rating. Such a rating is indicative of a high level of usability and acceptance, as outlined by [11].

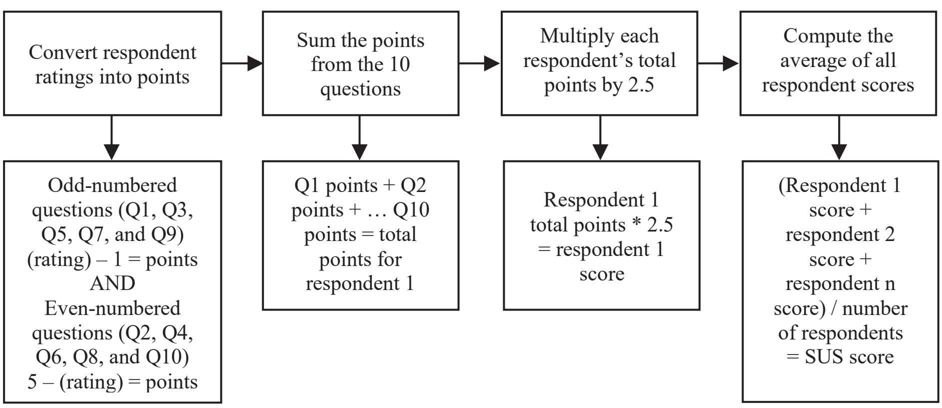

Fig. 3. The workflow of SUS score.

Conclusion

The developed system, based on IoT technology, turns a regular mirror into a useful multi-functional information display for sharing important information with users. It's mainly designed and developed for organizations to communicate with visitors and members effectively. The implementation process followed a successful approach, bringing benefits like saving time in searching for global information, monitoring fire hazards, and using electricity wisely. These advantages increase awareness among the organization's community. We discovered that the system, equipped with enhanced components such as higher-quality microphones, effectively captures user voices from considerable distances. Users in organizations find it user-friendly and easy to customize for daily use. In future work, the system is planned to incorporate emotion recognition for detecting emotions within the organizational community. Upon detecting negative emotions, the relevant departments will receive the recognized emotional data to offer mental health support. This is particularly crucial due to the alarming state of mental health among workers in Malaysia, with a report by the Non-Governmental Organization (NGO) Relate Mental Health Malaysia (Relate Malaysia) revealing that 29% of surveyed workers reported experiencing poor mental health conditions, indicating a concerning upward trend in cases.

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References

[1] D. A. Alboaneen *et al.*, “Internet of Things Based Smart Mirrors: A Literature Review,” in *2020 3rd International Conference on Computer Applications & Information Security (ICCAIS)*, Mar. 2020, pp. 1–6. doi: 10.1109/ICCAIS48893.2020.9096719.
[2] A. S. Sneha, J. Sonica, M. Pavithra, S. Luqman, and S. Rohith, “Multi-Function Digital Mirror Using Raspberry Pi with IOT,” in *ICDSMLA 2020*, A. Kumar, S. Senatore, and V. K. Gunjan, Eds., in Lecture Notes in Electrical Engineering. Singapore: Springer, 2022, pp. 1171–1179. doi: 10.1007/978-981-16-3690-5_112.
[3] D. Alboaneen *et al.*, “Smart information desk system with voice assistant for universities,” *Int. J. Electr. Comput. Eng. IJECE*, vol. 11, no. 6, Art. no. 6, 2021.
[4] K. Kous, M. Pušnik, M. Heričko, and G. Polančič, “Usability evaluation of a library website with different end user groups,” *J. Librariansh. Inf. Sci.*, vol. 52, no. 1, pp. 75–90, Mar. 2020, doi: 10.1177/0961000618773133.
[5] Y. P. Bakara, T. Raharjo, B. Hardian, and A. Suhanto, “Project Quality Management Challenges and Solutions in IT Project: A Systematic Literature Review,” in *2021 IEEE 7th International Conference on Computing, Engineering and Design (ICCED)*, Aug. 2021, pp. 1–6. doi: 10.1109/ICCED53389.2021.9664861.
[6] O. E. Olorunshola and F. N. Ogwueleka, “Review of System Development Life Cycle (SDLC) Models for Effective Application Delivery,” in *Information and Communication Technology for Competitive Strategies (ICTCS 2020)*, A. Joshi, M. Mahmud, R. G. Ragel, and N. V. Thakur, Eds., in Lecture Notes in Networks and Systems. Singapore: Springer, 2022, pp. 281–289. doi: 10.1007/978-981-16-0739-4_28.
[7] H. Bayomi, N. A.Sayed, H. Hassan, and K. Wassif, “Application-based Usability Evaluation Metrics,” *Int. J. Adv. Comput. Sci. Appl. IJACSA*, vol. 13, no. 7, Art. no. 7, 31 2022, doi: 10.14569/IJACSA.2022.0130712.
[8] S. C. Peres, T. Pham, and R. Phillips, “Validation of the System Usability Scale (SUS): SUS in the Wild,” *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, vol. 57, no. 1, Art. no. 1, Sep. 2013, doi: 10.1177/1541931213571043.
[9] J. R. Lewis, “The System Usability Scale: Past, Present, and Future,” *Int. J. Human–Computer Interact.*, vol. 34, no. 7, Art. no. 7, Jul. 2018, doi: 10.1080/10447318.2018.1455307.
[10] J. R. Lewis and J. Sauro, “Item Benchmarks for the System,” vol. 13, no. 3, 2018.
[11] M. Schmidt *et al.*, “User Experience (re)Design and Evaluation of a Self-Guided, Mobile Health App for Adolescents with Mild Traumatic Brain Injury,” *J. Form. Des. Learn.*, vol. 4, no. 2, pp. 51–64, Dec. 2020, doi: 10.1007/s41686-019-00038-x.