An IoT-based Smart Home Application with Barrier-Free Stairs for Disabled/Elderly People

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***Abstract*—Home automation based on the Internet of Things (IoT) includes various components such as lighting, security, and remote control. Smart Home (SH) components should be varied and customised according to the user's specific needs. Therefore, in this study, a SH system needed by users with specials is designed and implemented on a model. The NodeMCU microcontroller with ESP8266 Wi-Fi module, Radio Frequency Identification (RFID) tags, temperature-humidity, motion detection, gas and moisture sensors and several actuators are used to build the system. Thanks to If This Then That (IFTTT), Google Assistant, and Blynk, the SH components can be managed remotely and with voice commands via a user-friendly Android-based mobile interface. The multiple control system and the ability to control the home components with different methods make this study comprehensive. In particular, the barrier-free stairs design has added innovation to the SH system for disabled people. Thus, the accessibility, security, and comfort requirements of disabled people are met, and their quality of life is improved to live independently.**

***Index Terms*—Home automation; Internet of Things; Remote monitoring; Smart home.**

I. INTRODUCTION

The Internet of Things (IoT), known as interconnected machines, devices or objects, makes our lives easier by enabling interaction with the physical world [1] and is applied in many fields such as Smart Home (SH) systems [2]–[6], healthcare [7], [8], energy [9], [10], environmental monitoring [11], [12], manufacturing [13], [14], and industrial automation [15], [16]. SHs are one of the most common IoT applications. SH systems have a cost-effective and applicable technology that promotes comfort of life. The comfort of the homeowners differs according to features of SH design such as lighting control, automatic irrigation, voice-commanded control. The use of SH technologies also has the advantage of increased security [17].

Individuals living with disabilities face many physical obstacles or difficulties in their daily lives. In fact, due to these difficulties, the lives of these individuals become restrictive in cases such as going to school, finding a job, and participating in social life [18]. SH systems can be designed and developed to improve the comfort of people without disabilities, as well as considering the different needs and demands of physically disabled, elderly or sick people, and may include new additional features. This motivates the authors to design an accessible and user-friendly SH system that uses SH technologies to reduce the challenges facing disabled people. With this motivation, the objective is to present a barrier-free stair to increase accessibility in the space. The proposed barrier-free stairs have a simple, cost-effective, and applicable structure and can be transformed into a ramp with a voice command given by the user. In addition, home objects are also provided to be compatible with Google Assistant and remotely controllable. The developed SH system offers benefits such as energy efficiency with lighting control and socket control, thermal comfort providing the desired temperature in the house (air-conditioning control), safety and security via gas leakage and fire warning, and also accessibility with keyless entry-exit and control of the SH objects with voice-commanded. In addition, garden irrigation can be automated according to the moisture level of the soil.

Therefore, the major contributions of this study are outlined below:

– A barrier-free stair system has been designed and developed for individuals who have access problems when entering and exiting their homes;
– The developed SH has advantages such as low cost, user-friendly, energy efficiency, security, and comfort, as well as accessibility;
– The SH uses various technologies (IoT, Wi-Fi, Google Assistant, If This Then That (IFTTT), and Blynk) to enable easier control and better management of home appliances and meet the home automation requirements of users.

The rest of this research study is structured as follows. Section II presents briefly the existing literature in the field of SH systems. Section III comprehensively describes the architecture, design, hardware parts, and software parts of the developed SH automation system. Section IV focuses on the implementation details, the results of the IoT-based home system, and the contributions of research. The study implementation outcomes are concluded with a future scope in Section V.

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II. RELATED WORKS

Today's technologies such as IoT and sensors can provide increased comfort with SH applications, as well as overcome some restrictions in daily life specifically to meet the needs of people with disabilities. One of the most important of these restrictions is to ensure accessibility in the space. Although the popularity of SH studies has increased in recent years, studies on SH design for the special needs of individuals with disabilities are limited. IoT-based SH assistive systems [19], [20] have been developed to help physically challenged and elderly people to be active and safe at home. A voice-commanded home automation system for the elderly, disabled, and bedridden people [3], [6], [21]–[23]. Voice recognition is used to allow physically challenged and elderly people to access and turn appliances On/Off [19], [24]. In these systems developed for physically challenged people, voice commands can be captured via a mobile application, and then electrical appliances can be turned On/Off [22], [25]. Mobile applications have been designed to control home appliances using SMS inputs, Bluetooth, and voice. The design features of the current SH systems are presented comparatively in Table I.

TABLE I. SUMMARY OF SMART HOME SYSTEMS DEVELOPED IN RECENT STUDIES.

Reference	Microcontroller	Communication	User interface	Benefits	Drawbacks
[2]	Raspberry Pi 4 Model B, NodeMCU and an Arduino Nano	Wireless	Mobile, web-based	SH controller, smart blind, online/offline learning, speech recognition	Security and privacy issues, hardware improvements
[3]	Arduino	Bluetooth	Mobile	Voice-commanded control of the lights and electrical appliances	Limited accessibility due to Bluetooth, no real database connection
[4]	NodeMCU ESP 8266	Wi-Fi	Mobile	Indoor-outdoor control, security, safety, monitoring, energy management	Can be more energy efficient and environment friendly with solar panels, minimise space and the risk of connection losses/short circuits.
[5]	NodeMCU ESP 8266	Wi-Fi	Mobile	Control the light, humidity and temperature, gas leakage, voice-commanded open/close the windows/door and entry-exit	No energy monitoring, no smart staircase for accessibility
[6]	ESP32	Wi-Fi	Mobile	Monitor power consumption, control light, automatic On/Off of some electronic appliances, voice-commended home system	No people detection entering the building, security system, alert notification via email or message
[19]	Arduino, Raspberry Pi	Bluetooth, Wi-Fi	Mobile, web-based	Assist the elderly and physically challenged people with artificial intelligence-based voice recognition, remotely monitor and manage appliances	Only remotely manage home appliances with AI-based voice recognition
[24]	Raspberry Pi	Wi-Fi	Web-based	Voice recognition to turn devices On/Off, remotely monitor household appliances	Not available for people with hear disability
[26]	NodeMCU ESP 32	Wi-Fi	Mobile	Control of the heating system, energy efficiency, the comfort of the users	No voice-commanded control, only smart heating system
[27]	NodeMCU ESP 8266, Arduino	Wi-Fi	Mobile	Control of the switches	Only smart switch control system
[28]	Raspberry Pi, ESP 8266	Wi-Fi	Mobile, web-based	Multi-operational home automation, Google Assistant compatible, monitoring, security, irrigation, power and energy management	No monitoring of the air humidity
[29]	Arduino Mega, ESP 8266	Wi-Fi	Mobile, web-based	Remote monitoring, control of home appliances, monitor the temperature, humidity, and motion	No voice-commanded control, can be used with various sensors for more safety and security
[30]	Arduino, APC220 Wireless Module	Wi-Fi, Ethernet	Web-based	Automatic environmental control, PIN security, control of home appliances, monitoring	Can be enhanced with energy monitoring and energy saving
This study	NodeMCU ESP 8266, Arduino	Wi-Fi	Mobile	Barrier-free stairs, energy and water efficiency, accessibility, safety, security, comfort, remote monitoring, voice-commanded control, reduced restrictions for the disabled people	It can include water leak detection, PIN security, health monitoring, and indoor air quality monitoring, wind and rain sensors for smart window control, and voice recognition

The SH system proposed in [29] enables occupants to control home appliances easily and efficiently using Wi-Fi and a mobile application. The authors in [30] present a SH system for intrusion detection and environment control. Wireless and Ethernet modules are used for the communication of home components. The communication modules and selected sensors are evaluated in terms of suitability. The developed home system consists of smart lighting, automatic natural ventilation, gas leak detection, fire alarm, barrier-free stairs, water-efficient irrigation, keyless entry-exit, and socket control.

III. IoT-based Smart Home Application

In the study, an accessible-based SH system based on IoT has been developed to improve comfort areas and promote the quality of life of disabled and/or elderly people. Sensors, actuators, and related data sources have been interconnected and the developed SH system can be easily controlled with voice commands and remotely via a mobile device. Thus, the system provides these people with the accessibility and ease of use they need while maintaining the independence of their daily home life.

A. System Design and Architecture

The developed SH system is a single-storey and consists of 4 rooms and a garden, as seen in Fig. 1. Sensors and actuators have been placed for the control of lighting, temperature, and humidity, windows and door in the rooms, automatic irrigation of the garden, and detection and warning of gas leakage and fire in the kitchen. Keyless entry-exit is possible with the help of Radio Frequency Identification (RFID) technology. Barrier-free stairs are designed for ease of access and are located at the entrance of the house.

Fig. 1. The prototype design of the SH system.

The general operating structure of the designed SH system is given in Fig. 2. The designed system consists of various sensors to sense data from different home components, a central NodeMCU board with ESP8266 Wi-Fi module to transmit the sensed data through Internet, a remote cloud server, and an intermediate application (e.g., IFTTT) to understand and interpret voice commands given to the Google Assistant.

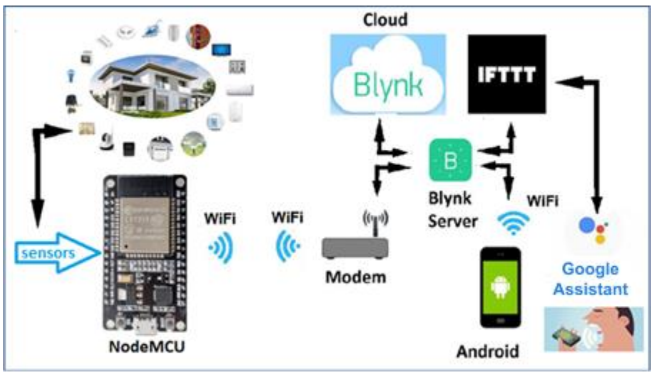


Fig. 2. Structure of the voice-controlled SH system.

Data on SH components are collected from sensors integrated with NodeMCU and transmitted to a remote cloud Blynk server over the Internet. Through the Blynk server, the sensed data are collated and a trigger is generated. Thus, home data are monitored through an Android-based mobile application developed for remote management of home components. In addition, the mobile application helps users control the home components using voice commands given through Google Assistant, which is connected to IFTTT. IFTTT can interpret voice commands and send an On/Off signal to the mobile application via the Blynk platform.

B. Hardware Implementation

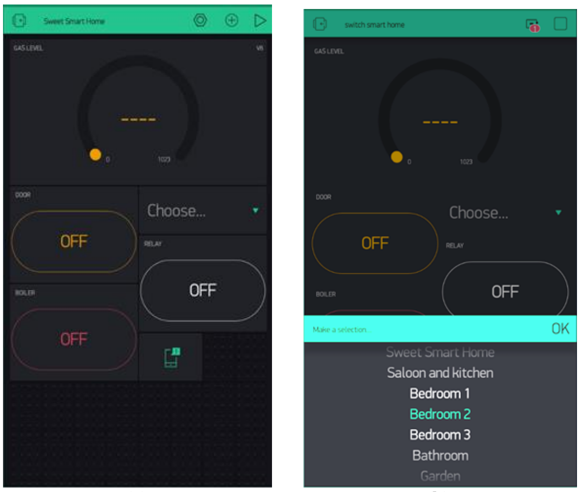
A microcontroller or processor is the main part of IoT-based home automation systems. In this study, the open source and cost-effective NodeMCU is used as the central unit. It enables IoT applications thanks to its integrated ESP8266 Wi-Fi module. DHT11 temperature and humidity sensor [31], RFID [32] tags, HC-SR501 adjustable passive infrared (PIR) motion detection sensor, MQ2 gas sensor [33], and HL-69 moisture sensor module [34] are used to collect data from the indoor and outdoor environments of the house. Then the collected data using sensors are transferred to the SH server at certain time intervals over the local network. The servo motor, the water pump, the Light Emitting Diode (LED), and the buzzer are connected to the NodeMCU to turn the devices On/Off, one of the main/top/most important features of SH systems, for control processes like fire alarm, automatic ventilation, socket control, gas leak detection, lighting management, and irrigation.

Individuals with walking difficulties, wheelchair users, and elderly people may find it difficult to walk up and down the stairs at the entrances. A cost-effective barrier-free stair has been designed to overcome this challenge as part of the study. The barrier-free stair has a mechanism that automatically activates and then turns into a ramp by integrating the mobile application (with a button on the user interface and voice commands), or a physical button. In addition, disabled or elderly individuals can easily and comfortably enter and leave their homes.

C. User Interface

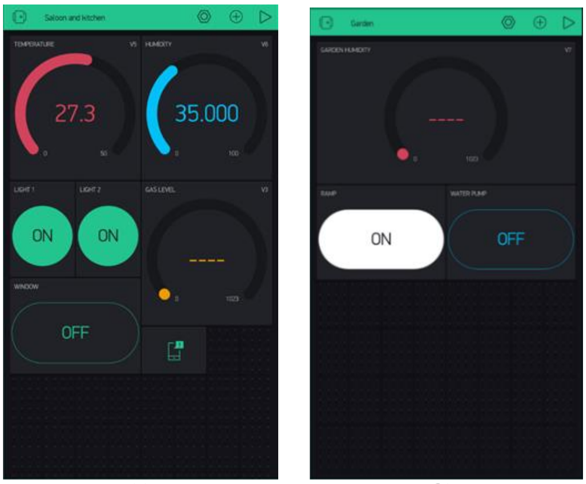
In this study, each component of the SH system can be remotely monitored and controlled with a web-enabled smart device over the Internet connection. The Arduino IDE with Python is preferred to develop software on the NodeMCU. A mobile application based on the Android Operating System is developed as shown in Fig. 3. The main page of the mobile application includes a display for gas level monitoring, a menu for easy access to the desired room, and shortcuts for opening/closing the entrance door and disconnecting the electricity and gas supply. The button labels show the current state of each component.

Before starting to write the code, the related libraries have been installed depending on the type of sensor being used. Data are retrieved from the Blynk platform through a mobile application for user monitoring, management, and control from all over the world. In addition to Blynk, Google Assistant, and IFTTT server have been used for voice-commanded control of home objects (doors, windows, lights, free-barrier stairs, etc.) and remote system management via Android mobile phones. The developed SH system has been made more user-friendly by ensuring compatibility with Google Assistant. Thus, the system provides access to individuals who are visually disabled, elderly, or cannot use their hands/feet. The user interface created with Blynk includes widgets for temperature, humidity, soil moisture, gas level, lighting, keyless entry-exit, barrier-free stairs, and door-windows control depending on the room type. In the mobile application, the user pages for the saloon and kitchen are shown in Fig. 4(a), and for the garden in Fig. 4(b). The Blynk dashboard displays the "On" status by a highlighted background colour, e.g., the buttons for the lighting operation are in green background colour when the light is "On".



(a) (b)

Fig. 3. The mobile user interface of the SH application: (a) main page and (b) access menu to rooms.

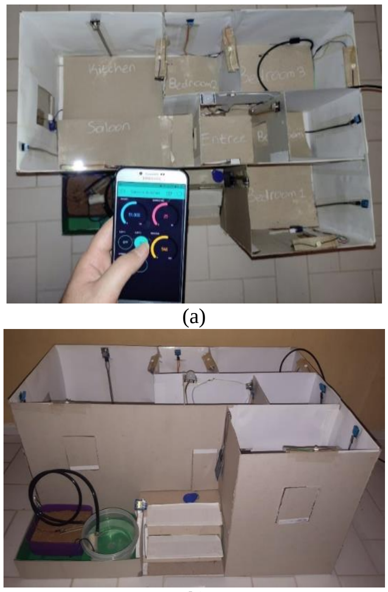


(a) (b)

Fig. 4. Blynk dashboard for the control of (a) the saloon and kitchen and (b) the garden.

IV. Experiments and Results

This study focusses primarily on physically disabled, sick, and elderly people. The main advantage of the developed SH system is to make their lives more normal considering individuals with physical disabilities and limited mobility, so IoT technologies are applied to be able to control and manage the objects in the home. The developed SH system has been successfully tested in the actual prototype. The top and front views of the actual prototype are presented in Fig. 5(a) and Fig. 5(b), respectively. This system has many benefits, but not limited to them, detailed as follows in terms of the SH components.



(a)

(b)

Fig. 5. The actual prototype of the designed SH system: (a) top view and (b) front view.

According to the collected data from the MQ2 gas sensor that allows gas detection, gas levels in the home environment can be monitored by using the mobile application as seen in Fig. 4(a). In the case of a fire, users are warned in 3 ways depending on the data read from the sensor: by sending a notification to the user's mobile phone, with a red warning light (LED) at a certain point in the house for the hearing-impaired individuals, and an audible warning for the visually impaired individuals. In addition to the user warning, the study has been advanced with additional measures listed as follows:

– After the warning notification, the smoke is evacuated from the house by automatically opening the windows with the user's approval. Therefore, the living things in the house will be less affected by smoke. The user approval notification as shown in Fig. 6 will be very useful, especially for relatives of people with Alzheimer's disease;

Fig. 6. A notification sent to the mobile application for the user's approval.

– The gas valve is automatically closed with the help of a motor so that the further growth of the fire hazard is prevented;

– The electrical connection is automatically disconnected with the help of a relay. However, the barrier-free stairs are not turned on to restrict wheelchair users from leaving the house.

Lighting management can be realised in the following ways, taking into account disabilities of users and energy efficiency:

– A PIR motion sensor detects whether there is a person moving in the room, and the motion data are sent to the NodeMCU to turn On/Off the lights. The lights activate only when the sensor detects the presence of persons; hence, both energy and money savings are provided as they are used in areas with frequent transitions such as corridors;

– Turning the lights On/Off with voice commands has increased the comfort of disabled people with mobility restrictions or visual impairments;

– The lights can be remotely controlled using the widgets in the mobile application, shown in Fig. 4(a) by green colour. Lighting control is achieved with minimal effort considering the inaccessibility problem of light switches faced by disabled people.

The DHT11 temperature and humidity sensor collects and transfers data to the NodeMCU, to activate window-connected actuators for natural ventilation when the room temperature is higher than the user-defined threshold value. In addition, a user with a physical disability can open and close the window by controlling these actuators with a voice command on a mobile phone. The temperature and humidity values of the indoor environment can also be monitored.

Automatic irrigation is more preferable for people with disabilities compared to manual garden irrigation. The Wi-Fi-based irrigation system in the study contains a water pump and an HL-69 moisture sensor. This system irrigates automatically according to the water needs of the plant and thus provides some advantages such as reducing water waste and saving energy and time.

The keyless entry-exit component helps people enter and exit the home easily with minimal effort. The RFID recognises the user access card ID, and the actuator is commanded to open the door safely. In addition, homeowners who cannot use their hands due to physical disability or who have visual impairments can perform the door opening-locking operation without a key with voice commands. Voice-commanded door opening-locking is especially useful for individuals who cannot use their hands, Parkinson’s patients, or visually impaired people.

The deactivation of sockets connected to any electrical device is performed by voice commands. Furthermore, it is possible to deactivate the socket with the buttons in the mobile application. Thus, if users have forgotten to disconnect a device such as iron, oven, and kettle from power before leaving, it will provide security when they are not at home.

People with various disabilities face some limitations in daily life. Stairs are an example of these limitations for wheelchair users. In this study, a “barrier-free staircase” is designed to overcome the problem mentioned for wheelchair users and improve the accessibility of the spaces for disabled people. The designed stair structure can become a ramp by using a servo motor and its prototype is realised on a mock-up model. The implemented structure is demonstrated in Fig. 7(a) with a ramp case and Fig. 7(b) with a stair case.

(a) (b)

Fig. 7. The prototype of the barrier-free staircase: (a) ramp case, (b) stair case.

Barrier-free stairs have a design that aims to be more user-friendly, so that the user can choose from the following 3 options to operate the stair-ramp conversion: by a user-issued voice command to Google Assistant, with the use of the button in the user interface by a smartphone, and with the physical button located near the stairs. The ability to perform stair-ramp conversion with voice commands will provide convenience, especially for individuals who cannot use their hands or who have visual and walking impairments. Thanks to the proposed structure, there will be no need to build additional ramps for disabled people as an alternative to stairs. In addition, there will be no need for a separate space for a ramp with this recommended barrier-free staircase, especially in places with limited space.

V. DISCUSSION

Although there are publications on SH system design in the literature, there are few publications ([19], [24], and [25]) on the needs of disabled people. In our study, unlike these studies in the literature, the “accessibility problem” was addressed and a detailed solution with the designed barrier-free staircase has been presented. In addition, the proposed study is more comprehensive than the existing studies, as it is detailed so as to offer alternative solutions to various need scenarios.

VI. CONCLUSIONS

This study proposes the design and implementation of an IoT-based SH system for disabled/elderly individuals with the features of low cost, user-friendly, and energy efficiency. The home data (temperature, humidity, soil moisture, gas, motion, and RFID) obtained from the sensors can be monitored in real time and the SH components can be controlled remotely or with voice commands via mobile application. The proposed SH system is quite comprehensive in terms of control and management of SH components. Furthermore, unlike other SH studies that consider various needs of people with disabilities, this study also has a significant component of “barrier-free stairs” to overcome accessibility problems of wheelchair users.

The IoT-based SH system developed in this study has given people with disabilities more control over their homes to achieve more on their own and live more freely. In the future study, the SH system will be expanded to include energy monitoring. In addition, the use and control of SH components may differ according to occupants/users. The developed SH system can be applied to a real home and is expected to widespread in further years. The relationship between behaviour and needs of all SH users, including people with disabilities, can be analysed and thus the obtained test results can offer various theoretical and practical implications.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] N. Paudel and R. C. Neupane, "A general architecture for a real-time monitoring system based on the Internet of Things", *Internet of Things*, vol. 14, art. no. 100367, 2021. DOI: 10.1016/j.iot.2021.100367.

[2] L. Filipe, R. S. Peres, and R. M. Tavares, "Voice-activated smart home controller using machine learning", *IEEE Access*, vol. 9, pp. 66852–66863, 2021. DOI: 10.1109/ACCESS.2021.3076750.

[3] S. M. S. Benigna, H. Devi, S. Ravichandran, and R. Angeline, "Voice controlled home automation system", *J. Netw. Commun. Emerg. Technol. (JNCET)*, vol. 8, no. 4, pp. 317–319, 2018.

[4] W. A. Jabbar *et al.*, "Design and fabrication of smart home with Internet of Things enabled automation system", *IEEE Access*, vol. 7, pp. 144059–144074, 2019. DOI: 10.1109/ACCESS.2019.2942846.

[5] E. Elçi, N. Yalçın, and S. Ünaldı, "Internet of Things based smart home system design for individuals with disabilities", in *Proc. of 2021 6th Int. Conf. on Computer Science and Engineering (UBMK)*, 2021, pp. 619–622. DOI: 10.1109/UBMK52708.2021.9558908.

[6] R. M. Roy, B. Sabu, A. Nisha, and R. P. Aneesh, "Voice controlled home automation system", in *Proc. of 2021 Seventh Int. Conf. on Bio Signals, Images, and Instrumentation (ICBSII)*, 2021, pp. 1–6. DOI: 10.1109/ICBSII51839.2021.9445150.

[7] B. Ç. Uslu, E. Okay, and E. Dursun, "Analysis of factors affecting IoT-based smart hospital design", *J. Cloud Comput.*, vol. 9, art. no. 67, 2020. DOI: 10.1186/s13677-020-00215-5.

[8] R. Rajavel, S. K. Ravichandran, K. Harimoorthy, P. Nagappan, and K. R. Gobichettipalayam, "IoT-based smart healthcare video surveillance system using edge computing", *J. Amb. Intel. Hum. Comp.*, vol. 13, pp. 3195–3207, 2022. DOI: 10.1007/s12652-021-03157-1.

[9] Y. Kabalci, E. Kabalci, S. Padmanaban, J. B. Holm-Nielsen, and F. Blaabjerg, "Internet of Things applications as energy internet in smart grids and smart environments", *Electronics*, vol. 8, no. 9, p. 972, 2019. DOI: 10.3390/electronics8090972.

[10] V. Nair, R. Litjens, and H. Zhang, "Optimisation of NB-IoT deployment for smart energy distribution networks", *Eurasip J. Wirel. Comm. Netw.*, vol. 2019, art. no. 186, 2019. DOI: 10.1186/s13638-019-1485-2.

[11] S. Zafar, G. Miraj, R. Baloch, D. Murtaza, and K. Arshad, "An IoT based real-time environmental monitoring system using Arduino and cloud service", *Eng. Technol. Appl. Sci. Res. (ETASR)*, vol. 8, no. 4, pp. 3238–3242, 2018. DOI: 10.48084/etasr.2144.

[12] J. Trevathan, S. Schmidtke, W. Read, T. Sharp, and A. Sattar, "An IoT general-purpose sensor board for enabling remote aquatic environmental monitoring", *Internet of Things*, vol. 16, art. no. 100429, 2021. DOI: 10.1016/j.iot.2021.100429.

[13] Z. Bi, L. D. Xu, and C. Wang, "Internet of Things for enterprise systems of modern manufacturing", *IEEE Transactions on Industrial Informatics*, vol. 10, no. 2, pp. 1537–1546, 2014. DOI: 10.1109/TII.2014.2300338.

[14] A. Rymaszewska, P. Helo, and A. Gunasekaran, "IoT powered servitization of manufacturing - An exploratory case study", *Int. J. Prod. Econ.*, vol. 192, pp. 92–105, 2017. DOI: 10.1016/J.IJPE.2017.02.016.

[15] D. Mondal, "The Internet of Thing (IoT) and industrial automation: A future perspective", *World J. Model. Simul.*, vol. 15, no. 2, pp. 140–149, 2019.

[16] T. B. Lokman, M. T. Islam, and M. U. Apple, "Design & implementation of IoT based industrial automation system", in *Proc. of 2020 11th Int. Conf. on Computing, Communication and Networking Technologies (ICCCNT)*, 2020, 1–6. DOI: 10.1109/ICCCNT49239.2020.9225388.

[17] S. Pira, "The social issues of smart home: A review of four European cities' experiences", *Eur. J. Futures Res.*, vol. 9, art. no. 3, 2021. DOI: 10.1186/s40309-021-00173-4.

[18] D. Matthews, "How IoT breaks barriers for people with disabilities", 10 Aug. 2020. [Online]. Available: https://theiotmagazine. com/how-iot-breaksbarriers-for-people-with-disabilities-e695eaeafa15

[19] S. K. Sooraj, E. Sundaravel, B. Shreesh, and K. Sireesha, "IoT smart home assistant for physically challenged and elderly people", in *Proc. of 2020 Int. Conf. on Smart Electronics and Communication (ICOSEC)*, 2020, pp. 809–814. DOI: 10.1109/ICOSEC49089.2020.9215389.

[20] C.-M. Wu, Y.-J. Chen, S.-C. Chen, and C.-H. Yeng, "Wireless home assistive system for severely disabled people", *Applied Sciences*, vol. 10, no. 15, p. 5226, 2020. DOI: 10.3390/app10155226.

[21] S. Rizvi, I. Sohail, M. M. Saleem, A. Irtaza, M. Zafar, and M. Syed, "A smart home appliances power management system for handicapped, elder and blind people", in *Proc. of 2018 4th Int. Conf. on Computer and Information Sciences (ICCOINS)*, 2018, pp. 1–4. DOI: 10.1109/ICCOINS.2018.8510595.

[22] P. Mtshali and F. Khubisa, "A smart home appliance control system for physically disabled people", in *Proc. of 2019 Conf. on Information Communications Technology and Society (ICTAS)*, 2019, pp. 1–5. DOI: 10.1109/ICTAS.2019.8703637.

[23] N. Chaitra, C. S. Ashwini, and S. Zaidi, "A research on home automation for elderly and physically challenged people by using IoT", *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 8, no. 6S4, pp. 473–475, 2019. DOI: 10.35940/ijitee.F1098.0486S419.

[24] A. G. Ismaeel, "Home automation system support for persons with different types of disabilities using IoT", in *Proc. of 2020 1st Int. Multi-Disciplinary Conf. Theme: Sustainable Development and Smart Planning, IMDC-SDSP 2020, Cyberspace*, 2020, pp. 1–10. DOI: 10.4108/eai.28-6-2020.2298216.

[25] H. Isyanto, A. S. Arifin, and M. Suryanegara, "Design and implementation of IoT-based smart home voice commands for disabled people using Google Assistant", in *Proc. of 2020 Int. Conf. on Smart Technology and Applications (ICoSTA)*, 2020, pp. 1–6. DOI: 10.1109/ICoSTA48221.2020.1570613925.

[26] M. Taştan, "Real time remote monitoring and control application with new generation IoT controller for smart home applications", *SDU J. Nat. Appl. Sci.*, vol. 23, no. 2, pp. 481–487, 2019.

[27] S. P. Makhanya, E. M. Dogo, N. I. Nwulu, and U. Damisa, "A smart switch control system using ESP8266 Wi-Fi Module integrated with an Android application", in *Proc. of 2019 IEEE 7th Int. Conf. on Smart Energy Grid Engineering (SEGE)*, 2019, pp. 125–128. DOI: 10.1109/SEGE.2019.8859904.

[28] C. Stolojescu-Crisan, C. Crisan, and B.-P. Butunoi, "An IoT-based smart home automation system", *Sensors*, vol. 21, no. 11, p. 3784, 2021. DOI: 10.3390/s21113784.

[29] W. A. Jabbar, M. H. Alsibai, N. S. S. Amran, and S. K. Mahayadin, "Design and implementation of IoT-based automation system for smart home", in *Proc. of 2018 International Symposium on Networks, Computers and Communications (ISNCC)*, 2018, pp. 1–6. DOI: 10.1109/ISNCC.2018.8531006.

[30] T. S. Gunawan, I. R. H. Yaldi, M. Kartiwi, and H. Mansor, "Performance evaluation of smart home system using Internet of Things", *International Journal of Electrical and Computer Engineering*, vol. 8, no. 1, pp. 400–411, 2018. DOI: 10.11591/ijece.v8i1.pp400-411.

[31] Lady ada, "DHT11, DHT22 and AM2302 Sensors", Adafruit Industries. [Online]. Available: https://learn.adafruit.com/dht

[32] B. Alsinglawi, M. Elkhodr, Q. V. Nguyen, U. Gunawardana, A. Maeder, and S. Simoff, "RFID localisation for Internet of Things smart homes: A survey", 2017. arXiv: 1702.02311. DOI: 10.5121/ijcnc.2017.9107.

[33] M. Domb, "Smart home systems based on Internet of Things", in *Internet of Things (IoT) for Automated and Smart Applications*. IntechOpen, 2019, pp. 1–13. DOI: 10.5772/intechopen.84894.

[34] M. Taştan, "Internet of Things based smart irrigation and remote monitoring system", *Eur. J. Sci. Tech. (EJOSAT)*, vol. 15, pp. 229–236, 2019. DOI: 10.31590/ejosat.525149.