Indonesian Journal of Electrical Engineering and Computer Science
Vol. 38, No. 3, June 2025, pp. 1624~1633
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v38.i3.pp1624-1633

Internet of things based autonomous robot system architecture for home automation and healthcare services

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Article Info

Article history:

Received Jul 22, 2024
Revised Dec 6, 2024
Accepted Feb 27, 2025

Keywords:

Health monitoring
Home automation
Internet of things
Raspberry Pi 4
Robot system
Sensors

ABSTRACT

The internet of things (IoT) is playing a major role in the development of the health industry by enabling more accessible and affordable virtual and distant patient contacts through applications that are easy to use. The IoT and automated homes are becoming more popular in recent days. A network of connected devices, including hardware, equipment, and technical support, is known as the IoT. Their purpose is to allow data exchange with other systems through the internet. This paper presents, internet of things based autonomous robot system architecture (IoT-ARSA) for home automation and healthcare services. The primary goal of this secure home automation system is to help the elderly and disabled people by allowing them to operate home appliances. Additionally, the system uses a cloud server to predict the health conditions of patients and the elderly people, providing information to a guardian. The patient's health condition is determined using sensors like temperature, pulse, blood pressure, and oxygen level. Ultrasonic sensor and face detection are used for home automation. Each sensor will interact with the Raspberry Pi 4 to record data, which will then be processed and stored in the cloud. From results it is clear that described (IoT-ARSA) for home automation and healthcare services model is very efficient with high accuracy and high security. Health monitoring is achieved with this model continuously with great efficiency.

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1. INTRODUCTION

The increasing need for internet-related products is transforming people to work on innovations, and wireless communication devices are becoming increasingly important as automation becomes a necessity in daily life [1]. The world has changed significantly in the past decade as a result of automation and IoT [2]. The IoT has demonstrated the ability to reduce human effort while also improving quality of life.

"Smart home" refers to a home that contains enough smart technology to allow its inhabitants to live independently and happily [3]. In order to create an interactive space, every mechanical and digital devices in a smart home is networked, to develop a network that can communicate with other devices and the user. With a focus on customer expectations and requirements as well as the interests of researchers, smart homes are expanding into several fields of specialization. Medical devices are used in smart homes to provide healthcare facilities. To monitor the health of patients, blood pressure, body temperature, and heart rate are often measured using equipment [4].

Every technological advancement made by humans has created significant concerns about health. In addition to improving the medical service systems, one innovative approach that shows promising for providing the previously mentioned healthcare services is the IoT platform [5]. All of the devices, apps, sensors, and networks that are connected to one another in order to exchange and collect data are collectively described to as the IoT. IoT is another web advancement that is gaining popularity fast due to developments in cloud computing, cellphones, sensor networks, remote exchanges, and systems management [6]. Nowadays, to keep a monitor on a patient's health through web, numerous IoT devices are available [7].

Constantly monitoring physiological indicators with wearable IoT devices such as wrist bands and belts are possible to continuously monitor fitness and health without requiring any invasive procedures. In a specific type of wireless sensor network, measurements from several wearable devices are continually transmitted to a master node (such a smart phone), which subsequently forwards the information to a server or cloud-based back end for archiving and analysis [8]. To identify any irregularities in health, medical professionals might examine the perceived health information closely. The following sensor types are frequently used: movement (with accelerometers), blood pressure, Electrocardiogram (ECG), body temperature, heart rate, Oxymeter oxygen saturation (SPo2), and Electroencephalogram (EEG), pulse oxymeter [9].

In daily life, security does matter. A high quality of life is ensured by smart home automation systems since they monitor and control the home environment. In order to provide localized or remote home control and enable communication, automation, appliances and other devices are networked with IoT home hardware technologies such as sensors and actuators [10]. This makes the home intelligent by providing services that require little to human activity or input. A home's temperature, humidity, appliance control, as movement detection and monitoring of water, electricity consumption, may all be done with sensors [11]. Simple and efficient device-to-home connectivity, reduced server failure data loss risk, data storage, one of the advantages of using cloud computing for home automation systems is the ability to automate routine services [12].

Unauthorized access by strangers is one of the main causes of security compromise. The traditional door security mechanisms made use of locks, chains, and keys. But it's easy to remove the locks [13]. There are cases when using keys to unlock doors is ineffective because they could be used by the incorrect person, stolen, or copied. Accurately identifying the individuals requesting to enter the door is the most important component of any door security system, yet uni-modal solutions fail of that standard. Because face recognition systems can measure facial points and identify a person's identity in an unobtrusive way, they are widely utilized for human identification. Face recognition technologies are useful for monitoring people at home, at work, and on campuses.

In Jose *et al.* [14], they suggest a two-stage smart home verification process that authenticates the user device the person accessing the home online using device fingerprints and login credentials. Device fingerprinting methodology takes into consideration the device's location when determining its fingerprint, which sets it apart from all previous methods. They used JavaScript, Flash, and Geolocation in device identification experiment, and they were able to successfully identify 97.93% of the devices that visited webpage.

In Jabbar [15], they demonstrate a cost-effective, laptop-based, hybrid (local and remote) internet of things (IoT) home automation system with an accessible user interface. With an algorithm, a prototype known as IoT@HoMe was being created to allow for automated operation of home appliances through the Internet, anywhere at any time, and to enable condition monitoring of the home. In order to link several sensors and update their data to the Adafruit IO (IO stands for internet of things) cloud server, this system makes use of a Node microcontroller unit (NodeMCU) acting as a Wi-Fi-based gateway. For owners of smart homes (SHs), IoT@HoMe is a low-cost, reliable automation system that may significantly improve convenience, security, and safety while consuming less energy.

In Tay *et al.* [16], the weighted constraint satisfaction problem (CSP) is the study's target application of this approach. In order to help in the development of planning rules and performance-enhancing strategies, knowledge representation is also recommended. Examples show that the system may create sophisticated and intelligent plans from actions based on semantic annotations of the devices and optimize to optimize the fulfillment of specific constraints. Through the use of existing tools and concepts from web technologies, automated planning is carried out through the extraction of transformed services from devices. To demonstrate the applicability and intelligence of the prototype smart home, real-time case studies are conducted, with each planning step taking no more than 10 seconds. In order to ensure the community's well-being, this paper aims to develop a system that allows devices from all over the everywhere to work together.

In Qayyum *et al.* [17], they offer a solution to the issue of planning a smart home appliance's activity within the given time range. They use a photovoltaic (PV) panel as a power-producing appliance that functions as a micro-grid in addition to appliances that consume power. Uninterruptible sequence phases are used to model appliance operations, which are then provided in a load demand profile with the aim of lowering electricity costs while satisfying constraints related to duration, energy requirement, and user desire. Simulation results show that proposed appliance scheduling method is useful.

In Pal *et al.* [18] an empirical theoretical framework is created to identify the key variables that could impact senior users' adoption of smart home healthcare services. Conceptual user perceptions were measured instead of actual usage intentions for a particular service. 81.4% of the variance in the dependent variable, or behavioral intention, could be explained by the model. The best indicator of smart home implementation for elder healthcare is effort expectancy. The elderly people's accepting behavior is heavily impacted by these four factors: perceived cost, perceived trust, expert advice, and perceived trust. In Yassine *et al.* [19], this research provides a methodology to learn and identify human activity patterns for health care applications using large data from smart homes. The approach they require using cluster analysis, prediction, and frequent pattern mining to monitor and evaluate changes in energy usage due to occupant behavior. Smart meter data is recursively mined in a 24-hour quantum/data slice, with the results being maintained between mining exercises. This research presents the results of determining human activity patterns from appliance usage, including the accuracy of both short and long-term predictions.

Kumar *et al.* [20] presents a safe and lightweight session key setup technique was designed for smart home environments. Every sensor and control unit produces a secure session key and utilizes a short authentication token to develop trust inside the network. Important security features of the suggested approach include protection against a number of well-known attacks, including eavesdropping and denial-of-service attacks. The proof-of-concept implementation provides the proof for the preliminary evaluation and feasibility tests.

In Alelaiwi [21] paper, this research proposes a multimodal input system for evaluating user satisfaction that combines speech and face image data. The multimodal inputs are subsequently sent to the cloud through this smart healthcare system. Following processing, fully satisfied and unsatisfied inputs are the two categories. The different parties involved in the smart healthcare environment is then given access to the results. During cloud processing, numerous speech and image features are retrieved. Additionally, for speech and image characteristics, respectively, directional derivatives and a weber local descriptor are used. After the features are integrated, a multimodal signal is generated and transmitted to a classifier through a support vector machine. The accuracy of suggested approach in detecting satisfaction is 93%.

In Alkhomsan *et al.* [22] enhance to the living conditions for seniors in ambient assisted living (AAL), an overview of the study results in multimodal data analysis is given in this paper. Additionally, it aims to improve complex event processing efficiency for situational awareness in real time. Therefore, utilizing decision-tree and association analysis methods, this research examines multimodal sensing for both current condition detection and future scenario prediction. They consider elderly activity recognition in the AAL environment to demonstrate the suggested methodology.

Tao *et al.* [23] first examine security and privacy issues related to the collection and transfer of healthcare data. Then, in order to address security issues, tackle to the ones mentioned above, they suggest SecureData, an IoT-based healthcare system's secure method of collecting data. The four layers of the SecureData system are: 1) fog layers; 2) cloud computing layer; 3) IoT network sensors/devices; and 4) healthcare provider layer. Field programmable gate array (FPGA) simulations are used to validate SecureData's performance in terms of the frequency of hardware, energy consumption, and total algorithm computation time. When utilized to lower security issues in IoT-based healthcare, the results show that SecureData can be effective.

In Islam and Bhuiyan [24], they offer an integrated framework for green healthcare and an interactive user interface with cutting-edge technologies. Scalability and performance ratio of the system have also been ensured. Wearable sensors allow patients to transmit healthcare data, which is received in real time by doctors through this system interface that has been developed specifically for communication between patients and doctors. They developed an approach to improve everyone's interactive healthcare experience by using Hierarchical clustering algorithms for data identification and analysis. In Elayan *et al.* [25] using the digital twin (DT) concept, the paper suggests and develops an intelligent, context-aware healthcare system. This framework helps to enhance healthcare operations and contribute positively to digital healthcare. The built models accurately predicted a specific heart state using multiple techniques. Implementing an ECG classifier to detect heart problems are provides the inspiration for integrating artificial intelligence, machine learning, and other body variables with human body characteristics allows for abnormal identification and continuous monitoring. Finally, it comes to handling ECG data, neural-network-based algorithms outperform traditional machine learning methods.

This paper presents, internet of things based autonomous robot system architecture (IoT-ARSA) the home automation and healthcare services. Therefore, home automation in addition with Healthcare service system is developed. Oxygen level sensor, Blood pressure sensor, temperature and pulse sensors are used to evaluate a patient's health. Ultrasonic sensor and face detection module are used for home automation. The primary goal of this house automation with safety is to help the elderly and disabled people by allowing them to operate home appliances. Additionally, this system predicts the health conditions of patients or elderly people, and provides information to a guardian through a cloud server.

Following is the organization of the remaining paper: In section 2 described (IoT-ARSA) the home automation and healthcare services, in section 3 results and discussions are presented, and the paper is finally concluded in section 4.

2. IOT BASED AUTONOMOUS ROBOT SYSTEM ARCHITECTURE FOR HOME AUTOMATION AND HEALTHCARE SERVICES

The block diagram of IoTs based autonomous robot system architecture for home automation and healthcare services is represented in Figure 1. Using sensors attached to the patient's body, an IoT-ARSA gathers the patient's temperature, blood pressure, oxygen level, and pulse rate. The patient will be closely monitored by the guardian or doctor, they will motivate them to stay at home and monitor, communicate with their health directly. To collect data in real time, the patient maintains all of the sensors, and the microcontroller provides the observed values. Suggested solution uses an infrared ray (IR) in a face detection module to detect motion in front of the door. This motion causes a camera to take an image, which is then sent to the owner by telegram. The door will automatically open if the visitor image data is stored in the database; if not, the owner receives the intruder image and chooses whether or not to provide access.

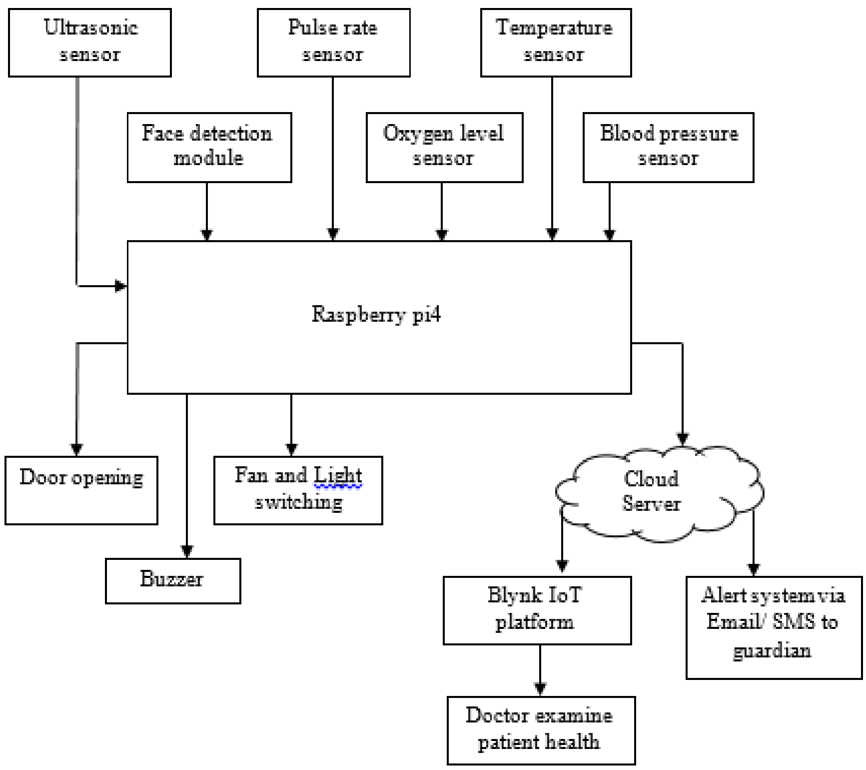

Figure 1. Block diagram of IoT based autonomous robot system architecture for home automation and healthcare service

The IoT-ARSA system uses an ultrasonic sensor placed inside the room to operate electrical home appliances, including the fan and lights. This sensor captures the movement of person. Whenever the person entered into the room, the fan and light are ON automatically. If the person leaves the room, then fan and light are OFF. This automation makes a lot of help to Elderly people or physically handicapped people.

Data generated from sensors are stored in a cloud server database. All of the data from this controller is gathered by an IoT platform (Blynk), which shows it to the doctor or Guardian. ESP32 (Espressif32) data transfer to the Blynk application is made possible by IOT. ESP32 receives the data from Blynk cloud and sets hardware to compare it with current values around the patient. Blynk uses an application programming interface (API) to transfer the data to the Blynk cloud after a level is determined using the slider. The ESP32 sends an email or SMS to the Guardian/doctor.

These days, IoT is the most prevalent and widely used application for the Raspberry Pi. Data storage is done once it has been converted. The cloud server is receiving the data. Using an advanced RISC machine (ARM) processor and a customized version of Linux/Android, the Raspberry Pi is a small single-board computer. This small device's functionality is improved by having Linux on board, allowing it to be used for system automation. It features an integrated display and local area network (LAN) port for connectivity, it can function with sensors and other devices. The fact that it is Python-programmable is an additional benefit.

Universal Serial Bus-C (A USB- C) connector can also be used for providing to the Raspberry Pi 4 when paired with the appropriate power supply unit (PSU), which allows for the connection of extra power to downstream peripherals. However, unlike other small computers in its class, the Pi can only run on 5 volts as opposed to 9 or 12. A design issue in the first Raspberry Pi 4 board caused third-party e-marked USB connections, like those seen on MacBooks, to incorrectly recognize it and refuse to supply power. 11 of the 14 cables that Tom's Hardware examined successfully powered the Pi and turned it on. For the Pi 4 B, the manufacturer is currently using this chip.

Wrapped around the arm, the BP sensor provides the microcontroller with three distinct values or data. The Raspberry Pi is provided with these values, which are divided into three categories: systolic, pulse rate, and diastolic. The board-mount blood pressure sensor, designated BP0001, with a pressure range of 0–300 mg.

digital non-contact infrared thermometer (MLX90614 Melexis) non-contact temperature sensor by putting it in close by to the body, it doesn't need to make direct contact with patients to take their body temperatures. High accuracy and resolution of the thermometer are achieved by the integration of a strong digital signal processing (DSP) unit, low noise amplifier, and 17-bit analog to digital converter (ADC) in the MLX90614.

The frequency of a heartbeat is known as heart rate, or pulse rate, and is expressed as the number of heart per minute (beats per minute or bpm. When monitoring oxygen saturation directly through a blood sample, a pulse oxymeter is a medical device that examines changes in blood volume in the skin to indirectly monitor a patient's blood oxygen saturation. This results in a photoplethysmogram that can be further processed into other measurements. A multiparameter patient monitor could include a pulse oximeter. The pulse rate is also typically shown on monitors. There are also battery-operated, portable pulse oximeters available for use at home or during transportation for blood oxygen monitoring. This research makes use of the MAX30100, an integrated sensor module for heart rate monitoring and pulse oximetry. To detect heart-rate signals, it includes two liquid crystal display (LEDs), a photo detector, reduced noise analog signal processing, and optimized optics. Therfore, the IoT-ARSA system controls electrical home appliances as well as monitoring the Patient health condition using sensors effectively.

3. RESULT ANALYSIS

This part presents the results of the system's real-time implementation, analyzes the results, makes comparisons between the suggested approach and several other approaches already in use. The Blynk app is intended to track blood pressure, body temperature, pulse rate, and oxygen level. In an emergency, the Blynk program can also display the patient position in the moment. The doctor receives an email from the ESP32. With the SIM900A module, the ESP32 can also make, receive messages and send messages. For experimentation results are the data gathered in an IoT-ARSA system home environment for 24 hours from one elder woman. This elder woman is equipped with all these sensors and home is automated with face detected module and ultrasonic sensors. Continuous health monitoring of old lady with these sensors are observed as follows:

The consequences of the heart beat sensor are represented in Figure 2. Adults typically have a heart rate between 60 and 100 bpm. In general, a lower, very still pulse indicates better cardiovascular fitness and more efficient heart work. When a person consistently has a pulse rate greater than 100 bpm, it is referred to as a high pulse, or tachycardia. In the unlikely event if a person's pulse exists between 60 and 100 beats per minute, that person's heartbeat is said to be in an average state. In this representation, X-axis denotes time whereas Y-axis denotes pulse rate. Figure 3 displays a person's blood pressure reading over time. Every 6 hours, adults have their blood pressure checked, and the typical reading is 120/80 millimeters of mercury (mmHg). In Figure 3, Y-axis represents blood pressure value and X-axis represents time.

Figure 4 shows the persons Temperature variance with time. Normal temperature of a human body in between 36^0 to 37.5 ˚C, if it cross 37.5 ˚C then we consider as temperature is high and if less than 36 ˚C then we consider as temperature is low. X-axis denotes time value and Y-axis denotes temperature value. Figure 5 shows the oxygen level monitoring of a woman for 24 hours. Values between 95% and 100% oxygen saturation are usually regarded as normal. Values below 70% are possibly life-threatening, and values below 90% could cause a significant decrease in status very quickly. In this graph, X-axis represents time value and Y-axis represents oxygen level in percentage.

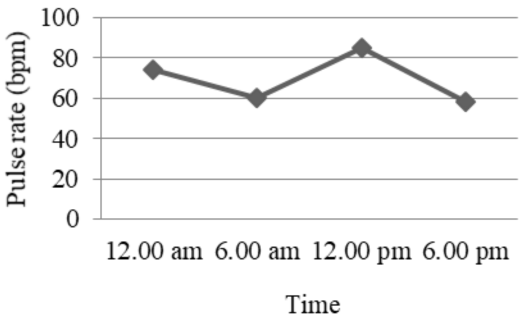

Figure 2. Pulse rate monitoring

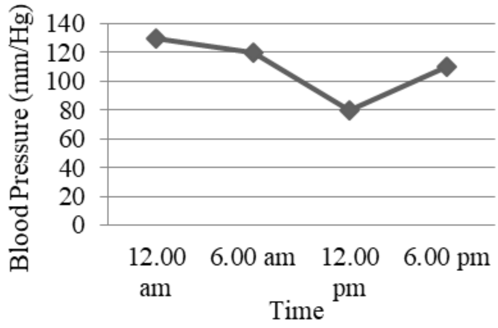

Figure 3. Blood pressure monitoring

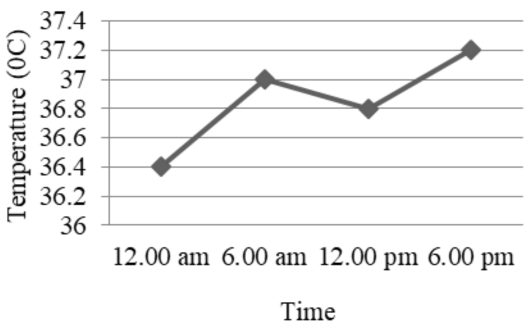

Figure 4. Temperature monitoring

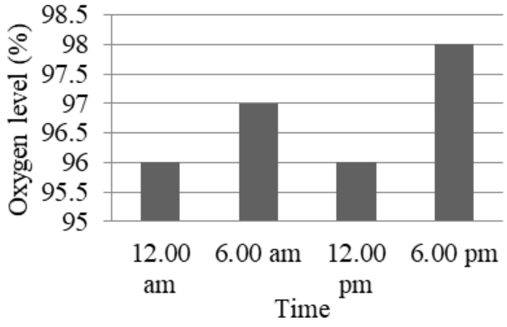

Figure 5. Oxygen level monitoring

Overall performance of a described (IoT-ARSA) for Home Automation and Healthcare Services is described by using Accuracy and Security parameters. If Accuracy of model is high indicates the system works efficiently and if accuracy value is low indicates system does not work properly. Comparative analysis is represented in Table 1 which includes described IoT-ARSA and Traditional healthcare model. Graphical representation of accuracy parameter is represented in Figure 6. In this graph X-axis denotes models and Y-axis denotes percentage value. From Figure 6 it shows that Accuracy of described model is high compared to traditional model. Figure 7 shows the Security parameter analysis of described IoT-ARSA and Traditional healthcare model in which Y-axis denotes percentage value and X-axis denotes models. Graph results shows that Security of described model is high compared to traditional model because it uses Face Detection module to open front door of the home.

Table 1. Comparative performance analysis

Models	Accuracy (%)	Security (%)
IoT-ARSA model	98	97
Traditional healthcare model	90	85

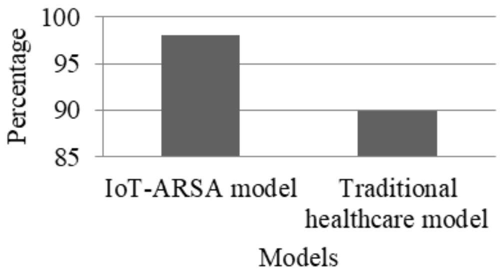

Figure 6. Comparative analysis for accuracy

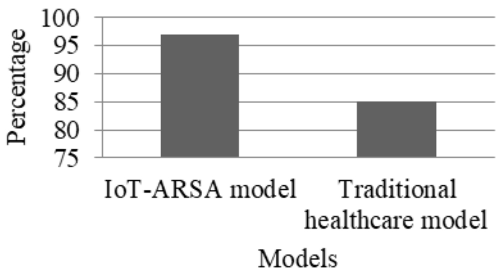

Figure 7. Comparative analysis for security

From results, it is clear that described (IoT-ARSA) for home automation and healthcare services model is very efficient with high accuracy (98%) and high security (97%). Health monitoring is achieved with this model continuously with great efficiency. If any abnormal records are observed then immediately alert message will be sent to guardian/doctor which save the life of elderly people.

4. CONCLUSION

In this paper, IoT-ARSA for home automation and healthcare services is described. The IoT-ARSA system measures the patient's pulse rate, oxygen level, blood pressure, and temperature using sensors attached to the patient's body. Ultrasonic sensor and face detection modules are used for home automation. Oxygen level sensor, Blood pressure sensor, temperature and pulse sensors are used to evaluate a patient's health. To record data, communicate to the cloud for storage additional processing, every sensor must be interfaced with the Raspberry Pi 4. Data generated from sensors are stored in a cloud server database. An IoT platform (Blynk) collects all the data from this controller and displays it to the Guardian or doctor. IoT enables the data transfer to Blynk application using ESP32. From results it is clear that described (IoT-ARSA) for home automation and healthcare services model is very efficient with high accuracy and high security. Health monitoring is achieved with this model continuously with great efficiency. In future work, we intend to include more sensors (e.g. gas, smoke and humidity sensors) to our prototype and control the electronic house appliances from anywhere for home automation.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Garapati Swarna Latha		✓				✓		✓			✓	✓		
Sreenivasulu Bolla	✓		✓	✓		✓			✓		✓		✓	
Jyotsna Amit Nanajkar			✓		✓		✓					✓		
Pattabhirama Mohan Patnala	✓				✓		✓			✓		✓		
Praveen Mande		✓					✓			✓				
Mukund Ramdas Kharde				✓	✓				✓		✓		✓	
Jonnadula Narasimharao		✓	✓				✓		✓		✓			

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

- The data that support the findings of this study are openly available in [F. Zeshan] at http://doi.org/[10.1109/ACCESS.2023.3332708], reference number [6].
- The data that support the findings of this study will be available in [A. M. Rahmani] [doi: 10.1109/ACCESS.2022.3224487] following a [6 month] embargo from the date of publication to allow for the commercialization of research findings.
- The data that support the findings of this study are available on request from the corresponding author, [B. J. Job Karuna Sagar]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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