Home Security and Automation Based on Internet of Things: A Comprehensive Review

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Abstract. The current trends of research are focused on the use of the Internet of Things (IoT) for various real-time applications. IoT is a type of “universal global neural network” and very common because of its benefits in smart application trends over traditional communication trends. Information is now accessible much easily because of the internet and inexpensive. So security and automation become a need of every department and organization. The main objective of this study is to overcome the different face detection approaches in the IoT domain and their application in the automation of smart home devices. However, this review concludes the constraints and gaps of existing published work related to the current topic and point towards feasible future research directions. Furthermore, we have discussed possible challenges of large data processing, as well as communication and automation protocols by applying different sensors, other hardware, and their interoperability. Similarities and differences of various key factors are presented in tables in terms of the proposed model, technology, application, software, user interface, algorithm, hardware, and purpose, etc. In this study, we also discussed the pros and cons of various facial detection approaches and gaps of IoT in home automation. We suppose that this review will be a solid base for future researchers in the field of automation and facial detection in IoT.

Keywords—Internet of Things, Smart Homes, Home Automation, Security

1 INTRODUCTION

Nowadays, technology is persuading our lifestyle from the way we react to the way we behave and make it more attractive like the computer, smartphones, smart television, and cars. The usage of Internet of Things (IoT) is dramatically growing according to the business situation [1].

1.1 Internet of Things

IoT is known as a network of interconnected devices, embedded with software, network connectivity and sensors and electronic devices to gather and share information to make those devices sensitive [2]. From the air conditioner that we can control from our smartphone to the smart car providing to the shortest route or smartwatch tracking our daily activities, IoT is creating a giant network with connected devices. These smart devices are connected to each other and share data about how they are used and the environment in which they are operated [3]. IoT provides a collective databank to all devices to store...
their data and same language to all kind of devices for mutual communication. Data is sent from different sensors to the IoT platform. It accesses the received data of various sources. Then it analyse the data and extract the information according to the requirement. In the end, the resulted information is shared between the connected devices to this IOT platform for better user experience in the future. The commonly used framework of smart homes using IOT is shown in fig.1 [4]. It contains smart home devices that are connected with network gateway. The user can easily control all home appliances with the smart phone or tablet. Smart home automation saves the times and effort of the user/owner.

The trend of establishing automatic connections between different devices is increasing dramatically day by day [5]. As shown in Fig.2 almost 15 billion devices were used to be connected in 2015 and just after 5 years, this number has been doubled in 2020 where around 31 billion devices are being connected. The incremental ratio of this trend is going to be above 1.5% in the upcoming 5 years until 2025.
In the last few decades, security performs a very important role in our life. The safety of a house and households is the most important for everyone. In the past, people were used to have one pet at home for their security but now a day's technology has changed the situation [6]. Home automation has provided the security assurance even when we are away from home by giving us the access to control our devices at home via smart phone or tablet. It’s highly strange for it to be a universal technology without describing the constraints and challenges in development of IoT and facilitating the privacy and security to the user. The distribution of IoT needs demanding efforts to implement and provide solutions for its security and privacy risks [7].

Face recognition system is used in security and protection of our property, companies, homes, markets and offices in the highest way as possible [8]. There are lots of problems and lacking in conventional safety systems because sometimes they do not provide data in real-time. Moreover, in biometric technology, a person can be recognized by using face recognition, which can extract different facial features of person formally and then recognize a person by applying different detection algorithms [2].

Security in home, apartments, companies and industries is become more essential now with the help of internet, is moved from traditional practices towards automation. Due to home automation, it not only gives comfort to human labour but also save the energy and time [9] [10]. Nowadays, home systems are automated and become smart and intellect with computing and information technology. It is necessary to make doors more secure because these are the main gateway to our home [11]. Currently using security systems are bare-metal locks and some other automated locking systems to secure doors. Performance and efficiency of smart locking systems can be evaluated in terms of cost. In recent years, different sensor devices are used to control home appliances and automated devices for home automation [12]. For handicapped and elder home members, home automation technology is much helpful. It helps to save energy of system sensors and also helpful for human labour. Therefore, big challenges for smart home systems are security and control management. Recognition based faces is most common biometric, which is used in control automation. Through smart mobile application based cloud services, e-mail or web based-services, a manager can access all the resources remotely, automatically and manually [6]. Face detection based on human discrimination in home automation is now an advance technology in which managers have an access to control all the resources remotely, naturally and manually through mobile application-based cloud Services [13] [14]. In this is era of information, access to internet has become more reliable and easy. Internet has made our life secure, manageable and easier. Smart devices are now available, such as smart TVs, computers, tablets, smartphones and smart vehicles etc. Smart objects are able to perform different tasks, includes sharing information through web or app and generating alerts via internal or external sensors and turning on and off devices [15]. In other terms, by utilizing the IoT, smart homes can control and automate house lights, microwave, fridges, doors, multimedia, windows, and vehicle systems.

The contribution of review paper is to discuss the using of internet of things in home security and automation. The review paper gathered the recent publish work, summarize the recent work and analyse the different technologies use in the smart homes. The sections of the review paper are having been organized as follow: discuss the how IoT works in smart homes. Sections II describes literature review of the different technologies use in smart homes and draw the comparison table in sub headings and section III describes the conclusion and possible future works.

2 TECHNOLOGIES USE IN HOME SECURITY AND AUTOMATION

Wireless Home Security (WHS) and Home automation are the dual aspects of this research [16]. The main components of this research are TI CC3200 Launchpad, accessible Wi-Fi, Passive Infra-Red (PIR) motion detector sensor and relay for connecting the home appliance. If the security system detects any unexpected motion then the owner will receive a call on his mobile. The owner can turn ON lights and alarm. In the second module, when the guest teaches the owner's house then he will receive a video call. Now the owner can turn on the lights, fans, and A.C for his guest. The facial expressions are based drowsiness detection system using dynamic modelling. During drowsiness, techniques of computer
vision are used to detect and recognize the facial expressions, motion and changes in appearance of driver. Camera in front of the driver capture stream of images and sent to system as input. Input images then go through the four vital image processing stages. Overall process is as: 1) face detection and tracking 2) feature extraction 3) feature selection and 4) classification. Hidden Markov Models (HMMs) is used for drowsy and non-drowsy dataset. Author used ad boost cascaded classifier for comparing results. HMM-based dynamic modelling has batter results as compared to single frame-based technique. HMM-based results have 97% accuracy in classification and which is more than 90% accuracy, achieved by single frame-based drowsiness detection’s house then he will receive a video call. Now the owner can turn on the lights, fans, and A.C for the guest [17].

2.1 Arduino-Based Smart Homes
Sawidin et al. [18] proposed home control system module is based on android. The main functions of this system are to control the lights, close and open the door, water faucet and garage of the home. The main components of this system are Ethernet shield, Arduino Uno, relay and android phones. When the user press the button open the door then door open and message send to the user. Asadullah et al. [19] introduced a smart home automation system using bluetooth technology. This system is the combination of hardware and software. Smartphones, the Arduino board and bluetooth modules are the main parts of hardware. Arduino integrated development environment (IDE) and bluetooth are parts of the software. Ultra-sonic sensor is also used to detect the water level inside the water tank as shown in Fig 3. When the water tank is filled then it automatically switches off the water pump and report is send to the smartphone. The soil moisture sensor is used to measure the water level inside the soil and also send a report to the smartphone. Arduino Uno is a microcontroller board which is based on A Tmega328P processor and bluetooth moduleHC-06 terminal used for wireless communication between the Arduino board and the smartphone. ASCII code is transmitted from smartphone to Arduino board via bluetooth terminal to control home appliances. The user will control the maximum of 18 appliances and sensors. Kak et al. [12] proposed a system for security purpose to control and manage the homes. The author develops the web application which run on cloud server and used by administrator anywhere, anytime to increase the security. The main objective of proposed system is to develop control management and automatic secure smart home system by using face detection and biometric techniques. The paper criteria certifying that proposed system is less expensive, user-friendly, adaptable and reliable for home members. The home owner can easily observe and control home activities by using web application. Only administrator can use the system and also can add, delete the members from dataset the proposed system also use PaaS (Platform as a Service), IaaS (Infrastructure as a Service) and SaaS (Software as a Service). Three types of member authentication process face detection, consecutive section, and feature extraction are used in this research paper. System components which are required for proposed system are Arduino microcontroller board, front door and back door camera, cloud devices, web based application.

GS,G et al. [20] proposed an Arduino-based home automation system. Arduino is connected to Wi-Fi and system is controlled by android application or social media network. The proposed system deals with the safety of home, and performs home technology with cost efficient. Different sensors are attached on Arduino which receive input signals from sensor. Analog temperature sensor chip as also used to tell about temperature conditions. This system is built for home automation. At the house door some motion sensors are fixed which detect any type of movement near the door. When sensor detect the darkness light 1 automatically on. The cooler or fan on when the room temperature exceed. The gas sensor MQ-6 is placed in the kitchen to detect any type of gas leakage in the kitchen. If gas leakage is detected the alarm which fix in the hall is raised. Relay is also used in this proposed system to switch electrical appliance light, fan, cooler etc. Intel Galileo is also placed in store room or garage which connected with Wi-Fi card with antennas for internet connectivity. System the intrusion detection featured also implemented which work with the help of motion sensors and control from web applications or android Applications. System components which are used in this system are Arduino, analog temperature sensor, DHT11 digital temperature humidity sensor, thermistor for the measurement.
of surrounding air, data pins, PIR sensor to sense the motion, MQ-6 gas sensor, relay, alarm, intel Galileo, motor drivers, power pins, and USB connectors.

Figure 3. Arduino-based network [19, 20]

Kesavan et al. [21] proposed a system which used to automate home appliance. Home appliances are automatically ON and OFF. The proposed system also detects gas leakage and sends notification to home owner using the smart phone. This system cannot sense human existence and not provide lightening functionality which sense person is existing there or not. A detailed summary of above mentioned different Arduino-based home automation system shown in Table 1 after perform a review.

| Author         | Proposed Model                      | Hardware                                                      | Software                                                      | Platform                                         | Purpose/Application                                           |
|----------------|--------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------|--------------------------------------------------------------|
| AsadUllah et al. [19] | Bluetooth Arduino                  | Arduino module, Bluetooth module, smart phone, soil moisture sensor, ultrasonic range sensor | Bluetooth terminal smartphone application and Arduino Integrated development Application(IDE) | Smart phone application | Control home appliance, check water level inside the tank, water level in the soil |
| Gunasekaran et al. [20] | Wi-Fi based using Arduino           | USB connector, power port, power pins, voltage regulator     | Motion detection algorithm on Arduino                         | Web based application                          | Temperature, motion detection, fire detection, door, light level video monitoring, controlling appliances. |
| Chan, Kok et al. [22] | GSM based using Arduino             | GSM module, relay 5 volt, cell phone, Arduino Uno            | Python algorithm                                             | Python supported mobiles                       | Control appliances                                           |
| Zaw Lin et al. [23]  | Bluetooth base using Arduino [24]   | Arduino module, smart phone, soil moistening sensor, ultrasonic sensor | Python algorithm on Arduino module                           | Python supported mobiles                       | Secured and low cost                                         |
| Kesavan et al. [21]  | IOT framework for monitoring home automation | Arduino Uno R3, Ethernet, server, sound, gas and temperature sensor | Arduino IDE, android application, data filter algorithm      | Linux, windows and smart phone platform         | Monitor home status using mobile phone easily, automatically alert notification. |
2.2 Raspberry Pi Based Systems

Raspberry Pi is a circuit board or microcontroller board having multiple components attached on it [25]. General purpose Input/Output (GPIO) pins are attached on board which connects the entire home appliance like LED, AC, fan, and television as shown in fig.4. These appliances are controlled by raspberry pi module on basis of different algorithms specified according to user requirements.

Othman et al. [26] embedded system is designed for human detection using smart security system. Images are captured by camera and sent on a smartphone. A possible solution to utilize Computer Vision techniques in the IoT. System is implemented using Raspberry Pi camera and a processor, known as Raspberry Pi 3. An image is captured by system when PIR detects any motion. For enhancement, computer vision techniques are applied on the captured images. Captured images then sent to smartphone through Wi-Fi or internet. Telegram application based on IoT, is used to check running activities and capture images, notifications and alerts. Raspberry Pi is a single.

According to Ibrahim Mohammad et al. [2] proposed system is a facial recognition system. System is implemented using python, openCV, Simple Mail Transfer Protocol (SMTP), email server and raspberry pi processor. Raspberry Pi processor is lighter and smaller in size. It can control power and efficiently work, by lower power consumption. System generates a security alert message according to authorized person’s utilities. Pi camera takes images from dataset directory. After enhancement, train these images by assuming them as vectors and save them in trainer.yml file. However, capture a fresh face in camera for comparison. For trained images, recognizer will accept image by returning data, which includes id and profile of captured person. System will send an e-mail if, captured face is unrecognized.

Pawar et al. [27] stated that proposed system is for security purpose and based on IoT and facial recognition. In this system smartphones and web applications are used for monitoring the persons which enter in home and also decide who will enter in the home. In this system web camera is connected to the Raspberry Pi which contain PIR (Passive Infrared) sensor and ultrasonic sensor. When someone try to enter in home web camera capture image of person than real face recognition done by using LBP (Local Binary Pattern). If detected image match with home member images which are already in database than door will unlock, if image not match than door bell will ring. If unauthorized person try to break the door then red light turn ON alarm will raised and SMS and e-mail with unauthorized person image will be send to the home owner. The house owner can track all the activities which happening in house by using android and web application which are connected to Raspberry Pi processor using internet. The owner can also add new person’s faces (e.g. guests) into the database by using android and web application. The proposed system consists of following components; a) Raspberry Pi which is main processor all other components are connecting on processor. b) PIR sensor used to sense the motion. c) Ultrasonic sensor used sound wave to measure the motion from distance. d) Stepper motor for door locking controlled by Raspberry Pi. e) Face recognition algorithm apply on Raspberry Pi. Android and web application’s to access the system by using internet.

Sayem et al. [2] proposed a system for security purpose which is based on facial recognition security system using IoT. The main objective of this system is to develop the smart security camera with the help of Raspberry Pi to recognize authorized and unauthorized faces. If unauthorized face is detected
than send email alert with image caption to the system owner. This system can implement face recognition from poor quality image and perform well over both authorized and unauthorized datasets. The technique which used for proposed is system is face recognition leverage technique which written in python language. The requirements which are used to build the system are Raspberry Pi model B+, Raspberry Pi camera module V2, python programming language, software library Open CV (Open source Computer Vision Library) which provide infrastructure for computer vision, and SMTP (Simple Mail Transfer Protocol) for sending and receiving email.

Jain et al. [11] system is combination of doorbell interface and Raspberry Pi. When someone presses the doorbell the camera is activate and capture the face after this it checking with already registered faces in database. If the person is authorized than door will open. If the face does not match with database it send an email to owner with that burglar image and OTP (One Time Password). When unauthorized person type OTP provided by the owner knowledge than it will allow to enter in home. Different types of hardware are used in these systems which are Raspberry pi, SD card, PIR (Passive Infrared) sensor, camera, DC motor, push button. Software components which are used in this system are Raspbian Jessie operating system, python, open CV, Apache (server), and PHP for database connectivity.

Othman N. A. et al. [28] introduced the security of a house by using the IoT concept. It is extremely helpful and vital if we want to protect the area. The main circuit board is Raspberry pi attached with the pi camera, PIR and smart mobile phone. In this system, the camera has been used to take the pictures when a motion is detected via the PIR sensor. The system will not go for face detection if there is no motion detected. But, if any movement is detected, then the detected movement of the current frame will be processed by the Viola Jones algorithm of face detection and the resulted image will be sent and displayed on the smartphone. Harr, Ada Boost and cascade classifier are used for the classification of random pictures. The flow chart of this proposed system is given in Fig.5. When motion detects pi camera capture the image and detects face. Finally it saves the image and sends to the owner.

![Figure 5. Flow chart motion detection and display result [28]](image-url)
S. Tanwar et al. [6] proposed IoT based security alert system for the smart home. A PIR sensor and web came is used to detect and capture the image of any movement and deliver this image to Raspberry Pi. In this research, the Pseudocode Approach is used. Signals of the PIR sensor are received from the GPIO pin and these signals are further connected with the Raspberry Pi. It takes the two signals from the PIR sensor and compares both of them with each other and if there is any differentiation between them then it registers it as motion and gives a command to the camera to start capturing the images. These images are stored on the temporary memory storage of Raspberry Pi and then it sends a defined mail to the user or the owner of the house with fixed subjects. A detailed summary of above mentioned different Raspberry Pi-based home automation system shown in Table 2 after perform a review.

Table 2. SUMMARY OF RASPBERRY PI-BASED SYSTEM

| Author            | System                   | Hardware                                                                 | Software                                                                 | User interface          | Application                      | Benefits                |
|-------------------|--------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------|----------------------------------|-------------------------|
| Jain, A et al. [11] | IoT based smart doorbell using Raspberry Pi | Raspberry Pi, SD card, PIR sensor, camera, doorbell, DC motor, push button | Raspbian OS, python, open CV, apache server, PHP for database              | Web based application or android | Face detection, capture image, send mail to owner | Low cost, Home security, |
| Pawar et al. [27]  | IoT based home security and face recognition using Raspberry Pi | Raspberry Pi, PIR sensor, ultrasonic sensor, stepper motor, camera, alarm, | Face recognition algorithm                                                 | Web and android applications | Facial recognition, motion detection, image capture, e-mail send, | Convenien ce, safety and security |
| Sayem et al. [2]   | Integration of face recognition security system with IoT using Raspberry Pi | Raspberry Pi model B+, camera module V2, SMTP alarm | Face recognition algorithm using python                                  | Mobile applications      | Face detection, send e-mail with image, Home security, Low cost, efficiency |
| Othman et al. [28] | Smart door security application using IoT | Raspberry Pi, PIR sensor, Pi camera, SD card | Viola jones algorithm                                                     | Android application      | Face detection, image capture. Home security |
| Tanwar et al. [6]  | Smart Home automation using IoT | Raspberry Pi, PIR sensor, Pi camera, SD card | Pseudo code                                                               | Web and smart phone      | Video capture, face detection, send email, Safety and security, low cost. |
2.3 Protocols-Based system

Message Queuing Telemetry Transferring protocol (MQTT) is a light weight IOT protocols [29] [30]. MQTT is a based on publish-subscriber [31]. Publisher publish the topic and broker receive the name of topic. When any client or subscriber need this topic it request to broker and broker send this topic to client. In MQTT, the broker is responsible of gathering data from various clients or subscriber. In fig. 5 MQTT establish connection, maintain and terminate the connections. In which PUBLISH, PUBACK, PUBREC, CONNECT, CONNACK, PINGREQ, DISCONNECT, PUBREL, and PUBCOMP are the MQTT packets.

![Figure 6. MQTT connections](image)

Prabaharan et al. [32] proposed home security and automation system by using MQ Telemetry Transport (MQTT) protocol. The system can control gas leakage, turning Off/On lights or fans and temperature of home. In the system, the three main modules is used in the system, first module is based on temperature sensor, light dependent resistor and grove gas sensor. The second and third module is node microcontroller unit (MCU) and end user interface module called Ad fruit open source cloud platform.

Lohokare et al. [33] proposed ecosystem of home automation system by using MQTT, Kafka and Spark Streaming. MQTT is IoT enabled protocol has three main components subscriber, publisher and broker. The publisher devices generate data and publish this data via topic. The broker server receives data in the form of topics and sent this data to the relative subscriber. When new device registered in the system then device get new id. When the temperature of device is greater than fifty then it send email to authorized user. Spark streaming analyse the data of the devices in every two minutes. A detailed summary of above mentioned different protocols-based home automation system shown in Table 3 after perform a review.
### Table 3. SUMMARY OF PROTOCOLS-BASED SYSTEM

| Author           | Proposed Model | Hardware                                                                 | Software                                      | User Interface       | Purpose/Application                      |
|------------------|----------------|--------------------------------------------------------------------------|-----------------------------------------------|----------------------|-------------------------------------------|
| Prabaharan et al. [32] | MQTT protocol | Node MCUs , buzzer alarm, temperature and humidity sensor, grove gas sensor, light dependent resistor | Ada fruit open source cloud platform          | Mobile phones, tabs, Laptop | Control leakage of gas, light or fan On/Off, check temperature and humidity |
| LohoKare et al. [33] | IoT protocols | Arduino enabled ESP8266, light intensity sensor, temperature sensor     | MQTT broker, apache kafka, apache spark streaming | Android application  | Home automation                           |
| Kodali et al. [29]  | MQTT protocol | ESP8266 processor                                                      | MQTT lens, MQTT broker                        | Smart phone, laptops | Home appliance                            |
| Upadhyay et al. [34] | MQTT protocols | Raspberry pi B+, apache server, humidity sensor, temperature sensor   | MQTT-mosquito                                 | Webpage              | Home appliance                            |

### 3 CONCLUSION

This review-based research addresses the vision about shift of traditional technology into automated technology in home automation. In this review, we have selected most relevant papers and articles through different search queries that address this topic comprehensively. Selected papers then divided into three different categories based on technologies used in home automation. First category is Arduino-based smart homes, in which we have discussed Arduino-based papers and comparison of those papers in tabular form including proposed model, hardware, software, user interface and purpose. Second category is about raspberry based home automation, in which we have discussed papers based on raspberry pi processor. Further we have also made a comparison of reviewed papers in tabular form including hardware, system, software, user interface, application and benefits. In third category, we have discussed papers based on protocols used in home automation and comparison of those papers in tabular form including proposed model, hardware, software, user interface and application.

Where IoT provides us benefits, it also has some issues. It is a complex network where a minor failure can cause serious consequences. Compatibility issues are also there because different devices from different manufacturers are interconnected. The main limitation of IoT is technology has taken control of life and we are now fully dependent on it.

In future, work can be done on face detection system based on state-of-art, IoT security, block chain-based IoT, Mobility in IoT security and automation of routers and integrated artificial intelligence (AI).

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ACKNOWLEDGMENT
The authors would like to thank the Department of Software Engineering at MUST University for facilitating the development of the paper and making available resources for final development of paper.